International University in Germany

School of Business Administration

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Working Paper 49/2007

Bruchsal, January 2007

ISSN 1613-6691 (print version)
ISSN 1613-6705 (online version)

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Asymmetric Information and Overinvestment in Quality

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This version: January 2007

Abstract

According to standard economic wisdom, asymmetric information about product quality leads to a quality deterioration in the market. Suppose that a higher investment level makes the realization of high quality more likely. Then, if consumers observe the investment (but not the realization of product quality) before purchase, they can infer the probability distribution of high and low quality that may be put on the market. This, as we show, may make the firm overinvest in quality compared to a market with full information.

Keywords: asymmetric information, product quality

JEL-Classification: D82, D92, L15

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1 Introduction

We examine the effects of asymmetric information on firms' incentives to invest in the quality of their product. Asymmetric information prevails because consumers cannot ascertain the quality of the product before they buy it. However, through a risky investment, firms have the ability to increase the average quality of their product. Consumers can observe the investment level and thereby, obtain information about the expected quality in the market. Using a simple model, we show that in such a situation, firms might end up investing *more* in quality under asymmetric information than under full information.

We provide two simple arguments that support the overinvestment result. First, under asymmetric information low quality is always put on the market whereas it is not offered if the willingness-to-pay is below the cost under full information. From an ex ante point of view, the firm can then increase its profits by overinvesting compared to the full information case because this reveals to consumers that the risk of obtaining low quality is reduced, which is reflected in the price. Second, we have to take the participation constraint of the high-quality firm into account if it is more costly to produce high quality than low quality. Under asymmetric information, the price that can be charged increases in the probability that high quality will result. To make sure that high quality stays in the market, this price has to be above the cost of high quality because otherwise a lemons problem arises. The existence of the lemons problem, in turn, may make it optimal for the firm to distort the investment level upward.

Key requisite for our result is the consumers' ability to draw inferences from investment levels on expected product quality. For instance, pharmaceutical firms provide information about their input in research and development for a particular prescription drug, apparently to make prescribing doctors and hospital pharmacists think that their product is likely to be successful. In the cosmetics industry, the leading company, L'Oréal, emphasizes in its advertisement campaigns the large number of patents it files every year (over 500 in 2005) and how much it invests in cosmetic and dermatological research (3% of sales or $625 million in 2005), so as to convince consumers of its commitment to market high-quality products. Hollywood studios hire well-known actors with the idea that these actors lead to better movies on average. Producers of wines, organic food and other food products invest in production processes (and inform consumers about these investments) with the idea that the adoption of such processes leads to better products on average.

The type of investment we have in mind can also be exemplified by a firm's effort to meet standards for quality management systems, such as ISO 9000. The ISO 9000 certification does not guarantee the quality of end products and services; rather, it certifies that consistent business processes are being applied. That is, it proves that the firm (actually, any type of organization) has put in place the necessary processes (i.e., a quality management system) "to fulfil the customer's quality requirements, and applicable regulatory requirements, while aiming to enhance customer satisfaction, and achieve continual improvement of its performance in pursuit of these objectives."[1] Cole (1998, p. 68) confirms our view by suggesting that firms may make ISO 9000 "their primary instrument for signaling quality to their customers."[2]

While there is an abundant economic literature on quality in asymmetric information situations, we are not aware of work that obtains a result similar to ours.[3] Inspired by previous work that alludes to the adverse se-

[1]Taken from www.iso.org (*ISO 9000. Understanding the basics*).

[2]However, firms may also seek certification simply in compliance with requirements of major customers or regulators. To disentangle the relative importance of these two motivations, Anderson et al. (1999) estimate a probit model of ISO 9000 certification. They show that the signaling motivation is indeed important: the desirability of communicating quality outcomes to external parties provides incremental explanatory power for the certification decision (even after including compliance motivations for seeking certification). Quality management systems seem thus to correspond to the type of investments we refer to in our model.

[3]This literature starts with Akerlof's (1970) "lemons' principle", according to which adverse selection (resulting from asymmetric information) causes the bad quality to drive the good quality out of the market. Various ways have then been explored to remedy, or at least alleviate, the underprovision of quality that prevails under asymmetric information. For instance, Leland (1979) has explored the role of minimum quality standards as a policy to cope with the underprovision of quality. Price and advertising signals are other means by which firms may reduce the asymmetric information and convince consumers of the

lection problem arising from an unmodeled investment in quality (see, e.g., Milgrom and Roberts, 1986), we explicitly model that the level of the investment affects the probability distribution over quality and show that due to asymmetric information, the firm may overinvest in quality.

