Markets with untraceable goods of unknown quality: a market failure exacerbated by globalization

McQuade, Timothy and Salant, Stephen W. and Winfree, Jason

Harvard University, University of Michigan (Ann Arbor), University of Michigan (Ann Arbor)

14 December 2009

Markets with Untraceable Goods of Unknown Quality: A Market Failure Exacerbated by Globalization*

Timothy J. McQuade Stephen W. Salant
Jason Winfree

December 14, 2009

In markets for many fruits, vegetables, and an increasing number of imported goods, consumers cannot discern the quality of a product prior to purchase and can never identify its producer. Producing high-quality, safe goods is costly for a firm and raises the collective reputation for quality shared with its rivals. Minimum quality standards improve welfare. If consumers observe the country of origin of a product, quality, profits, and welfare increase. Exports from countries with more exporting firms are of lower quality and sell for lower prices. If one country imposes a minimum quality standard on its exports while other countries do not, consumers benefit. As for sellers, the regulation *raises* the profits of firms in the country with regulation and lowers the profits of firms in countries without regulation.

1 Introduction

In many markets, consumers cannot evaluate the quality of a good before buying it. How can the the pleasure of consuming a French brie or a California navel orange be judged without consuming them? How can the feel of a

*We would like to thank Jim Adams, Axel Anderson, Heski Bar-Isaac, Tilman Börgers, Will Fogel, Wenting Hu, Greg Lewis, Tom Lyon, Jill McCluskey, Marc Melitz, Ariel Pakes, and Nicola Persico for helpful comments and insights.

Bic ball-point pen be determined without writing with it? Consumers assess the quality of such goods by purchasing them repeatedly and eventually learn to anticipate their quality.

When the quality of a good cannot be discerned prior to purchase, we call it an "experience good." But there are really *two* distinct classes of experience goods. In the first, the consumer knows the identity of the producer. In the second, it is either impossible or too costly for the consumer to identify the producer. A Bic ballpoint pen belongs to the first class of experience goods whereas a French brie belongs to the second class—which farm produced the product is not apparent.

Although little attention has been paid in the IO literature to this second class of experience goods, it is becoming the subject of countless news stories. At this moment, U.S. beef is the subject of massive protests in South Korea because of fears that it will expose Koreans to mad cow disease. Meanwhile, U.S. consumers—having experienced Chinese toothpaste, cold medicines, toys, and other products containing lead, antifreeze, and other poisons—are developing an aversion to the "Made in China" label.

When goods are imported from distant countries, identifying the producer of a particular product may be too costly for a consumer. But not all experience goods in this second class are imports. Who knows which particular apple orchard produced a given Washington apple or what orange grove produced a particular California navel? In some circumstances, outputs from different firms are pooled together *before* their quality is assessed. Olmstead and Rhode (2003) describe the case of cotton grown in the South in the early twentieth century. Partly because of the high cost of testing quality, sometimes only samples of cotton pooled from many growers were tested. This prevented an individual farmer from increasing his own specific reputation. A similar situation recently confronted tomato growers. Although tomatoes are grown on separate farms, they are pooled together for washing and processing. In the recent salmonella outbreak, it was thought that the contamination originated after the tomatoes from the various individual growers were pooled. In such cases, an individual grower has no way to distinguish the quality of his produce from that of his competitors.

Producers of this second class of experience goods are in a difficult situation. They know the quality of the goods they produce. But they realize that there is no way to distinguish the quality of *their* product from the quality of the other products lumped together in the consumer's mind. They share a "collective reputation." Not surprisingly, a producer does not have as much incentive to make a product of high quality as he would if consumers distinguished his products from those of his competitors.

