Public Report, Price, and Quality

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Abstract

A monopolist produces a good with two qualities. All consumers have the same valuation of the first quality, but their valuations of the second vary, and are their private information. Qualities cannot be directly observed by consumers. A public agency can verify the qualities, and make credible reports to consumers. In Full Quality Report, the public agency reports both qualities. In Average Quality Report, it reports a weighted average of the two qualities. The equilibrium qualities in Full Quality Report can be implemented by Average Quality Report by suitable choices of report weights. Equilibrium qualities in Average Quality Report give higher surplus to consumers than Full Quality Report. Bertrand competition under Average Quality Report yields first-best qualities.

Keywords: Public report, price, quality

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1 Introduction

Qualities of many goods and most services are unknown to consumers before purchase. Many social and regulatory institutions can be regarded as mechanisms to resolve problems due to missing quality information. Here are a few examples. Consumer Reports specializes in reviewing consumer products and services. US News and World Report publishes influential annual ranking on colleges and graduate schools. Centers for Medicare & Medicaid Services compare health care providers and insurance plans across the United States.

Reports on product and service qualities, such as those just mentioned, certainly provide information to consumers. It is often thought that better information lets consumers make better decisions. Quality reports, however, also change how markets function because firms may act on consumers’ responses to reports. Thus, if a nursing home realizes that Centers for Medicare & Medicaid Services report on its qualities, it may have a better incentive to invest in qualities; more important, the nursing home also raises prices because consumers, now informed of qualities, are more willing to pay for its services. In sum, quality reports affect how firms and consumers interact. In this paper, we study how quality reports influence this interaction.

We study two quality report regimes. The first is Full Quality Report: a public agency obtains information of qualities from a firm, and credibly report it to consumers. The second is Average Quality Report: a public agency obtains information of qualities, compiles indexes in the form of weighted averages of qualities, and credibly reports these indexes to consumers. Such quality indexes are common. In fact, Consumer Reports, US News and World Report, and Centers for Medicare & Medicaid Services all publish them. We show in this paper that Average Quality Report benefits consumers more than Full Quality Report. By carefully choosing the weights to reveal partial information of qualities, the public agency restrains the firm from extracting consumer surplus.

In our model, there is a set of consumers, each wanting to buy one unit of a good. The good has two qualities, which we call Quality 1 and Quality 2. Consumers’ preferences are described by how they value these qualities. We assume that all consumers have the same valuation of Quality 1, but their valuations of Quality 2 vary. A consumer’s valuation of Quality 2 is her private information. Quality 1 can be regarded as a primary attribute of the product, so consumers value them in a simple and uniform way. Quality 2 is a
secondary attribute; consumers have more diverse preferences on it. In the nursing home example, Quality 1 refers to general care, while Quality 2 refers to specialty care. Nursing home occupants value general care uniformly, but because individual health conditions differ, each consumer values specialty care differently.

There is a monopolist supplying the good. It chooses Quality 1 and Quality 2, and the unit cost is increasing and convex in qualities. Qualities cannot be observed by individual consumers. This is because verifying qualities can be very costly. However, a public agency can find out about the qualities of the good, either by legally requiring the firm to report the qualities or by monitoring them.

Because consumers’ valuations of Quality 2 vary, the monopolist uses a price-quality menu to screen consumers. It produces the good with many combinations of Quality 1 and Quality 2, and each combination is sold at a different price. For example, a nursing home can have two tiers of services, one attracting those who value specialty care less, and another attracting those who value specialty care more. The less specialty-intensive service may be priced lower while the more specialty-intensive service may be priced higher.

The public agency commits to a quality-report policy before the monopolist makes its quality and pricing decisions. We consider two report regimes. In Full Quality Report, the public agency reports both Qualities 1 and 2 of each good in the monopolist’s menu. In Average Quality Report, the public agency commits to reporting a weighted average of qualities of each good to be produced by the monopolist, where the weight can vary according to items in the menu. In the nursing home example, the weights on Qualities 1 and 2 can be 50-50 for the less expensive, low specialty-intensive service, but 30-70 for the more expensive, high specialty-intensive service. The public agency chooses these weights to maximize consumer surplus.

Full Quality Report corresponds to a standard model in which the monopolist’s product qualities are verifiable. Standard second-degree price discrimination techniques for deriving the equilibrium price-quality menu apply. The monopolist lowers Quality 2 from the efficient levels in order to screen consumers, and leaves information rent to them.

Full Quality Report allows trades to occur, but lets the monopolist collect most of the surplus. Full Quality Report favors the monopolist too much. Consumers possess private information but the monopolist
does its best to limit information rent. Average Quality Report does not make qualities verifiable. Upon seeing a reported average, consumers realize that the monopolist has chosen some combination of Quality 1 and Quality 2, and that this combination will yield the reported average.

Which combinations of Quality 1 and Quality 2 can arise as equilibria in Average Quality Report? Our first result says that equilibrium Quality 1 and Quality 2 must be those that minimize the monopolist’s cost for achieving a reported average. Given any reported average, the monopolist is free to choose any combination of Qualities 1 and 2 to achieve it. The monopolist’s equilibrium quality combination must be one that minimizes the cost of achieving that average. More important, for any reported average, the unique equilibrium consumer belief on the qualities must be the least-cost combination.

Through its choice of quality weights, the public agency influences the monopolist’s choice of Qualities 1 and 2 of each item in the menu. For example, switching from a 50-50 weight to a 30-70 weight, the public agency encourages the monopolist to increase Quality 2 and to decrease Quality 1 to achieve an average. We first show that the public agency can implement the Full Quality Report equilibrium menu in the Average Quality Report regime. This implementation is by quality weights relative to which the equilibrium qualities in Full Quality Report are indeed cost-minimizing.

Can consumers be made better off than their equilibrium payoff under Full Quality Report? Consumers’ information rent is directly proportional to the level of Quality 2. To improve consumer surplus from the equilibrium level in Full Quality Report, the public agency implements higher levels of Quality 2. In Average Quality Report, this can be achieved by increasing the weight on Quality 2. In effect, the public agency lowers the firm’s (marginal) cost of using Quality 2 to achieve any given level of average quality.

The basic point of our analysis is that Average Quality Report creates a new constraint for the firm. Qualities must be cost-minimizing relative to the public agency’s report weights; consumers will not believe that the firm has chosen any other quality combinations. This new constraint prevents the monopolist from exercising its full power of second-degree price discrimination.

When many firms compete in a Bertrand fashion under Full Quality Report, the first best will be achieved. Firms make zero profit, and consumers enjoy the first-best qualities. Surprisingly, in Bertrand competition
the same first-best outcome can be implemented under Average Quality Report. The public agency simply chooses the quality weights for which the first-best qualities are cost-minimizing.

Our model and results yield a clear policy implication. Public reports on firms’ qualities create some degree of verifiability on firm’s quality choices. Completely verifiable quality information—Full Quality Report—means giving firms more market power because firms exercise price discrimination more successfully. This harms consumers. A quality index makes qualities only partially verifiable. Only those that are cost-minimizing are credible to consumers. A firm faces an extra constraint, and must give up profits. Thus, full information on quality does not benefit consumers, but a quality index does.

A more provocative policy implication from our model is on the regulation of quality certification. In our model, the monopolist would like to hire a certification party to verify credibly its product qualities. It then avoids the constraint due to the quality index. Consumers may be better off if the government becomes the only certification party. The public agency should then refuse to verify all qualities, but instead report weighted averages of qualities. Our model provides a justification for why many reports are often indexes and compiled by nonprofit and public organizations.

Many papers examine how information influences the interaction between firms and consumers, and differ in various ways. In Lewis and Sappington (1994) and Schlee (1996), a monopolist and consumers lack complete information about preferences or product qualities; these papers show that more public information may harm consumers due to the firm responding with higher prices. In Mirman et al. (1994) and Harrington (1995), duopolists are uncertain about either the market demand of a homogeneous good or the degree of product differentiation. More information may lead to more intense competition, so firms may engage in “signal jamming” to reduce public information. By contrast, in this paper, we adopt a regulatory perspective, and study both monopoly and Bertrand cases.

Several recent papers analyze firms’ voluntary disclosure incentives. In Sun (2008) and Hotz and Xiao (2010), firms produce a good with both horizontal and vertical attributes. These papers show that both a monopolist and duopolists may not disclose an attribute even if disclosure is costless. In Bar-Isaac et al. (2009), consumers can verify one of two vertical attributes at a cost; when the verification cost of
one attribute falls, the monopolist reacts by underinvesting in the other attribute, and welfare decreases. These papers conclude that mandatory disclosure benefits consumers. Our model yields the opposite policy implication: mandatory disclosure harms consumers because that lets the monopolist price more aggressively.