In an important paper, de Meza and Webb (1987) obtain an overinvestment result of a different sort. They consider a competitive market in which entrepreneurs face an asymmetric information problem when asking for outside finance. Entrepreneurs have to make the same level of investment to enter the market but they differ in the probability to be successful. De Meza and Webb show that too many entrepreneurs invest. In their model the overinvestment result directly stems from the adverse selection framework that makes high-quality projects draw in low-quality projects.[4] Hence, in their model more aggregate investment *lowers* average quality. This is in line with the general tenor in the literature that asymmetric information problems tend to lead to a quality deterioration. By contrast, in our model, in which a higher investment level increases the probability of high quality, asymmetric information may lead to *higher* quality.

Creane (2006) considers a market in which an unlimited number of homogeneous firms decide whether to enter with uncertain quality. After entry, firms observe the quality; high quality is more costly than low quality. The number of firms, determined by the free entry condition according to which high and low quality firms stay in the market, is not sustainable because the participation constraint of high-quality firms is violated, and thus would lead to adverse selection. Therefore firms enter in smaller number and obtain positive equilibrium profits under free entry. While Creane considers entry for a given investment level we analyze the situation for a given firm

good quality of their product; see, e.g., the seminal contributions by Nelson (1974) and Milgrom and Roberts (1986). In a price-signalling context, Shieh (1993) has analyzed the investment incentives in cost-reducing innovations under asymmetric information, where neither the investment nor product quality is observable to consumers. He shows that asymmetric information about quality may strengthen the firm's incentive to invest in cost-reducing innovation.

[4] In a related model, Lensink and Sterken (2001) also obtain an overinvestment result, which however stems from the possibility to delay the investment decision and not from the heterogeneity of expected returns of projects.

in which the probability distribution over quality is continuously affected by the investment level.

The paper is organized as follows: in Section 2, we lay out the model; in Section 3, we analyse the benchmark of full information; in Section 4, we develop the asymmetric information case and we contrast it to the benchmark in order to establish our main result (which we illustrate through a numerical example); in Section 5, we reconsider the analysis introducing outside options; we conclude in Section 6.

2 The model

Suppose a single seller offers a product to a unit mass of buyers. The seller's opportunity cost is c_s, where $s \in \{L, H\}$ is the quality of the product. High quality is assumed to be more costly than low quality, $c_H > c_L$. There is a unit mass of buyers who are assumed to be identical and have unit demand. The valuation of each buyer is assumed to be r_s. By definition, high quality is more valuable than low quality, $r_H > r_L$. Denote $I(\lambda)$ the investment that is needed to obtain that with probability λ the product is of high quality. We view this investment as a commitment to meet on average a certain reliability of the product. Suppose that $I(\lambda) = (k/2)\lambda^2$, which satisfies $I' > 0$, $I'' > 0$, and $\lim_{\lambda \to 0} I'(\lambda) = 0$. As stated in the introduction, $I(\lambda)$ can be interpreted as efforts to meet standards for quality management systems.

We consider the following three-stage game: at stage 1, the firm invests I in quality; at stage 2, after learning the quality realization it sets its price; at stage 3, buyers form beliefs about product quality and make their purchasing decision. As we will explore below, under full information the firm chooses a strictly positive investment level if $r_H - c_H > r_L - c_L$ and zero investment if the reverse inequality holds. Note that in our setting the full-information solution implements the first best allocation (this is due to the fact that the firm fully extracts all surplus); thus deviations from the first best are the result of asymmetric information.

If the quality choice and the underlying investment decision cannot be observed by consumers, the firm has no means to convince consumers that its product is of high quality; the firm will therefore invest zero. This confirms that in markets in which firms choose quality, firms tend to provide too low a quality from a social point of view.