In markets exhibiting collective reputation, high-quality production can be difficult to maintain. Akerlof's famous lemons paper (1970) can be interpreted as a characterization of the dangers of collective reputation in the used-car market. However, in Akerlof's model, qualities are exogenous. In our model, we show that firms will choose to produce low-quality products when they share a collective reputation. To prevent this degradation of quality, minimum quality standards are often imposed as a form of quality (and consumer) protection. Concern for health and safety first prompted congressional action in the 1880s and 1890s on issues ranging from "pickles dyed with copper salts" to "trichinosis in beef."[1] In 1891, worried by the declining reputation of American meat abroad, Congress sent inspectors to all slaughterhouses preparing meat for export. Throughout the early twentieth century, policymakers struggled to create meaningful minimum quality standards. In 1938, Congress passed the Food, Drug, and Cosmetics Act, legislative action that strengthened the regulatory power of the government. By the mid-1960s, nearly half of all food products were regulated in some way. Today, the U.S. Department of Agriculture (USDA) offers fee-based voluntary grading of nearly all fruits and vegetables. The USDA also enforces mandatory quality standards in 26 industries, regulating over four billion dollars in business annually.

Perhaps because there has been little discussion of this second class of experience goods, such attempts to impose minimum quality standards are often interpreted by the antitrust authorities (rightly or wrongly) as attempts to cartelize the market. For example, the U.S. Department of Justice (DOJ) made the following comment about the plan of the Federal agricultural marketing board governing Michigan tart cherries to impose minimum quality standards: "For the reasons set forth in these comments, DOJ also opposes those provisions in the proposed marketing order providing for minimum quality standards for tart cherries. We oppose those provisions because they also appear to establish volume controls; that is, they appear to give the administrative board the discretion to vary quality standards from year to year in response to the size of the cherry crop." The response of DOJ raises an in-

[1] Gardner (2004). The following historical summary draws heavily from Gardner's work, a must for those interested in USDA's employment of minimum quality standards.

teresting set of questions. In an oligopoly, must the imposition of a minimum quality standard result in smaller aggregate output and lower welfare?

Klein-Leffler (1981) and Shapiro (1983) considered markets for experience goods of the first type. In their formulations, the quality of products cannot be distinguished prior to purchase, but consumers can identify the producer of each product. In the steady state of Shapiro's model, identical firms exhibit heterogeneous behavior with some specialized to one quality and receiving one price and other firms specialized to different qualities and receiving different prices. In these formulations, one firm's quality choice has no effect on another firm's future reputation for quality.

In contrast, the recent IO literature on "collective reputations" investigates the situation where consumers do not distinguish the products of different agents (be they firms or farms)—such as U.S. tomatoes, Washington apples, Chinese toys, and so forth. As a result, all firms sell at a common price and share a common reputation for quality. The first paper in this literature was Winfree and McCluskey (2005).[2] In their model, output is exogenous, entry is prohibited, and firms are constrained to offer a single quality. Under these assumptions, Winfree and McCluskey show that when firms share a collective reputation, they have an incentive in the steady state of their dynamic model to free-ride and to produce low-quality goods. In a recent working paper, Rouvière and Soubeyran (2008) retain the assumption

[2]Tirole (1996) coined the term "collective reputation" and was the first to analyze the phenomenon. However, his focus was not on the strategic interaction of firms but on the reputations of workers. In Tirole's formulation, an agent's own past behavior is imperfectly observed and he is assessed not only on the basis of his own past actions but also on the collective past actions of others. In contrast, past behavior of our firms is not observed and they have no individual reputations, only a collective one.

of a fixed output and the constraint that firms choose a single quality but permit entry. They show that free-riding causes entry into the market to be suboptimal.

Our paper is closest to a working paper by Fleckinger (2007). Both our papers, although static, build on Winfree and McCluskey (2005) by endogenizing the quantity decision. But because the two studies were developed independently, they are otherwise based on different assumptions. Fleckinger, for example, constrains each firm to a single quality, whereas firms in our model are free to produce multiple qualities. Fleckinger assumes that inverse demand is multiplicatively separable and, in addition, that one of the multiplicative factors is linear. We work with a much wider class of inverse demand functions and consider the implications of this abstraction. Unlike Fleckinger, we also consider equilibria in which consumers know the country of origin of the imported experience good. If some countries impose minimum quality standards on their exporting firms while other countries leave their exporters unregulated, the imposition of regulation makes consumers better off. It *increases* the profits of firms in the countries with regulations and lowers them in countries without regulations.

We proceed as follows. In the next section, we present our benchmark model in which each profit-maximizing firm chooses both quantity and quality in a simultaneous-move game. Section 3 considers the case where consumers are able to identify the country of origin of the product. Section 4 concludes the paper.