Another strand of the literature focuses on how a certification intermediary manipulates reports to maximize profit. In Albano and Lizzeri (2001), a monopolist’s quality choice is only observed by a profit-maximizing agency. They show that the agency fully reports quality only if reporting fees can be made contingent on quality. When the agency charges a fixed fee, quality information is reported with noise. Lizzeri (1999) focuses on markets with adverse selection. He shows that a monopoly agency maximizes profit by withholding quality information. In our model, the reporting agency aims to maximize consumer surplus, but in equilibrium, withholding some information raises consumer welfare.

Quality reporting has become increasingly popular in health markets. Lu (2009) finds that after the implementation of the Nursing Home Quality Initiative, reported qualities have improved, but unreported ones have deteriorated. Glazer et al. (2008a) propose a method to mitigate the problem of unmeasured attributes in quality reports. Glazer et al. (2008b) show how user satisfaction ratings can correct a provider’s incentive to skim on high-cost consumers.

Glazer and McGuire (2006) first point out the use of a quality index to mitigate adverse selection in a Rothschild-Stiglitz class of models. They show that a single quality index can implement pooling equilibria in a competitive insurance market. In equilibrium, consumers with different preferences pay the same premium, but receive first-best qualities. We consider a monopolist’s price and quality decisions. Equilibrium prices and qualities will screen consumer types, and equilibria are never first best.

In Glazer and McGuire (2007) a firm sells a single good with two qualities. These qualities may be unknown, but a quality index can be constructed. Given a demand function, the firm produces one set of qualities and charges a single price to clear the market. The paper shows situations where average information may or may not improve welfare. By contrast we specify consumer preferences, allow for price-quality screening, and derive optimal quality weight functions for both consumer surplus and social surplus in monopoly and competition regimes.
In Section 2, we present the model. We characterize equilibria under Full Quality Report in Section 3. Next, in Section 4, we analyze the monopolist’s choice of qualities under Average Quality Report. Section 5 derives the equilibrium weights under Average Quality Report. In Section 6, we let many firms compete in the market, and show that equilibria are first best under both Full Quality Report and Average Quality Report. Some final remarks are in Section 7. The Appendix contains all proofs.

2 The Model

2.1 A monopolist and consumers

A monopolist produces a good to sell to consumers. The good consists of two qualities, which we call Quality 1 and Quality 2. The nonnegative vector \((q, r)\) describes the levels of these qualities. We use the term good \((q, r)\) to mean a good with \(q\) units of Quality 1 and \(r\) units of Quality 2. The monopolist incurs a unit cost \(c(q) + d(r)\) for producing good \((q, r)\). The cost functions \(c\) and \(d\) are both strictly increasing and strictly convex, with \(c(0) = d(0) = c'(0) = d'(0) = 0\). We further assume that both \(c\) and \(d\) are three-times differentiable, with \(c''\) and \(d''\) nonnegative, and \(c''/c'\) and \(d''/d'\) nonincreasing; the derivative of \(c''/c'\) is 
\[
\frac{c'c''' - (c'')^2}{(c')^2},
\]
so the third-order derivative \(c'''\) cannot be too big, and similarly for \(d''\). There are no fixed costs. If the monopolist sells a unit of good \((q, r)\) at a price \(p\), it makes a profit \(p - c(q) - d(r)\).

There is a continuum of consumers, with the total mass normalized at 1. Each consumer buys, at most, one unit of the good. A consumer’s per-unit valuations of the good’s Quality 1 and Quality 2 are given by two parameters, respectively, \(u\) and \(v\). The parameter \(u > 0\) is the same for all consumers. The parameter \(v\) is random, and follows distribution \(F\) and density \(f\) on the positive support \([v, \bar{v}]\). Consumers’ valuations of Quality 2 are independent. We sometimes call a consumer with valuation parameter \(v\) a type-\(v\) consumer or consumer \(v\). If a type-\(v\) consumer purchases good \((q, r)\) at price \(p\), her utility is \(uq + vr - p\). If a consumer does not purchase, she obtains a utility 0.

Although there are two qualities, consumers’ preferences are only heterogenous in Quality 2. We use this setup for several reasons. First, our model is tractable. If consumers’ preferences were heterogenous in both Qualities 1 and 2, the pricing-screening problem would become much more difficult. This will distract
us from our study of effects of quality reports on market outcomes. Second, we can adopt a more general interpretation. Suppose that, in fact, the good has a single quality, and this is Quality 2, for which consumer preferences are heterogenous. Now consider a second good, which has a single quality, namely Quality 1. Now Quality 1 may be a standardized attribute on which consumers have homogenous preferences. Our model would correspond to this setup when the firm offers these two goods as a bundle. A regulator can mandate that the two goods must be sold together, and implement the quality-report policies studied here. The issue about quality report is then whether quality information of these two goods should or should not be disclosed together, and in what form.

2.2 Information and quality report

A consumer's valuation of Quality 2 is her private information. Qualities may not be directly observed by consumers. However, a public agency can find out about these qualities. Alternatively, the monopolist may be required to supply quality information to a public agency. The public agency can verify and credibly report information about these qualities. Consumers can obtain quality information only through the public agency.

The public agency commits to a quality-report policy before the monopolist makes its production and pricing decisions. We consider two information report regimes. In Full Quality Report, the public agency commits to reporting both Qualities 1 and 2 of each good the monopolist produces. In Average Quality Report, the public agency commits to reporting a linearly weighted average of qualities of each good that the monopolist produces.

Because the consumer’s valuation of Quality 2 varies, the monopolist may want to use a price-quality menu \( \{p(v), q(v), r(v)\}, v \in [\underline{v}, \overline{v}] \), to screen consumers. In fact, we specify that the monopolist must produce such a menu, although it is allowed to set identical values for different items in the menu. In Full Quality Report, this entire menu will be reported by the public agency. In Average Quality Report, we let the regulator choose a specific weight to compute the average quality of a good produced by the monopolist. The weights are represented by a function \( \theta : [\underline{v}, \overline{v}] \to [0, 1] \). At \( v \), the weights on Quality 1 and Quality 2 are \( \theta(v) \) and \( 1 - \theta(v) \), respectively, and \( 0 < \theta(v) < 1 \). For good \( (q(v), r(v)) \), the weighted-average quality is
$A(v) \equiv \theta(v)q(v) + (1 - \theta(v))r(v)$. The menu $\{p(v), A(v)\}$, $v \in [\underline{v}, \bar{v}]$, will be reported to consumers. In each report regime, a consumer picks an item from the menu.

### 2.3 Extensive forms

The extensive form for Average Quality Report is as follows.

**Stage 0:** Nature determines $v$ according to distribution function $F$ and an independent realization of $v$ is made known to each consumer.

**Stage 1:** The public agency chooses a weight function $\theta$ for reporting the average quality, and the function is public information.

**Stage 2:** The monopolist chooses a menu of prices and qualities, $\{p(v), q(v), r(v)\}$, $v \in [\underline{v}, \bar{v}]$.

**Stage 3:** After observing the menu, the public agency constructs the average quality $A(v) \equiv \theta(v)q(v) + (1 - \theta(v))r(v)$ of each good in the menu, and then $\{p(v), A(v)\}$, $v \in [\underline{v}, \bar{v}]$ is reported to consumers.

**Stage 4:** Each consumer decides to buy an item from the menu $\{p(v), A(v)\}$, $v \in [\underline{v}, \bar{v}]$, or buy nothing.

We do not write down the extensive form for Full Quality Report. It can be obtained straightforwardly by replacing $\{p(v), A(v)\}$, $v \in [\underline{v}, \bar{v}]$ in the above by $\{p(v), q(v), r(v)\}$, $v \in [\underline{v}, \bar{v}]$. We study perfect Bayesian equilibria of both games.

The monopolist maximizes expected profit, and each consumer maximizes her utility. In the Average Quality Report game, the public agency chooses a weight function $\theta$ to maximize aggregate consumer utility. Consumers form their beliefs about Qualities 1 and 2 upon observing the reported menus. We will focus on weight functions $\theta$ that induce the monopolist to offer incentive compatible menus. That is, we consider weight functions $\theta$ such that, in the continuation equilibrium after Stage 1, the firm offers a menu $\{p(v), q(v), r(v)\}$, $v \in [\underline{v}, \bar{v}]$, the public agency reports $\{p(v), A(v)\}$, $v \in [\underline{v}, \bar{v}]$, where $A(v) \equiv \theta(v)q(v) + (1 - \theta(v))r(v)$, and consumer $v$ picks item $(p(v), A(v))$.