What we investigate is whether a risky investment in quality, where the investment is observable to consumers, results in the same type of quality trap as before. Clearly, the situation we envisage now potentially allows consumers to obtain information about the expected quality in the market, since consumers observe the investment effort and have a clear understanding of the relationship between investment spending and expected quality. We assume that the high quality is socially beneficial, i.e. $r_H > c_H$. We make no such assumption for the low quality; rather, we want to contrast the cases where the low quality is either socially beneficial ($r_L > c_L$) or not ($r_L < c_L$). To simplify the exposition, and with minimum loss of generality, we also assume that the high quality is socially more beneficial than the low quality, $r_H - c_H > r_L - c_L$ (which is trivially satisfied when the low quality is not socially beneficial). We restict attention to equilibria in which the firm extracts all rents so that price is equal to expected surplus.[5]

3 Full information benchmark

We first analyze the *full information* case (i.e., consumers observe the investment *and* the realization of quality). We distinguish between two cases: (1) $r_L > c_L$ so that under full information also low quality is put on the market and (2) $r_L < c_L$ so that under full information low quality is not put on the market.

In case (1), the firm's maximization problem is $\max_\lambda E\pi_1 = \lambda(r_H - c_H) + (1-\lambda)(r_L - c_L) - (k/2)\lambda^2$. Solving the first-order condition of profit maximization, we obtain as the probability for high-quality: $(r_H - c_H - r_L + c_L)/k$. Note that we have an interior solution if $k > r_H - c_H - r_L + c_L$ (otherwise the probability is 1).[6] We also check that the firm's expected

[5] In a modified model in which the number of consumers exceeds the number of available units and in which consumers bid for the product, equilibrium price is necessarily equal to expected surplus (see e.g. Tadelis, 1999).

[6] From our assumption that $r_H - c_H > r_L - c_L$, the probability is necessarily strictly

profit evaluated at $\lambda = (r_H - c_H - r_L + c_L)/k$ is positive:

$$E\pi_1|_{\lambda=(r_H - c_H - r_L + c_L)/k} = \frac{1}{2k}\left(r_H - c_H - r_L + c_L\right)^2 + (r_L - c_L) > 0 \quad (1)$$

In sum, the probability for high quality under full information in case (1) is

$$\lambda_1^f = \begin{cases} \frac{1}{k}\left[(r_H - c_H) - (r_L - c_L)\right] & \text{if } k > r_H - c_H - r_L + c_L \equiv k_0, \\ 1 & \text{if } k \leq k_0. \end{cases} \quad (2)$$

In case (2), the firm's problem is $\max_\lambda E\pi_2 = \lambda(r_H - c_H) - (k/2)\lambda^2$, which yields the following profit-maximizing probability for high-quality: $(r_H - c_H)/k > 0$. Note that we have an interior solution as long as $k > r_H - c_H$ (otherwise the probability is 1) and that the firm's expected profit evaluated at $\lambda = (r_H - c_H)/k$ is positive. We can then define the probability for high quality under full information in case (2) as

$$\lambda_2^f \equiv \begin{cases} \frac{1}{k}(r_H - c_H) & \text{if } k > r_H - c_H \equiv k_1, \\ 1 & \text{if } k \leq k_1. \end{cases} \quad (3)$$

4 Asymmetric information

Consider now the situation of *asymmetric information* in which consumers observe I but not the realization of quality. We analyze perfect Bayesian equilibria of the game in which the firm observes quality after stage 1 and consumers only observe the investment level (and price) but not the realized quality. We start with the situation where consumers expect any quality realization to be put on the market (clearly, if high quality is put on the market, so is low quality since its costs are lower). The expected surplus is thus $\lambda r_H + (1-\lambda)r_L$, which is the price the firm will set at stage 2. Hence, expected profits at stage 1 are

$$\begin{aligned} & \lambda[\lambda r_H + (1-\lambda)r_L - c_H] + (1-\lambda)[\lambda r_H + (1-\lambda)r_L - c_L] - (k/2)\lambda^2 \\ = \; & \lambda(r_H - c_H) + (1-\lambda)(r_L - c_L) - (k/2)\lambda^2. \end{aligned}$$

Solving the first-order condition of profit maximization, we obtain as the probability for high-quality:

$$\lambda^a \equiv \frac{1}{k}\left(r_H - c_H - r_L + c_L\right). \quad (4)$$

positive.