2 Model of Oligopoly

2.1 A Preliminary Simplification

Suppose n firms simultaneously choose how to distribute their production of a good over the quality set $K = [0, \infty)$. We define the strategy of a firm i to be the tuple $\xi_i = (\mu_i, q_i)$, where μ_i is a probability measure on the Borel algebra of K and $q_i \in [0, \infty)$ is the total output of firm i.[3] Note that mass points are allowed. Let $Q = q_1 + \cdots + q_n$ be the total output in the market. The per unit cost of producing a quality k is given by $c(k) : K \to [0, \infty)$, which is strictly increasing away from 0 and strictly convex. Given a probability measure μ_i, the total cost bill of firm i is:

$$C(\mu_i, q_i) = q_i \int_K c(k) d\mu_i \tag{1}$$

where we use the Lebesgue integral.

We define the collective reputation in the market by:

$$R(\mu_1, ..., \mu_n) = \sum_{i=1}^{n} \frac{q_i}{Q} \int_K k d\mu_i. \tag{2}$$

We assume consumers are unable to discern the individual quality of any firm's good prior to consumption and can never determine which firm produced the good. Rather, consumers only observe the collective reputation of the experience good. Inverse demand is given by the function $P(Q, R) : [0, \infty) \times K \to [0, \infty)$. Given a strategy profile $\xi = (\xi_1, ..., \xi_n)$ of the n firms,

[3] We define the Borel algebra of K to be the minimal σ-algebra containing the closed interval subsets of K.

the profit of a firm i is given by:

$$\Pi_i(\xi_i, \xi_{-i}) = q_i[P(Q, R) - \int_K c(k)d\mu_i], \tag{3}$$

where Q and R are as given above.

This formulation is a substantial departure from the previous literature on collective reputation. Winfree and McCluskey (2005), Fleckinger (2007), and others arbitrarily restrict each firm to a *single* quality level. The possibility therefore remains that Nash equilibria where firms produce *several* qualities at once have been ruled out by assumption. In addition, the Nash equilibria which have been identified in the literature may be *artifacts* of the restriction that no firm can offer multiple qualities. That is, once this restriction is relaxed, a firm may have a profitable deviation from the strategy profile identified in the literature as a Nash equilibrium.

The prior literature assumes strict convexity of the cost function, however, and this permits us to establish the following surprising result.

Theorem 2.1 *If the per-unit cost function of each firm is strictly convex, there can be no Nash equilibrium of the game where some active firm i ($q_i >$ 0) chooses a probability measure that assigns mass to more than one point.*

Thus, the restriction invoked in these papers does not limit the generality of their results.

Proof Suppose the contrary—that we have a Nash equilibrium strategy profile $\xi = (\xi_1, ..., \xi_n)$ in which a firm i chooses an output $q_i > 0$ and a probability measure μ_i which does not consist of a single mass point. Figure I will be helpful in understanding the result. Let $\bar{k}_i = \int_K k d\mu_i$. Let us consider the the strategy $\xi_i^\star = (\mu_i^\star, q_i)$ of firm i, where $\mu_i^\star(\{\bar{k}_i\}) = 1$ and $\mu_i^\star = 0$ for $k_i \neq \bar{k}_i$. Suppose the strategy profile of the other firms, denoted by ξ_{-i}, is unchanged. It is clear that the total output and the collective reputation in the market does not change. Thus, the price firm i receives does not change as well. However, since the per unit cost function is strictly convex in quality, by Jensen's inequality we have that $\int_K c(k) d\mu_i^\star = c(\bar{k}_i) < \int_K c(k) d\mu_i$. Thus firm i's cost bill is lower, which implies profits are higher. Therefore, firm i has a profitable unilateral deviation and ξ fails to constitute a Nash equilibrium. ∎

By a similar argument, no Nash equilibrium in which firms are constrained to choose a single quality would be eliminated if they were allowed instead to produce multiple qualities. This follows since, by Jensen's inequality, a unilateral deviation to multiple qualities is always strictly less profitable than a deviation to a single-quality profile with the same mean and, by hypothesis, no such single-quality deviation is profitable.