In the Full Quality Report game, consumers have perfect information about qualities. From the revelation principle, we only need to let the monopolist offer menus $\{p(v), q(v), r(v)\}$, $v \in [\underline{v}, \bar{v}]$, that are incentive
compatible, so consumer \( v \) in equilibrium chooses item \((p(v), q(v), r(v))\) from the offered menu.

### 2.4 Full information benchmark

We now write down the full information benchmark. Here, consumers’ valuations are public information, and the firm’s quality choices can be perfectly observed. The monopolist can perfectly price-quality discriminate consumers to extract all surplus. The total surplus of good \((q, r)\) for type-\( v \) is \( uq + vr - c(q) - d(r) \).

The first-best qualities, \((q^{FB}, r^{FB}(v))\), are given by \( u = c'(q^{FB}) \) and \( v = d'(r^{FB}(v)) \), respectively. The first-best Quality 1, \( q^{FB} \), depends only on \( u \), which is the same for all consumers. The first-best Quality 2, \( r^{FB}(v) \), depends only on the realization of \( v \) of a consumer. Under full information, the monopolist offers the first-best qualities to consumer \( v \) at a price \( p(v) = uq^{FB} + vr^{FB}(v) \). The equilibrium allocation is first best, but each consumer obtains no surplus from the purchase. The monopolist makes a profit \( uq^{FB} + vr^{FB}(v) - c(q^{FB}) - d(r^{FB}(v)) \) from each consumer.

Finally, we note that if no reporting of quality information is feasible, the market collapses. The monopolist cannot convey any information about qualities, and all consumers refuse to buy at any positive price. At a zero price, the firm does not produce.

### 3 Full Quality Report

In this section, we present the equilibria in the Full Quality Report game. In Stage 3 the public agency reports both Qualities 1 and 2. Consumers’ valuations on Quality 2 remain their private information. By the revelation principle, the monopolist offers an incentive-compatible and individually-rational menu. A menu \( \{p(v), q(v), r(v)\}, v \in [v, \bar{v}] \), is incentive compatible if \( v = \arg\max_{v'} uq(v') + vr(v') - p(v'), \ v, v' \in [v, \bar{v}] \), and is individually rational if \( uq(v) + vr(v) - p(v) \geq 0, v \in [v, \bar{v}] \). The equilibrium is an incentive compatible and individually rational menu that maximizes expected profit \( \int_{\underline{v}}^{\bar{v}} [p(v) - c(q(v)) - d(r(v))] f(v) dv \).

The following derivation is standard in the screening literature (see, for example, Section 2 of Laffont and Martimont 2001). Let \( W(v) \equiv \max_{v'} uq(v') + vr(v') - p(v'), \ v, v' \in [v, \bar{v}] \). Applying the envelope theorem on \( W \), simplifying, applying integration by parts, and substituting for \( p \) in the monopolist’s profit function,
we can obtain the the equilibrium by finding \( \tilde{q} \) and an increasing function \( \tilde{r}(v) \) that maximize

\[
\int_{\underline{v}}^{\overline{v}} \left[ uq + \left( v - \frac{1 - F(v)}{f(v)} \right) r(v) - c(q) - d(r(v)) \right] f(v)dv.
\]

We assume the common monotone hazard rate condition,

\[
\frac{1 - F(v)}{f(v)} \text{ decreasing in } v,
\]

and present the following (proof omitted):

**Proposition 1** *In the Full Quality Report game, under monotone hazard rate, the equilibrium \( \tilde{q} \) and \( \tilde{r}(v) \) are given by

\[
\begin{align*}
\bar{u} &= c'(\tilde{q}) \\
v - \frac{1 - F(v)}{f(v)} &= d'(\tilde{r}(v)).
\end{align*}
\]

**Consumer** \( v \)'s equilibrium utility is given by \( \tilde{W}(v) \equiv \int_{\underline{v}}^{v} \tilde{r}(v)dx \). The equilibrium price of good \( (\tilde{q}, \tilde{r}(v)) \) is

\[
\tilde{p}(v) \equiv u\tilde{q} + v\tilde{r}(v) - \int_{\underline{v}}^{v} \tilde{r}(v)dx.
\]

The monopolist’s decisions on the two qualities are separable. Consumers’ valuation on Quality 1 is fixed at \( u \), so, for each \( v \), the firm chooses the first-best Quality 1, \( \tilde{q} = q^{FB} \), and extracts all surplus \( u\tilde{q} - c(\tilde{q}) \) from Quality 1. For Quality 2, the firm misses information of consumers’ valuations \( v \). The Myerson virtual valuation, \( \frac{1 - F(v)}{f(v)} \), is subtracted from \( v \) to adjust for this missing information. We assume \( \frac{1 - F(v)}{f(v)} < v \) and hence \( \tilde{r}(v) \) is positive for all \( v \). Proposition 1 records the marginal conditions. Compared to the full information benchmark, the equilibrium Quality 2 \( \tilde{r}(v) \) is lower, but consumer \( v \) earns information rent equal to \( \int_{\underline{v}}^{v} \tilde{r}(v)dx \). Reporting full quality information prevents the market from collapsing but also lets the monopolist practice standard second-degree price-quality discrimination. In the next two sections, we consider Average Quality Report, and will show that consumers benefit from less information about product qualities.

### 4 Average Quality Report

We begin by characterizing the firm’s choices of Quality 1 and Quality 2 to achieve any average quality.
4.1 Cost minimizing qualities

Consider an average quality $A(v)$ reported by the public agency in Stage 3. Our first result says that Qualities 1 and 2 must be chosen to achieve this average at the minimum cost. This is a new constraint for the monopolist whose product qualities cannot be fully disclosed to consumers.

**Lemma 1** Given a weight function $\theta$ chosen by the public agency in Stage 1, in equilibrium the monopolist chooses Qualities 1 and 2, $\tilde{q}(v)$ and $\tilde{r}(v)$, that minimize $c(q(v)) + d(r(v))$ subject to $\theta(v)q(v) + (1 - \theta(v))r(v) = A(v)$, for any average quality $A(v)$ to be reported in Stage 3. Hence, $(\tilde{q}(v), \tilde{r}(v))$ satisfy

$$\frac{c'(\tilde{q}(v))}{\theta(v)} = \frac{d'(\tilde{r}(v))}{1 - \theta(v)} \quad (4)$$

$$A(v) = \theta(v)\tilde{q}(v) + (1 - \theta(v))\tilde{r}(v). \quad (5)$$

When choosing qualities, the monopolist is, in fact, choosing the average which the public agency will report in Stage 3. If an item $(p(v), A(v))$ is to be purchased by consumers, the monopolist raises profits by choosing qualities that minimize the cost of achieving average quality $A(v) = \theta(v)q(v) + (1 - \theta(v))r(v)$. For any average quality, consumers must therefore believe that only cost-minimizing qualities will be chosen to achieve that average. Equation (4) is the familiar optimality condition: the ratio of the marginal costs, $c'/d'$, should be equal to the ratio of quality weights contributing to the average, $\theta(v)/[1 - \theta(v)]$. Equations (4) and (5) implicitly define $(\tilde{q}(v), \tilde{r}(v))$ as functions of $A(v)$ and $\theta(v)$.