As we have seen above, $\lambda^a < 1$ provided that $k > k_0$. Moreover, from expression (1), we know that the firm's expected profit evaluated at $\lambda = \lambda^a$ is positive in case (1) but might be negative in case (2) as $r_L - c_L < 0$. Therefore, in case (2), the firm is better off by entering the market than not being active as long as $\lambda^a(r_H - c_H) + (1-\lambda^a)(r_L - c_L) - (k/2)(\lambda^a)^2 > 0$, or

$$k < \frac{(r_H - c_H - r_L + c_L)^2}{2(c_L - r_L)} \equiv k_2.$$

It is easily checked that in case (2), $k_1 < k_0 < k_2$.

Comparing expression (4) with expressions (2) and (3), we observe that, when consumers expect both qualities to be put on the market, the probability for high-quality is weakly greater under asymmetric information than under full information. Investment incentives are not affected by consumer information if $r_L \geq c_L$ ($\lambda^a = \lambda_1^f$) but are stronger under asymmetric information if the reverse inequality holds. Indeed, in the latter case, we observe that low-quality products are not released on the market under full information, but that low quality is always consumed under asymmetric information. Since this expected lower quality is reflected in price and since low quality is produced at costs above the consumers' willingness to pay, the firm has an incentive to reduce the probability of low quality products through higher investments. It is only when the investment cost is very high (i.e., $k > k_2$) that the firm prefers not to invest under asymmetric information while it keeps on investing under full information. The results for case (2) are summarized in the following table (where λ_2^a denotes the probability of high quality under asymmetric information in case (2)).

$k \leq k_1$	$k_1 < k \leq k_0$	$k_0 < k \leq k_2$	$k > k_2$
$\lambda_2^a = \lambda_2^f = 1$	$\lambda_2^a = 1 > \lambda_2^f$	$\lambda_2^a = \lambda^a > \lambda_2^f$	$\lambda_2^a = 0 < \lambda_2^f$

The previous results were derived under the assumption that a high quality product stays in the market under asymmetric information. However, at stage 2, the firm may not be interested in offering high quality on the market, while it is always willing to do so under full information (under our assumption that $r_H > c_H$). For a high-quality firm to make positive operating profits, the price must exceed costs, i.e. $\lambda r_H + (1-\lambda)r_L - c_H \geq 0$, which is equivalent to

$$\lambda \geq \widetilde{\lambda} \equiv \frac{c_H - r_L}{r_H - r_L}.$$

Hence, the firm will indeed implement λ^a if $\lambda^a \geq \widetilde{\lambda}$, which can be rewritten as

$$\lambda^a \geq \widetilde{\lambda} \iff k \leq \frac{r_H - r_L}{c_H - r_L}(r_H - c_H - r_L + c_L) \equiv k_3.$$

If $k > k_3$ and the firm implemented λ^a, consumers would know that a high-quality firm would not participate, so that their beliefs about product quality would not be confirmed. Consumers expect a sufficiently high probability that the product is of low-quality, which reduces their willingness to pay. Hence, the firm cannot charge a sufficiently high price to cover its cost in case it is of high quality. In such a case (i.e., $\lambda^a < \widetilde{\lambda}$ or $k > k_3$), the firm has the option to increase its investment expenditure, so as to increase the probability of high quality up to $\widetilde{\lambda}$. The condition for this option to be profitable for the firm differs according to whether we are in case (1) or in case (2).

In case (1), as $r_L > c_L$, the firm may alternatively invest zero and offer low quality on the market. The former action is more profitable than the latter if $\widetilde{\lambda}(r_H - c_H) + (1 - \widetilde{\lambda})(r_L - c_L) - (k/2)\widetilde{\lambda}^2 > r_L - c_L$ or, equivalently, $\widetilde{\lambda}[(r_H - c_H) - (r_L - c_L)] - (k/2)\widetilde{\lambda}^2 > 0$. Solving for k we must have $k < 2[(r_H - c_H) - (r_L - c_L)]/\widetilde{\lambda}$, which is

$$k < 2\frac{r_H - r_L}{c_H - r_L}[(r_H - c_H) - (r_L - c_L)] = 2k_3.$$

Noting that $k_3 > k_0$ (since, by assumption $r_H > c_H$), we now have a complete picture of the probability of high quality in case (1) under asymmetric information. We contrast it with the solution under full information in the following table:

$k \leq k_0$	$k_0 < k \leq k_3$	$k_3 < k \leq 2k_3$	$2k_3 < k$
$\lambda_1^a = \lambda_1^f = 1$	$\lambda_1^a = \lambda_1^f < 1$	$\lambda_1^a > \lambda_1^f$	$\lambda_1^a = 0 < \lambda_1^f$