For given $A(v)$ and $\theta(v)$, the monopolist’s choice of $(\tilde{q}(v), \tilde{r}(v))$ is the solution of a standard cost-minimizing problem. Figure 1 illustrates the solution. The iso-cost line contains $(q(v), r(v))$ pairs that have the same total cost. From the convexity of the $c$ and $d$ functions, the iso-cost line is concave to the origin. The iso-average quality line contains $(q(v), r(v))$ pairs that achieve the same average quality, and is a negatively sloped straight line. The cost-minimizing qualities for achieving $A_1(v)$ are at the tangency point $(\tilde{q}_1(v), \tilde{r}_1(v))$. Holding $\theta(v)$ fixed, we can trace out all cost-minimizing quality pairs as $A(v)$ changes. This is the dotted line in Figure 1. For a fixed $A(v)$, the slope of the iso-average quality line is $-\theta(v)/[1 - \theta(v)]$, which is decreasing in $\theta(v)$. If $\theta(v)$ decreases, the iso-average quality line becomes flatter, and the entire dotted line will pivot in an anti-clockwise direction to become the dashed line.
4.2 Equilibrium qualities

By Lemma 1, if average quality $A(v)$ is reported in Stage 3, consumers must believe that that average quality comes from good $(\hat{q}(v), \hat{r}(v))$, implicitly defined by equations (4) and (5). Hence, from the item $(p(v'), A(v'))$, consumer $v$ obtains a utility $u\hat{q}(v') + v\hat{r}(v') - p(v')$. A menu $\{p(v), A(v)\}$ is then equivalent to $\{p(v), \hat{q}(v), \hat{r}(v)\}$, with $(\hat{q}(v), \hat{r}(v))$ given by (4) and (5). A menu is incentive compatible if $v = \arg\max_{v'} u\hat{q}(v') + v\hat{r}(v') - p(v')$, $v, v' \in [\underline{v}, \bar{v}]$, and individually rational if $u\hat{q}(v') + v\hat{r}(v') - p(v') \geq 0$.

As in Full Quality Report, we can apply the envelope condition to simplify the incentive and individual rationality constraints. Again, the Myerson adjustment has to be applied to $v$ to account for consumers' private information. After the usual simplification via integration by parts, the monopolist will choose $\hat{q}(v)$ and $\hat{r}(v)$ to maximize

$$
\int_{\underline{v}}^{\bar{v}} \left[ u\hat{q}(v) + \left( v - \frac{1 - F(v)}{f(v)} \right) \hat{r}(v) - c(\hat{q}(v)) - d(\hat{r}(v)) \right] f(v) dv. \quad (6)
$$

Incentive compatibility also requires that $\hat{r}(v)$ be an increasing function. (Details are in a supplement at the end of the paper.) Also, for each $v$, there is the new constraint (4) on $\hat{q}(v)$ and $\hat{r}(v)$ according to Lemma 1. The Lagrangian of the constrained maximization problem is

$$
\int_{\underline{v}}^{\bar{v}} \left[ u\hat{q}(v) + \left( v - \frac{1 - F(v)}{f(v)} \right) \hat{r}(v) - c(\hat{q}(v)) - d(\hat{r}(v)) + \lambda(v) \left( \frac{c'(\hat{q}(v))}{\theta(v)} - \frac{d'(\hat{r}(v))}{1 - \theta(v)} \right) \right] f(v) dv, \quad (7)
$$
where \( \lambda(v) \) is the multiplier at \( v \).

**Proposition 2** For a given weight function \( \theta \) that induces the monopolist to offer incentive-compatible menus, under monotone hazard rate equilibrium Qualities 1 and 2, \( \tilde{q}(v) \) and \( \tilde{r}(v) \), in the Average Quality Report game are given by

\[
[u - c'(\tilde{q}(v))] \frac{\theta(v)}{c''(\tilde{q}(v))} + \left[ v - \frac{1 - F(v)}{f(v)} - d'(\tilde{r}(v)) \right] \frac{1 - \theta(v)}{d''(\tilde{r}(v))} = 0
\]  

(8)

\[
\frac{c'(\tilde{q}(v))}{\theta(v)} - \frac{d'(:\tilde{r}(v))}{1 - \theta(v)} = 0.
\]

(9)

Consumer \( v \)’s equilibrium utility is \( \tilde{W}(v) \equiv \int_{u}^{v} \tilde{r}(v) dx \). The equilibrium price of an item with average quality \( A(v) \) is

\[
p(v) \equiv u\tilde{q}(v) + v\tilde{r}(v) - \int_{u}^{v} \tilde{r}(v) dx.
\]

(10)

Proposition 2 presents two conditions, (8) and (9), for the equilibrium qualities. The two terms in square brackets in (8) have the forms of the equilibrium quality characterizations, (1) and (2), in Proposition 1 of Full Quality Report. The sum of these two square-bracketed terms multiplied by terms that are dependent on \( \theta(v) \) must be equal to 0. For most weight functions \( \theta \), the qualities \( \tilde{q}(v) \) and \( \tilde{r}(v) \) are different from those equilibrium qualities \( q(v) \) and \( r(v) \) in Full Quality Report. Furthermore, even though consumers have identical valuations on Quality 1, each consumer \( v \) may be offered a different level of that quality.

The monopolist’s choices of Qualities 1 and 2 are no longer separable. Although the marginal profit from increasing Qualities 1 and 2 remains at \( u - c'(q) \) and \( v - \frac{1 - F(v)}{f(v)} - d'(r) \), the monopolist cannot convince consumers that these qualities are provided independently. Consumers only observe the average quality, and believe that Qualities 1 and 2 are jointly chosen to minimize the cost to achieve this average.

How does the cost-minimization belief restrict the monopolist’s quality choices? Consider the first-order derivatives of the Lagrangian (7) with respect to \( q \) and \( r \):

\[
u - c'(\tilde{q}(v)) - \lambda(v)(1 - \theta(v))c''(\tilde{q}(v))
\]

\[
v - \frac{1 - F(v)}{f(v)} - d'(\tilde{r}(v)) + \lambda(v)\theta(v)d''(\tilde{r}(v)).
\]
The last terms in these expressions, \(-\lambda(v)(1 - \theta(v))c''(\tilde{q}(v))\) and \(\lambda(v)\theta(v)d''(\tilde{r}(v))\), come from the constraint (4), and they cause distortions on Qualities 1 and 2 from the equilibrium in the Full Quality Report game.

Figure 2 illustrates these distortions. In Figure 2, we have plotted the equilibrium qualities under Full Quality Report by the vertical, solid line. The equilibrium Quality 1 is constant at \(e_q\), while the equilibrium Quality 2 increases with \(v\), and the range of values of \(e_r(v)\) as \(v\) varies between \(v_0\) and \(v_s\) spans that vertical line. Consider \(v = v_2\), the corresponding average quality report weight being \(\theta(v_2)\). The point \(B\) denotes the equilibrium qualities in the Full Quality Report game at \(v = v_2\). The positively sloped graph passing through the point \(B\) is the set of Qualities 1 and 2 that minimize the monopolist’s cost for various average qualities, given weight \(\theta(v_2)\) on Quality 1. But point \(B\) happens to be qualities that minimize costs. Then the monopolist chooses the same combination of qualities at \(B\), and the multiplier \(\lambda(v)\) at \(v = v_2\) becomes 0; equilibrium qualities at \(B\) across both games happen to coincide.

Now consider point \(A\), which denotes the equilibrium qualities in the Full Quality Report game at \(v = v_1\). The dashed curve right above \(A\) graphs the qualities that minimize costs when the quality weight is \(\theta(v_1)\). But qualities at \(A\) do not minimize costs. Under Average Quality Report, the monopolist distorts the qualities at \(A\) in a northwestern direction, reducing Quality 1 and raising Quality 2. The equilibrium is the solid point to the northwest of \(A\). Here, the multiplier \(\lambda(v)\) at \(v = v_1\) is positive, so there is under-provision.
of Quality 1 and over-provision of Quality 2 compared to the Full Quality Report game.

Finally, consider point $C$. This denotes the equilibrium qualities in the Full Quality Report game at $v = v_3$. The dashed curve right below $C$ graphs the qualities that minimize costs when the quality weight is $\theta(v_3)$. Again, qualities at $C$ do not minimize costs. Under Average Quality Report, the monopolist distorts the qualities at $C$ in a southeastern direction, raising Quality 1 and lowering Quality 2. The equilibrium is the solid point to the southeast of $C$. Here, the multiplier $\lambda(v)$ at $v = v_3$ is negative, so there is over-provision of Quality 1 and under-provision of Quality 2 compared to the Full Quality Report game.

5 Report weights and consumer utilities

We now characterize the public agency’s choice of the weight function $\theta$ in Stage 1. We begin by showing that the public agency can implement Full Quality Report equilibrium outcomes by an appropriate choice of the weight function.

5.1 Implementing Full Quality Report outcomes

Under Average Quality Report, consumers receive partial quality information from the public agency, and their beliefs about qualities are restricted to those in Lemma 1. However, the following Lemma says that the public agency can choose the weight function to nullify consumers’ cost-minimization belief restrictions.

**Lemma 2** Under Average Quality Report, the public agency can implement the equilibrium qualities in the Full Quality Report game by the weight function

$$\tilde{\theta}(v) = \frac{c'(\bar{q})}{c'(\bar{q}) + d'(\bar{r}(v))}, \quad (11)$$

where $\bar{q}$ and $\bar{r}(v)$ are the equilibrium qualities in Full Quality Report, and given by (1) and (2), respectively.

Average Quality Report constrains the firm to choose cost-minimizing quality pairs, but the public agency can assign weights on qualities according to the marginal costs of $\bar{q}$ and $\bar{r}(v)$, as in (11), effectively neutralizing the constraints. Given $\tilde{\theta}(v)$, the ($\bar{q}, \bar{r}(v)$) pair minimizes the cost of achieving average quality $\bar{A}(v) = \tilde{\theta}(v)\bar{q} + (1 - \tilde{\theta}(v))\bar{r}(v)$ at each $v$. Upon observing $\bar{A}(v)$, consumers must infer that the average quality
Figure 3: Implementing full quality report qualities

comes from good \((\bar{q}, \bar{r}(v))\). But then this is the best the monopolist can ever hope to achieve, so choosing \((\bar{q}, \bar{r}(v))\) is an equilibrium.

Figure 3 illustrates how the result applies to three items in the equilibrium menu. As in Figure 2, the solid line in Figure 3 plots the equilibrium qualities under Full Quality Report. Points A, B and C are the Full Quality Report equilibrium qualities for consumers \(v_1\), \(v_2\) and \(v_3\), respectively, where \(v_1 < v_2 < v_3\). The three dashed lines in Figure 3 graph the cost-minimizing quality pairs that the monopolist may offer to consumers \(v_1\), \(v_2\) and \(v_3\), respectively, under Average Quality Report. For \(\tilde{\theta}\) defined by (11), the three dashed lines must pass through the Full Quality Report equilibrium qualities, points A, B, and C. The constraints due to cost minimization do not bind.

### 5.2 Quality weights to maximize consumer utility

Lemma 2 implies that consumers cannot become worse off if the public agency switches from Full Quality Report to Average Quality Report. The public agency can always implement the Full Quality Report equilibrium qualities \(\{\bar{q}, \bar{r}(v), \bar{p}(v)\}, \quad v \in [\underline{v}, \bar{v}]\). In fact, the public agency can do more. Under Full Quality Report, the monopolist leaves consumers only their information rent, 
\[
\int_{\underline{v}}^{\bar{v}} \left( \int_{\underline{v}}^{v} \tilde{r}(x)dx \right) f(v) dv.
\]

The public agency can reduce rent extraction by increasing Quality 2 from \(\tilde{r}(x)\) by a reduction of the report weights.
Proposition 3  In the equilibrium of the Average Quality Report game, \( \widehat{r}(v) \) is higher than \( \check{r}(v) \) at every \( v \), whereas \( \check{\theta}(v) \) is smaller than \( \overline{\theta}(v) \) at every \( v \). Each consumer (except type-\( v \)) obtains a higher equilibrium utility in the Average Quality Report game than in the Full Quality Report game. At every \( v \), the Average Quality Report equilibrium weight and qualities are characterized by (8), (9) and

\[
\widehat{\theta}(v) = \frac{d'(\widehat{r}(v)) - \left( v - \frac{1 - F(v)}{f(v)} \right)}{d''(\widehat{r}(v)) - \left( v - \frac{1 - F(v)}{f(v)} \right) + d''(\widehat{r}(v)) \left( \frac{c''(\widehat{q}(v))}{c'(\widehat{q}(v))} - \frac{c''(\check{q}(v))}{c'(\check{q}(v))} \right)^{-1}}.
\]  

(12)

In Proposition 3, the equilibrium Quality 2 has been increased from the equilibrium in the Full Quality Report regime. This is achieved by reducing the report weight on Quality 1. Because the firm is missing information of consumers’ valuation \( v \), consumers earn information rent, which is increasing in Quality 2. Consumers’ valuation of Quality 1 is fixed, and the firm leaves no rent to consumers from Quality 1. From the equilibrium under Full Quality Report, further changes in Quality 1 have no consequence for consumer welfare, but an increase in Quality 2 raises it.

Lemma 1 constrains the way how Quality 1 and Quality 2 must change: the ratio of the marginal costs, \( c'/d' \), must be equal to the ratio of quality weights, \( \theta(v)/[1 - \theta(v)] \). To see the effect of changing the quality weight function from \( \check{\theta} \) to \( \overline{\theta} \) on equilibrium qualities, we rearrange (12) to get

\[
v = \frac{1 - F(v)}{f(v)} = d'(\widehat{r}(v)) - \left[ d'(\widehat{r}(v)) \left( \frac{c''(\widehat{q}(v))}{c'(\widehat{q}(v))} - \frac{c''(\check{q}(v))}{c'(\check{q}(v))} \right)^{-1} \right] \frac{\overline{\theta}(v)}{1 - \overline{\theta}(v)}.
\]  

(13)

Here, on the left-hand side, we have the consumer’s virtual valuation—the Myerson adjustment accounting for the distortion from the firm’s attempt to screen different consumer types. On the right-hand side, we first have the marginal cost of Quality 2, and then must take into account the distortion due to cost-minimization. This distortion depends on the slopes and the curvatures of the marginal cost functions, \( c' \) and \( d' \). This is because the firm must equate the ratio of the marginal costs and the ratio of quality weights to minimize the cost of producing average quality \( \widehat{A}(v) = \overline{\theta}(v)\check{q}(v) + (1 - \overline{\theta}(v))\widehat{r}(v) \). Because \( c''/c' \) is nonincreasing, the square-bracketed term in (13) is strictly positive. By lowering the weight at \( v \) from \( \check{\theta}(v) \) to \( \overline{\theta}(v) \), the public agency lowers the relative cost of using Quality 2 to achieve every level of average quality. This implements
a higher level of Quality 2 at every \( v \).

Figure 4 illustrates the equilibrium choices. The diagram builds on the presentation in Figure 3. Points \( A, B \) and \( C \) are the qualities pairs for consumers \( v_1, v_2 \) and \( v_3 \) under the weight function \( \tilde{\theta} \). The three dashed lines represent the cost minimizing quality pairs under equilibrium weight function \( \hat{\theta} \). In the equilibrium of the Average Quality Report game, the monopolist distorts the qualities at each \( v \) in a northwest direction, lowering Quality 1 and raising Quality 2. The three solid points on the dashed lines are the equilibrium qualities obtained by consumers \( v_1, v_2 \) and \( v_3 \), respectively. Quality 2 has increased, raising consumer welfare, while Quality 1 has decreased, but it has no effect on consumer welfare. As the three solid points show, the equilibrium qualities \( \hat{q}(v) \) and \( \hat{r}(v) \) are both increasing in \( v \). The equilibrium menu \( \{\hat{q}(v), \hat{r}(v), \hat{p}(v)\} \), \( v \in [\underline{v}, \bar{v}] \), induced by \( \hat{\theta} \) is incentive compatible.

### 5.3 Quality weights for general welfare

In the previous subsection, we have shown that the public agency can implement a higher consumer surplus in the Average Quality Report game than Full Quality Report game. Can Average Quality Report also implement a higher general welfare index that is a weighted sum of consumer surplus and profit?

By Proposition 2, consumer surplus under Average Quality Report is \( \int_{\underline{v}}^{\bar{v}} \left( \int_{\underline{v}}^{v} \hat{r}(x)dx \right) f(v)dv \). Using
integration by parts, we can rewrite consumer surplus as \( \int_{v}^{b} [1 - F(v)] \tilde{r}(v) \, dv \). A general welfare index, \( I(\alpha) \), can be written as

\[
I(\alpha) = \int_{v}^{b} \left\{ \alpha \left[ \frac{1 - F(v)}{f(v)} \tilde{r}(v) \right] + (1 - \alpha) \left[ u \tilde{q}(v) + \left( v - \frac{1 - F(v)}{f(v)} \right) \tilde{r}(v) - c(\tilde{q}(v)) - d(\tilde{r}(v)) \right] \right\} f(v) \, dv,
\]

(14)

where \( \tilde{q}(v) \) and \( \tilde{r}(v) \) are given by (8) and (9), and where \( \alpha, 1/2 \leq \alpha \leq 1 \), is the weight on consumer surplus. When \( \alpha = 1/2 \), (14) becomes social surplus \( \int_{v}^{b} [u \tilde{q}(v) + v \tilde{r}(v) - c(\tilde{q}(v)) - d(\tilde{r}(v))] \, f(v) \, dv \). When \( \alpha = 1 \), the second square-backeted term in (14) vanishes, so (14) becomes consumer surplus. The public agency’s objective now is to maximize the general social welfare in (14). Let \( \theta^I(v) \) and \( r^I(v) \) be the equilibrium weight function and Quality 2, respectively, when the public agency maximizes (14).