In case (2), with $r_L < c_L$, overinvestment is profitable if $\widetilde{\lambda}(r_H - c_H) + (1 - \widetilde{\lambda})(r_L - c_L) - (k/2)\widetilde{\lambda}^2 > 0$, which is equivalent to

$$k < \frac{2(r_H - r_L)(c_H - c_L)(r_H - c_H)}{(c_H - r_L)^2} \equiv k_4.$$

Summarizing our previous findings, we have that the probability of high quality under asymmetric information in case (2), λ_2^a, is equal to λ^a as long as (i) $k > k_0$ (otherwise, it is equal to 1), (ii) $k < k_2$ (otherwise, it is equal to 0), and (iii) $k < k_3$. If the latter condition is not met, the firm will increase the probability of high quality up to $\widetilde{\lambda}$ as long as $k < k_4$. To get a complete picture, we need to rank the thresholds k_0, k_1, k_2, k_3 and k_4. We detail this ranking in the appendix, which allows us to state the following proposition, where we define

$$\Delta \equiv -\tfrac{(c_H - r_L)(r_H - c_H)}{(2r_H - c_H - r_L)}.$$

Proposition 1 *If consumers observe investments in the quality of products but not the quality itself, a firm invests strictly more in quality under asymmetric information than under full information, provided that (1)* $r_L - c_L > 0$ *and* $k_3 < k \leq 2k_3$ *or (2a)* $\Delta < r_L - c_L < 0$ *and* $k_1 < k \leq k_4$*, or (2b)* $r_L - c_L < \Delta$ *and* $k_1 < k \leq k_2$*.*

The three situations of over-investment are depicted in Figure 1. To get the intuition behind our result, let us restate the two arguments. First, we have seen that ignoring the participation constraint of the high-quality firm, investment incentives weakly increase under asymmetric information compared to full information. The reason for the potential overinvestment is that a low-quality firm stays in the market under asymmetric information even though its value is less than the cost because it is sold at the expected and not the actual value. The fact that the product may be of low quality is taken into account by consumers and thus reflected in the price. Therefore, by investing more, the firm can convince consumers that the risk of obtaining low quality is reduced. Secondly, taking into account the participation constraint of a high-quality firm, investments under given beliefs may be insufficient to make selling high quality worthwhile. This implies that λ^a cannot be the equilibrium belief at the investment level $I(\lambda^a)$. To make the participation of the high-quality firm worthwhile, the firm has to distort its investment upward in order to convince consumers that a high-quality outcome is more likely, in which case they are willing to pay more. Thirdly, at the investment stage the firm has to compare profits with such an upward distorted investment to the outside option (which is either zero or to sell low

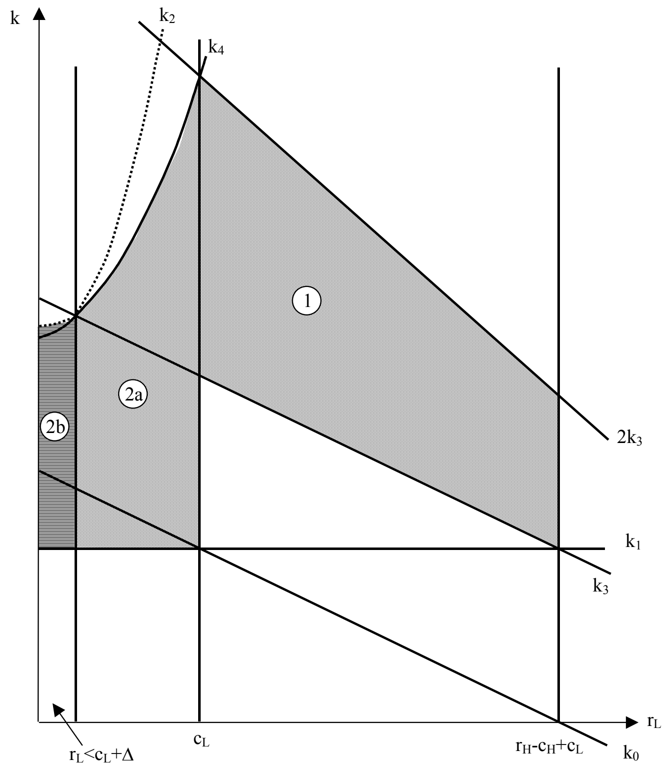

Figure 1: Overinvestment under asymmetric information

quality). It may be profitable to overinvest. It is only when investments are too costly (i.e. $k > 2k_3$ for $r_L > c_L$ or $k > k_2$ or k_4 for $r_L < c_L$) that the standard underinvestment result under asymmetric information holds.