Recall that the public agency can implement the equilibrium under Full Quality Report using the weights \( \dot{\theta} \) in (11) of Lemma 2, but that in equilibrium, it uses the lower weights \( \tilde{\theta} \) in Proposition 3. Also, the equilibrium Quality 2 \( \tilde{r}(v) \) is always strictly greater than the equilibrium Quality 2 \( \tilde{r}(v) \) under Full Quality Report. The next proposition says that when the public agency maximizes the general social welfare (14), the equilibrium is in-between equilibria under Full Quality Report and Average Quality Report for consumer utility maximization.

**Proposition 4** When the public agency maximizes the general welfare index (14), the equilibrium weight \( \theta^I(v) \) satisfies \( \tilde{\theta}(v) \leq \theta^I(v) < \tilde{\theta}(v) \), and the equilibrium quality \( r^I(v) \) satisfies \( \tilde{r}(v) < r^I(v) \leq \tilde{r}(v) \) at every \( v \). Moreover, the equilibrium welfare under Average Quality Report is higher than Full Quality Report.

The intuition behind Proposition 4 is this. By Lemma 2, the public agency can implement the Full Quality Report Qualities 1 and 2, \( \tilde{q} \) and \( \tilde{r}(v) \), by \( \tilde{\theta} \). By lowering the weight at \( v \) from \( \tilde{\theta}(v) \), say to \( \tilde{\theta}(v) - \epsilon \), the public agency raises the cost of using Quality 1 and lowers the cost of using Quality 2 to produce an average quality. The new weight function \( \tilde{\theta}(v) - \epsilon \) thus reduces Quality 1 but raises Quality 2. This change improves welfare. This is because under Full Quality Report, Quality 1 is first best but Quality 2 is lower than first best. Therefore, the increase in Quality 2 results in a first-order welfare gain while the decrease in Quality 1 merely results in a second-order welfare loss. Because the welfare weight \( \alpha \) is greater than a half,
the weight function will never fall below $\hat{\theta}$.

The increase in equilibrium welfare in Proposition 4 is due to a redistribution of surplus from the monopolist to the consumers. Because $r^I(v)$ is higher than $r(v)$ at each $v$, all consumers (except type-$v_0$) obtain higher utilities in the equilibrium in Proposition 4 than in the Full Quality Report game. On the other hand, the monopolist’s profit in Proposition 4 is lower than in the Full Quality Report game. This is because $\theta^I(v)$ is lower than $\hat{\theta}(v)$, so the profit-maximizing Qualities 1 and 2 in the Full Quality Report game cannot be equilibrium in Proposition 4.

6 Quality report and competition

In this section, we let there be many competing firms in the market. Because we have not included horizontal product differentiation in the model, it is natural to continue the analysis with a Bertrand game. We let firms simultaneously make decisions on Qualities 1 and 2, and prices, all as functions of $v$. When quality information is unavailable, the market collapses, as in the case of monopoly. A public agency can remedy the problem by credibly reporting quality information. Under Full Quality Report, the public agency reports all quality pairs of all firms that engage in production. Under Average Quality Report, the public agency first chooses a quality weight function, computes the weighted averages of qualities of all firms that engage in production, and then reports the averages.

Recall that the first-best Qualities 1 and 2 are, respectively, $q^{FB} \equiv \arg\max_q u_q - c(q)$, and $r^{FB}(v) \equiv \arg\max_r v_r - d(q)$, $v \in [\underline{v}, \bar{v}]$. The Bertrand equilibrium in Full Quality Report is simply the first best. Each firm produces quality pairs $(q^{FB}, r^{FB}(v))$, and charges prices $c(q^{FB}) + d(r^{FB}(v))$, $v \in [\underline{v}, \bar{v}]$. Consumer $v$ picks $(q^{FB}, r^{FB}(v))$ because the equilibrium offers are incentive compatible. The Bertrand equilibrium in Full Quality Report is simply the first best. Each firm makes a zero profit.

Clearly, consumer welfare is highest under Bertrand competition and Full Quality Report. Actually, Average Quality Report also can implement the first best. Consumers must form their beliefs about qualities when an average is reported by the public agency. Lemma 1 applies to any firm’s reported average quality; each firm must minimize the cost for achieving the average. Now Lemma 2 can be applied. The public

\footnote{By definitions of $q^{FB}$ and $q^{FB}(v)$, we have $u_{q^{FB}} + v_{r^{FB}(v)} - c(q^{FB}) - d(r^{FB}(v)) \geq u_{q^{FB}} + v_{r^{FB}(v') - c(q^{FB}) - d(r^{FB}(v'))}$, all $v, v' \in [\underline{v}, \bar{v}]$.}
agency can choose a quality weight function $\theta_{FB} : [v, \bar{v}] \rightarrow [0, 1]$ as follows:

$$\theta_{FB}(v) = \frac{c'(q_{FB})}{c'(q_{FB}) + d'(r_{FB}(v))}. \quad (15)$$

Given this weight function, the first-best qualities are cost-minimizing. It is therefore an equilibrium for firms to produce first-best qualities.

**Corollary 1** When firms compete in the Bertrand fashion, under Average Quality Report the public agency implements the first-best Qualities 1 and 2, $q_{FB}$ and $r_{FB}(v)$, by the quality weight function $\theta_{FB}(v)$ in (15). Equilibria under Full Quality Report and Average Quality Report are identical.

In Average Quality Report we can compare equilibrium qualities between monopoly and competition. These are, respectively, those in Proposition 3 and Corollary 1. Figure 5 illustrates these three functions. Equilibrium Quality 2 under competition is first best, and described by the solid line $r_{FB}(v)$. For monopoly, equilibrium Quality 2 under Full Quality Report is the dashed line $\tilde{r}(v)$, while it is the dotted line $\tilde{r}(v)$ under Average Quality Report.

For monopoly, at each $v$, equilibrium Quality 2 under Average Quality Report is higher than Full Quality Report (Proposition 3), so $\tilde{r}(v) > \tilde{r}(v)$. For competition, at each $v$ equilibrium Quality 2 is first best (Corollary 1). But then under monopoly, the equilibrium Full Quality Report Quality 2 is lower than first
best, so $\bar{r}(v) < r^{FB}(v)$, but $\bar{r}(v)$ and $r^{FB}(v)$ have the same limit as $v$ tends to $\bar{v}$. We therefore have the general intersection properties of the three graphs in Figure 5.

In the Average Quality Report regime, switching from monopoly to competition must reduce Quality 2 for those consumers with high valuations (those $v$ near $\bar{v}$), but vice versa for consumers with low valuations (those $v$ near $v$). However, this switch will raise Quality 1 because $\bar{q}(v) < q^{FB}$. Consumer utility must increase when the monopolist is replaced by a set of competitive firms.

7 Concluding remarks

We have studied policies for reporting qualities of a good under different structures. Most of the analysis is on a monopolistic market. In Full Quality Report, the monopolist underprovides the quality that consumers have different and private valuations. In equilibrium, the monopolist extracts surplus by second-degree price-quality discrimination. In Average Quality Report, the public agency can restrain the monopolist’s pricing and quality decisions by the choices of quality weights. The public agency implements a higher consumer surplus through Average Quality Report by assigning higher weights on the quality that has been under-provided. Under Bertrand competition, Full Quality Report yields first-best qualities and the maximum consumer surplus, while Average Quality Report implements the same outcome by suitable choices of quality weights.

For tractability, we let a single parameter describe consumers’ private preferences of a multi-dimensional good. Armstrong (1996), and Rochet and Choné (1998) analyze screening models in which qualities and preferences have the same dimension. Generally, the monopolist depresses all qualities to extract surplus. In their models, qualities are public information. The design of optimal report policies when preferences are multi-dimensional is likely to be complex but may be fruitful research.
Appendix

Proof of Lemma 1: Consider an item \((p(v), A(v))\) in a menu \(\{p(v), A(v)\}, v \in [\underline{v}, \bar{v}]\). The monopolist earns a profit \(p(v) - c(q(v)) - d(r(v))\) if it chooses to achieve the average \(A(v)\) by good \((q(v), r(v))\). By definition, \(p(v) - c(q(v)) - d(r(v)) \leq p(v) - c(\bar{q}(v)) - d(\bar{r}(v))\), with a strict inequality if \((q(v), r(v)) \neq (\bar{q}(v), \bar{r}(v))\) due to the strict convexity of \(c\) and \(d\). Regardless of consumers’ beliefs, the monopolist earns a higher profit by choosing \((\bar{q}(v), \bar{r}(v))\). Hence, any \((q(v), r(v)) \neq (\bar{q}(v), \bar{r}(v))\) cannot be equilibrium choices for achieving the average \(A(v)\). Finally, (4) and (5) are obtained from the first-order conditions of the constrained maximization problem.