A *numerical example* (which gives parameter values to all parameters except k) illustrates our results for cases (1) and (2a). Take $r_H = 10$, $c_H = 6$, and $c_L = 2$. We take two values for r_L: either $r_L = 3 > c_L$ (case (1)) or $r_L = 1 < c_L$ (case (2a)). Consider first case (1) with $r_L = 3$. Under full information, the firm would choose its investment such that $\lambda_1^f = 3/k$. As we have seen above, under asymmetric information and provided that consumers expect that products are sold on the market independent of the realization of the random variable, the firm would invest such that $\lambda^a = \lambda_1^f$. However, for a high-quality firm to make positive operating profits the price must exceed costs, i.e. $\lambda r_H + (1-\lambda) r_L - c_H \geq 0$, which becomes $\lambda \geq \widetilde{\lambda} \equiv 3/7$

under our parameter values. Hence, the firm will indeed implement λ^a if $\lambda^a \geq \widetilde{\lambda}$. Otherwise, if the firm implemented λ^a, consumers would know that a high-quality firm would not participate so that their beliefs about product quality would not be confirmed. Consumers expect a sufficiently high probability that the product is of low-quality which reduces their willingness to pay. Hence, the firm cannot charge a sufficiently high price to cover its cost in case it is of high quality. The firm can then increase its investment expenditure to increase the probability of high quality. Expected quality is higher than under full information if $\widetilde{\lambda} = 3/7 > 3/k = \lambda_1^f$, which is equivalent to $k > k_3 = 7$. To be an equilibrium strategy also at the investment stage, expected profits must be greater than $r_L - c_L = 1$, i.e. $4\lambda + (1-\lambda) - (k/2)\lambda^2 \geq 1$. Evaluated at $\widetilde{\lambda} = 3/7$, this is equivalent to $k \leq 2k_3 = 14$. Hence, for parameter values $k \in (7, 14]$ the firm invests strictly more under asymmetric than under full information.

Suppose now that $r_L = 1$, so that we are in case (2a). We check that $c_L - r_L = 1 < \Delta = 20/13$, so that $k_2 > k_3$. Under full information, the firm would choose its investment such that $\lambda_2^f = 4/k$. Hence, $k_1 = 4$. Redoing the computations under asymmetric information, we find that $k_0 = 5$, $k_3 = 9$, $k_4 \simeq 11.5$ and $k_2 = 12.5$. Take, e.g., $k = 10$ and compute the various thresholds on λ:[7]

$$\widetilde{\lambda} = \tfrac{5}{9} > \lambda^a = \tfrac{1}{2} > \lambda_2^f = \tfrac{2}{5}.$$

Hence, for parameter values $k \in (4, 11.5]$ the firm invests strictly more under asymmetric information than under full information. For an intermediate range of investment cost levels ($k \in (9, 11.5)$) the firm has to further increase its investment in order to convince consumers that a high-quality product will be put on the market. Only if investment costs are too high ($k > 11.5$), investment under asymmetric information breaks down to zero and is therefore less than under full information. Figure 2 illustrates our results in case (2a), where $r_L < c_L$.[8]

[7] We have checked that expected profits at stage 1 under $\widetilde{\lambda}$ are positive (namely, $\widetilde{\lambda}(r_H - c_H) + (1-\widetilde{\lambda})(r_L - c_L) - (k/2)\widetilde{\lambda}^2 = 19/81$).

[8] Although the firm invests more under asymmetric information, it can easily be checked that it always makes at least as much profits under full information than under asymmetric information.

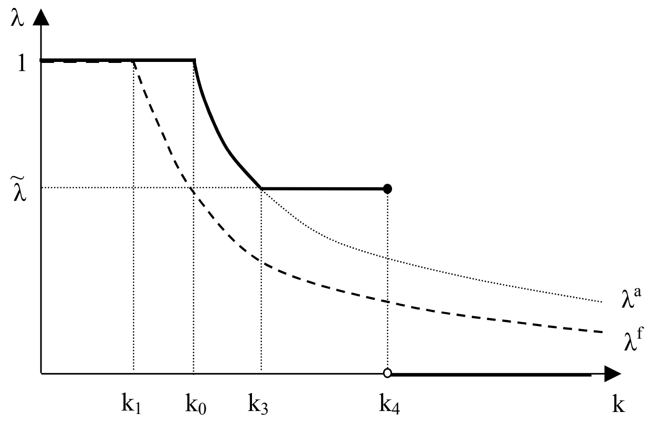

Figure 2: Investment in quality in case (2a)

5 The analysis with outside options

Our analysis can be criticized for the fact that under asymmetric information, high quality is less profitable than low quality since both are sold at the same price, while low quality is cheaper to produce. If a successful investment enables the firm not only to produce high but also low quality, the firm will always deviate to low quality due to the moral hazard problem. This in turn would imply that a firm does not have any incentive to invest under high quality because a higher investment does not contain information about the expected product quality that will be put on the market. However, if the production cost of high and low quality is the same whereas high and low quality give different values for an outside option, a high quality firm does not have an incentive to deviate to low quality (provided that its production costs do not increase in quality).[9] We can then show that our qualitative findings from above are confirmed.

Let v_H and v_L denote the value of the outside option for high and low quality, respectively, while c denotes the production cost which is indepen-

[9] We can think of the outside option as a costly action taken by the firm; in particular, it may use the services of a third-party certifyer, who certifies realized product quality (on the logic of third-party certification, see e.g. Biglaiser, 1993). If this action fully reveals its product quality the firm can sell high quality under full information at a price v_H. In particular, $r_H - v_H$ constitutes the cost of certification.

dent of quality. By the nature of the problem, $r_H > v_H > v_L$. In addition, we assume that the value of the outside option for high quality exceeds production costs, $v_H > c$. We can then replicate the analysis of Section 3. First, we obtain the probability for high quality under full information as

$$\lambda^f \equiv \begin{cases} \frac{1}{k}(r_H - c) & \text{if } r_L < c, \\ \frac{1}{k}(r_H - r_L) & \text{if } r_L \geq c, \end{cases}$$

and we define $\hat{k}_0 \equiv r_H - c$. Next, we turn to the analysis under asymmetric information and consider first the case $r_L \geq c$. In analogy to Section 4, we obtain that $\hat{\lambda}^a = (1/k)(r_H - r_L)$ and $\hat{\hat{\lambda}} = (v_H - r_L)/(r_H - r_L)$, where the latter expression comes from the condition that the price $\lambda r_H + (1-\lambda)r_L$ has to exceed the value of the outside option for a high-quality product v_H. We then can calculate the critical value of k above which overinvestment with $\hat{\hat{\lambda}} > \hat{\lambda}^a$ may be required to solve the adverse selection problem:

$$\hat{k}_3 = \frac{(r_H - r_L)^2}{v_H - r_L}.$$

For an investment $I(\lambda)$ with $\lambda \leq \hat{\lambda}^a$ to be worthwhile we must have that the profit is non-negative for $r_L < c$. We obtain that this is the case for all $k \leq \hat{k}_2$ where

$$\hat{k}_2 = \frac{(r_H - r_L)^2}{2(c - r_L)},$$

which is always greater than $\hat{k}_0$. Hence, the non-negativity condition is not binding for all $k \leq \hat{k}_3$ if $\hat{k}_2 > \hat{k}_3$. This is equivalent to $v_H + r_L > 2c$.

Consider now $k > \hat{k}_3$. For $r_L > c$, an upward distortion of the investment gives greater profit than offering low quality in the market at zero investment, i.e. $\lambda r_H + (1-\lambda)r_L - c - (k/2)\lambda^2 > r_L - c$, as long as $k < 2\hat{k}_3$.

For $r_L \leq c$, an upward distortion of the investment gives greater profit than being inactive with zero investment, i.e. $\lambda r_H + (1-\lambda)r_L - c - (k/2)\lambda^2 > 0$, as long as $k < \hat{k}_4$ where[10]

$$\hat{k}_4 = 2\frac{v_H - c}{v_H - r_L}\frac{(r_H - r_L)^2}{v_H - r_L}.$$

[10] The inequality can be rewritten as $2[\lambda(r_H - r_L) + r_L - c]/\lambda^2 > k$. To obtain $\hat{k}_4$, we substitute the expression for $\hat{\hat{\lambda}}$. Clearly, $\hat{k}_4 > \hat{k}_3$ is equivalent to $(v_H + r_L)/2 > c$ because in this case profits at $\hat{\lambda}^a$ are strictly positive, so that an upward distortion that solves the adverse selection problem is worthwhile.