Proof of Proposition 2: Using pointwise optimization, the first-order conditions of (7) with respect to \(\bar{q}(v), \bar{r}(v)\) and the Lagrangian \(\lambda(v)\) are, respectively,

\[
\begin{align*}
\frac{u - c'(\bar{q}(v)) - \lambda(v)(1 - \theta)c''(\bar{q}(v))}{\theta(v)} &= 0 \\
\frac{v - 1 - F(v)}{f(v)} - d'(\bar{r}(v)) + \lambda(v)\theta d''(\bar{r}(v)) &= 0 \\
\frac{c'(\bar{q}(v))}{\theta(v)} - \frac{d'(\bar{r}(v))}{1 - \theta(v)} &= 0.
\end{align*}
\]

We combine (16), (17) and eliminate the Lagrangian \(\lambda(v)\) to get (8).

Proof of Lemma 2: First, use the definition of \(\bar{\theta}\) in (11), and substitute it in (4). We then easily verify that \((\bar{q}, \bar{r}(v))\) satisfies the cost-minimization constraint in Lemma 1. Second, by Proposition 1, the quality pair \((\bar{q}, \bar{r}(v))\) is incentive compatible and maximizes the monopolist’s profit at each \(v\) when the monopolist’s quality choices are not subject to the cost-minimization constraint. Therefore, we conclude that \((\bar{q}, \bar{r}(v))\) is an equilibrium in the continuation game defined by \(\bar{\theta}\) in (11).

Proof of Proposition 3: By Proposition 2, total consumer utility under Average Quality Report is

\[
\int_{\underline{v}}^{\bar{v}} \left( \int_{\underline{v}}^{\bar{v}} \hat{r}(x)dx \right) f(v)dv,
\]

where \(\hat{r}(v)\) is given by (8) and (9). Using integration by parts, we rewrite total consumer utility as

\[
\int_{\underline{v}}^{\bar{v}} [1 - F(v)] \hat{r}(v)dv
\]

because \(- \left[ [1 - F(v)] \int_{\underline{v}}^{\bar{v}} \hat{r}(x)dx \right]_{\underline{v}}^{\bar{v}}\) is equal to 0.
We begin by showing that in the equilibrium of the Average Quality Report game, \( \overline{r}(v) \leq \hat{r}(v) \) at each \( v \). First, by the Maximum Theorem, \( \overline{r}(v) \) and \( \hat{r}(v) \) are continuous. Also, since \( \overline{r}(v) \) and \( \hat{r}(v) \) are equilibrium qualities, each must be increasing. So suppose that in equilibrium there exist \( v_1 < v_2 \) such that for all \( v \in (v_1, v_2) \subset [v, \overline{v}] \), \( \hat{r}(v) < \overline{r}(v) \). Now replace \( \hat{r}(v) \) by \( \overline{r}(v) \) for \( v \in (v_1, v_2) \). This new Quality 2 function can be implemented simply by replacing \( \hat{\theta}(v) \) by \( \overline{\theta}(v) \) for \( v \in (v_1, v_2) \). We have raised the consumer’s utility in (19). This is a contradiction. We conclude that \( \overline{r}(v) \leq \hat{r}(v) \) at each \( v \).

By Proposition 1, \( \overline{q}(v) \) and \( \hat{r}(v) \) are given by (1) and (2). If \( \overline{q}(v) \) and \( \hat{r}(v) \) in (8) are respectively substituted by \( \hat{q}(v) \) and \( \overline{r}(v) \), each square-bracketed terms in (8) becomes 0. Now for (8) to hold, we must have \( \hat{q}(v) \leq \overline{q}(v) \) if and only if \( \hat{r}(v) \leq \overline{r}(v) \). Substituting \((\hat{q}(v), \hat{r}(v)) \) and \((\overline{q}(v), \overline{r}(v)) \) into (9), we have

\[
\frac{c'\overline{r}(v)}{\theta(v)} - \frac{d'\overline{r}(v)}{1 - \theta(v)} = 0 = \frac{c'\hat{q}(v)}{\theta(v)} - \frac{d'\hat{r}(v)}{1 - \theta(v)}.
\]

Because \( \overline{r}(v) \leq \hat{r}(v) \), we have \( \overline{q}(v) \leq \hat{q}(v) \), so from (20) \( \overline{\theta}(v) \leq \hat{\theta}(v) \) at each \( v \).

We now derive the equilibrium weight function \( \hat{\theta} \). At an equilibrium (19) is maximized. By pointwise optimization, we have \( \frac{d\hat{\theta}(v)}{\hat{\theta}(v)} = 0 \) at every \( v \). By Proposition 2, equations (8) and (9) implicitly define the equilibrium \( \hat{q} \) and \( \hat{r} \) as two functions in terms of \( v \) and \( \theta(v) \). After totally differentiating these equations, and simplifying, we obtain

\[
\frac{d\hat{r}(v)}{d\hat{\theta}(v)} = \frac{c'}{\theta(v)(1 - \theta(v))d'} \left[ \left( v - \frac{1 - F(v)}{f(v)} - d' \right) \left( \frac{c''}{c'} \right) - \frac{d''}{c'} \right].
\]

We get (12) by setting (21) equal to 0 and rearranging terms.

We have shown that \( \overline{r}(v) \leq \hat{r}(v) \) and \( \overline{\theta}(v) \leq \hat{\theta}(v) \) at each \( v \). By (12), we can rule out \( \overline{r}(v) = \hat{r}(v) \) and \( \overline{\theta}(v) = \hat{\theta}(v) \). Suppose not; that is, suppose that at some \( v^* \), \( \overline{r}(v^*) = \hat{r}(v^*) \) and \( \overline{\theta}(v^*) = \hat{\theta}(v^*) \). By (2) and (12), then at \( v^* \) we have \( \hat{\theta}(v^*) = 0 \). This contradicts Lemma 2. Finally, because \( \frac{c''}{c'} \) is nonincreasing, we have \( \frac{c''}{c'} \leq \frac{c''}{c'} \) and the denominator of (12) strictly positive. We conclude that \( 0 < \hat{\theta}(v) < \overline{\theta}(v) \) and \( \overline{r}(v) < \hat{r}(v) \) at each \( v \).

We now verify that the equilibrium menu is incentive compatible. It is sufficient to show that \( \hat{r}(v) \) is increasing. We totally differentiate (8) and (9) with respective to \( \hat{r}(v) \) and \( v \), then evaluate the derivative at
\[ \theta(v) = \hat{\theta}(v). \]

After simplification, we have

\[
\frac{d\hat{r}(v)}{dv} \bigg|_{\theta(v)=\hat{\theta}(v)} = \frac{1}{d''\theta(v)} \left[ \frac{d}{dv} \left( v - \frac{1 - F(v)}{f(v)} \right) \right] = \frac{1}{d''\theta(v)} \left[ \frac{d}{dv} \left( v - \frac{1 - F(v)}{f(v)} \right) - \left( v - \frac{1 - F(v)}{f(v)} - d' \right) \frac{c''}{c'} + \left( u - c' \right) \frac{d''}{c'} \right]. \tag{22}
\]

We show that (22) is strictly positive. First, using (9) to eliminate \( \hat{\theta}(v) \) in (8) and rearranging terms, we have

\[
\left[ d' \frac{c''}{c'} + c' \frac{d''}{c'} \right] - \left[ \left( v - \frac{1 - F(v)}{f(v)} \right) \frac{c''}{c'} + u \frac{d''}{c'} \right] = 0. \tag{23}
\]

Next, subtracting the left-hand side of (23) from the denominator of (21), we obtain

\[
\left[ \left( v - \frac{1 - F(v)}{f(v)} \right) \left( \frac{c''}{c'} - \frac{c''}{c'} \right) \right] + \left[ u \left( \frac{d''}{c'} - \frac{d''}{c'} \right) \right] + \left[ d' \frac{c''}{c'} + c' \frac{d''}{c'} \right]. \tag{24}
\]