We thus obtain the following result:

Proposition 2 *Suppose that a successful investment allows the firm to choose between high and low quality, which are produced at equal cost, but that high quality has a higher value than an outside option. If consumers observe investments in the reliability of products but not reliability itself, a firm invests strictly more in reliability (or quality) under asymmetric information than under full information, provided that (1)* $r_L > c$ *and* $\hat{k}_3 < k \leq \hat{k}_4$*, or (2)* $r_L < c$ *and* $\hat{k}_0 < k \leq \max\left\{\hat{k}_2, \hat{k}_3\right\}$*.*

6 Conclusion

We have provided a counter-example to the belief that asymmetric information about product quality reduces the incentives to provide higher quality; we have shown that the reverse may actually be true. It obtains in situations where firms have the possibility to make a risky and observable investment to increase the average quality (reliability) of their products. An example of such investments could be the effort to obtain the ISO 9000 certification for the firm's quality management system. Although consumers do not observe the realization of quality, they observe how much the firm has invested and, thereby, infer useful information about the expected quality on the market. Knowing this, a firm producing high quality may overinvest in the quality or reliability of its product to convince consumers that high quality is indeed very likely to be put on the market; this avoids the lemons problem and thus may be the firm's optimal strategy. Also, if selling low quality has a negative social value, the firm may want to reduce the probability of low quality realization compared to the full-information world, because under full information low quality would not be put on the market, whereas in an adverse selection environment low quality is always offered. We have thus identified two simple reasons for overinvestment in quality under asymmetric information.

7 Appendix. Proof of Proposition 1

Most of the proof is in the main text. The missing part concerns the ranking of the thresholds k_0 to k_4 in case (2). We already know that $k_3 > k_0$. A few lines of computation establish that

$$\begin{aligned} k_3 &> k_2 \iff r_L - c_L < -\tfrac{(c_H - r_L)(r_H - c_H)}{(2r_H - c_H - r_L)} \equiv \Delta, \\ k_2 - k_4 &= \tfrac{\left(r_L r_H - 2c_L r_H - r_L^2 + r_L c_L + r_H c_H - c_H^2 + c_L c_H\right)^2}{2(c_L - r_L)(c_H - r_L)^2} > 0, \\ \tfrac{k_2 - k_3}{k_4 - k_3} &= \tfrac{(r_H - c_H - r_L + c_L)(c_H - r_L)}{2(r_H - r_L)(c_L - r_L)} > 0. \end{aligned}$$

(Note that the last two inequalities hold because we are in case (2) where $c_L > r_L$). We need then to distinguish among two cases.

1. If $k_2 < k_3$, then the firm prefers to exit the market ($k > k_2$) before λ^a becomes inferior to $\widetilde{\lambda}$ ($k > k_3$). Then, if $k_0 < k_2$, we have that $\lambda_2^a = 1$ for $k \leq k_0$, $\lambda_2^a = \lambda^a$ for $k_0 < k \leq k_2$ and $\lambda_2^a = 0$ for $k > k_2$; otherwise, if $k_0 > k_2$, we have that $\lambda_2^a = 1$ for $k \leq k_2$ and $\lambda_2^a = 0$ for $k > k_2$. Comparing with expression (3) and recalling that (i) $k_0, k_2 > k_1$ and (ii) $\lambda^a > \lambda_2^f$ for $k > k_1$, we have that in both cases, the firm invests strictly more under asymmetric information than under full information if $k_1 < k \leq k_2$.

2. If $k_2 > k_3$, we also have that $k_4 > k_3$ (as $k_2 - k_3$ and $k_4 - k_3$ have the same sign). Then, $\lambda_2^a = 1$ for $k \leq k_0$, $\lambda_2^a = \lambda^a$ for $k_0 < k \leq k_3$, $\lambda_2^a = \widetilde{\lambda}$ for $k_3 < k \leq k_4$ and $\lambda_2^a = 0$ for $k > k_4$. It follows that the firm invests strictly more under asymmetric information than under full information if $k_1 < k \leq k_4$.

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