Since \( \frac{c''}{c'} \) and \( \frac{d''}{c'} \) are nonincreasing, we have \( \frac{c''}{c'} < \frac{c''}{c'} \) and \( \frac{d''}{c'} < \frac{d''}{c'} \). Therefore, the first two square-bracketed terms in (24) are strictly positive. The last square-bracketed term in (24) is nonnegative because \( c \) and \( c \) are convex and \( c'' \) and \( d'' \) are nonnegative. Because of equations (23) and (24) being strictly positive, the denominator of (22) is strictly positive. Finally, by the monotone hazard rate assumption, the square-bracketed term in the numerator of (22) is strictly positive. We conclude that the equilibrium menu is incentive compatible. \( \blacksquare \)

**Proof of Proposition 4:** By pointwise optimization, the first-order condition of (14) with respect to \( \theta(v) \) is

\[
\alpha \left[ \frac{1 - F(v)}{f(v)} \frac{d\hat{r}(v)}{d\theta(v)} \right] + (1 - \alpha) \left[ (u - c'(q(v))) \frac{d\hat{q}(v)}{d\theta(v)} + \left( \frac{1 - F(v)}{f(v)} \right) \frac{d\hat{r}(v)}{d\theta(v)} \right] = 0, \tag{25}
\]

where (8) and (9) implicitly define \( \frac{d\hat{r}(v)}{d\theta(v)} \) and \( \frac{d\hat{q}(v)}{d\theta(v)} \) as (21) and

\[
\frac{d\hat{q}(v)}{d\theta(v)} = \frac{d'}{d\theta(v)(1 - \theta(v))} \left[ \frac{d'}{c' + c' \frac{d''}{c'}} - \left( \frac{1 - F(v)}{f(v)} - d' \right) \frac{c''}{c'} + \left( u - c' \right) \frac{d''}{c'} \right]. \tag{26}
\]

respectively. Using (21) and (26) to replace \( \frac{d\hat{r}(v)}{d\theta(v)} \) and \( \frac{d\hat{q}(v)}{d\theta(v)} \) in (25) and rearranging terms, we get

\[
\theta^\dagger(v) = \frac{\left[ d' - \left( \frac{1 - F(v)}{f(v)} \right) \right]}{\left[ d' - \left( \frac{1 - F(v)}{f(v)} \right) \right] + \left[ d'' - \Psi(\alpha) \left( \frac{c''}{c'} - \frac{d''}{c'} \right) \right]^{-1}}. \tag{27}
\]
at every \( v \), where \( \Psi(\alpha) \) is given by

\[
\Psi(\alpha) \equiv \frac{\alpha (u - c') \left[ \left( u - c' \right) \left( \frac{d''}{d'} - \frac{d'''}{d''} \right) \frac{d'}{c''} + \frac{d'' d'''}{c'} \right]}{\alpha \left( v - \frac{1 - F(v)}{f(v)} - d' \right) + (1 - \alpha) \left( \frac{1 - F(v)}{f(v)} \right)}.
\]  

(28)

Conditions (8), (9), (27), and (28) characterize the equilibrium weight and qualities at each \( v \).

We now show that \( \tilde{\theta}(v) \leq \theta^I(v) < \bar{\theta}(v) \) at each \( v \). First, by Lemma 2, the monopolist’s profit is maximized at \( \theta(v) = \tilde{\theta}(v) \). Hence, the second square-backeted term in (25) is strictly positive if \( \theta(v) < \tilde{\theta}(v) \) and non-positive if \( \tilde{\theta}(v) \leq \theta(v) \). Second, by Proposition 3, the first square-backeted term in (25) is strictly positive if \( \theta(v) < \tilde{\theta}(v) \) and is strictly negative if \( \tilde{\theta}(v) < \theta(v) \). Finally, Proposition 3 also says \( \tilde{\theta}(v) < \bar{\theta}(v) \). Therefore, if \( \theta^I(v) < \tilde{\theta}(v) \) at some \( v \), the left-hand side of (25) must be strictly positive for \( \frac{1}{2} \leq \alpha \leq 1 \), which is a contradiction. We have \( \tilde{\theta}(v) \leq \theta^I(v) \). Similarly, if \( \tilde{\theta}(v) \leq \theta^I(v) \) at some \( v \), the left-hand side of (25) must be strictly negative for \( \frac{1}{2} \leq \alpha \leq 1 \). This is a contradiction, so we have \( \theta^I(v) < \tilde{\theta}(v) \).

We have shown that \( \tilde{\theta}(v) \leq \theta^I(v) < \bar{\theta}(v) \) at each \( v \). By condition (21), \( \tilde{r}(v) \) is maximized at \( \tilde{\theta}(v) \) and strictly decreasing in \( \theta(v) \) if \( \tilde{\theta}(v) < \theta(v) \). Therefore, we conclude that \( \tilde{r}(v) < r^I(v) \leq \tilde{r}(v) \) at every \( v \). Moreover, because \( \theta^I(v) < \tilde{\theta}(v) \) and \( I(\alpha) \) is maximized at \( \theta^I(v) \), the equilibrium welfare under Average Quality Report is higher than Full Quality Report. ■
Supplement: monotonicity and incentive compatibility

A menu \( \{p(v), A(v)\}, \ v \in [\underline{v}, \bar{v}] \), is incentive compatible if
\[
v = \arg \max_{v'} u q(v') + v r(v') - p(v'), \quad v, v' \in [\underline{v}, \bar{v}]. \tag{29}
\]
Define \( W(v) \equiv \max_{v'} u q(v') + v r(v') - p(v') \). A menu \( \{p(v), A(v)\}, \ v \in [\underline{v}, \bar{v}] \), is individually rational if
\[
W(v) \geq 0, \quad v \in [\underline{v}, \bar{v}]. \tag{30}
\]

**Lemma 3**: A menu \( \{p(v), A(v)\}, \ v \in [\underline{v}, \bar{v}] \), is incentive compatible and individually rational if and only if
\[
\hat{r}(v) \text{ is increasing in } v \tag{31}
\]
\[
W(v) = W(\underline{v}) + \int_{\underline{v}}^{v} \hat{r}(x) dx \tag{32}
\]
\[
W(\underline{v}) \geq 0. \tag{33}
\]

**Proof of Lemma 3**: We first show that conditions (29) and (30) imply conditions (31) to (33). Since \( W(v) \) defined by (29) is the maximum of an affine function of \( v \), it is continuous, convex on \([\underline{v}, \bar{v}]\) and almost everywhere differentiable. Thus, \( W(v) \) satisfies the envelope condition: \( W'(v) = \hat{r}(v) \). Upon integration, the envelope condition gives (32). Moreover, the convexity of \( W \) says that \( W'(v) \) is increasing in \( v \). Hence, \( \hat{r}(v) \) is also increasing in \( v \). Finally, (33) is implied by (30).

Next, we show that conditions (31) to (33) imply conditions (29) and (30). Obviously conditions (32) and (33) imply condition (30). It remains to show that (31) and (32) imply (29). From any increasing function \( \hat{r}(v') \) and \( W(\underline{v}) \), construct a price function \( p(v') \) by
\[
p(v') \equiv u q(v') + v' \hat{r}(v') - W(\underline{v}) - \int_{\underline{v}}^{v'} \hat{r}(x) dx.
\]
Adding \( v \hat{r}(v') \) to both sides, and rearranging terms, we have
\[
(u q(v') + v \hat{r}(v') - p(v')) = (v - v') \hat{r}(v') + W(\underline{v}) + \int_{\underline{v}}^{v'} \hat{r}(x) dx,
\]
the left-hand side being the utility for a type-\( v \) consumer picking item \( (p(v'), A(v')) \).

Subtracting the expression above from condition (32) gives
\[
W(v) - [u q(v') + v \hat{r}(v') - p(v')] = \int_{\underline{v}}^{v} \hat{r}(x) dx - \int_{\underline{v}}^{v'} \hat{r}(x) dx - (v - v') \hat{r}(v').
\]

27
If $v > v'$,

$$W(v) - [u\hat{q}(v') + v\hat{r}(v') - p(v')] = \int_v^{v'} \hat{r}(x)dx - (v - v')\hat{r}(v') > 0$$

because $\hat{r}(v)$ is increasing. If $v' > v$,

$$W(v) - [u\hat{q}(v') + v\hat{r}(v') - p(v')] = -\int_v^{v'} \hat{r}(x)dx + (v' - v)\hat{r}(v') > 0$$

again because $\hat{r}(v)$ is increasing. ■
References