2.2 Existence, Characterization, and Uniqueness of Nash Equilibrium

Given the previous discussion, we now assume without loss of generality that each firm chooses to produce a single quality. Inverse demand depends now on the aggregate quantity of goods sold and on their quality averaged across the firms, which we again refer to as their collective reputation (denoted R). More precisely, collective reputation is now the quantity-weighted average of the qualities the n firms sell:

$$R = \frac{q_i k_i}{q_i + Q_{-i}} + \frac{\sum_{j \neq i} q_j k_j}{q_i + Q_{-i}}. \tag{4}$$

The variables q and k in (4) denote quantity and quality, respectively; the subscripts i and $-i$ refer, respectively, to firm i and to every other firm; $Q_{-i} = \sum_{j \neq i} q_j$ and $k_{-i} = (k_j)_{j \neq i}$. The right-hand side of (4) is undefined when $q_i = Q_{-i} = 0$. We specify inverse demand as follows. Consider $\tilde{P}(Q, R) : [0, \infty) \times K \to [0, \infty)$, which is twice differentiable; strictly decreasing, strictly concave in Q; and strictly increasing, strictly concave in R. We assume that $\tilde{P}_2(Q, R) \to 0$ as $R \to \infty$ for all Q and that, for all R, there exists $\bar{Q}(R)$ such that $\tilde{P}(\bar{Q}(R), R) = 0$. Note that P_i refers to the i^{th} partial derivative of P and P_{ij} refers to the ij^{th} second derivative of P. We assume that $\bar{Q}(R)$ is continuous, strictly increasing in R, and $\bar{Q}(0) > 0$. Now for a given reputation R, inverse demand is given by:

$$P(Q, R) = \begin{cases} \tilde{P}(Q, R); & \text{if } Q < \bar{Q}(R) \\ 0; & \text{if } Q \geq \bar{Q}(R). \end{cases} \tag{5}$$

Note that for a given R, the inverse demand function is everywhere continuous; however, there is a single kink at $Q = \bar{Q}(R)$. As for the per unit cost function, we continue to assume that $c(k)$ is strictly increasing away from 0. We moreover assume that it is twice differentiable and $c(0) = c'(0) = 0$.

Consider the game where each firm simultaneously chooses its output and quality to maximize the following payoff function:

$$q_i[P(q_i + Q_{-i}, R(k_i, q_i, k_{-i}, Q_{-i})) - c(k_i)]. \tag{6}$$

We define firm i's profit whenever it is inactive ($q_i = 0$) as zero. This assignment never conflicts with (6) since that equation, evaluated at $q_i = 0$, gives the same result when $Q_{-i} > 0$ and is undefined when $Q_{-i} = 0$.

Since firm i maximizes profits, its decisions must satisfy the following pair of complementary slackness (denoted c.s.) conditions for $Q_{-i} > 0$:

$$q_i \geq 0,\ P(Q,R) - c(k_i) + q_i P_1(Q,R) + q_i P_2(Q,R)\frac{\partial R}{\partial q_i} \leq 0,\ \text{c.s.} \tag{7}$$

$$k_i \geq 0,\ q_i[P_2(Q,R)\frac{\partial R}{\partial k_i} - c'(k_i)] \leq 0,\ \text{c.s.} \tag{8}$$

where, from (4), $\frac{\partial R}{\partial k_i} = q_i/Q$ and $\frac{\partial R}{\partial q_i} = (k_i - R)/Q$.

The first three terms of equation (7) are standard. They reflect the excess of the marginal gain from selling another unit over the marginal cost of producing it. The last term, $q_i P_2(Q,R)\frac{\partial R}{\partial q_i}$, is novel and captures an additional consequence (beneficial or adverse) of expanding output marginally. If firm i's quality is greater than the reputation in the market, then increasing output will increase the collective reputation of the good, which will raise the price. On the other hand, if firm i's quality is below average, then increasing output will decrease the price. The meaning of equation (8) is straightforward: if the firm produces no output, any quality is optimal; if the firm is active ($q_i > 0$) and quality is set optimally, then a marginal increase in quality would raise the revenue from sales of the goods by as much as it raises their cost of production.

We suppose that the profit function is pseudoconcave so that when the first-order conditions are satisfied, a global maximum has been achieved. We first note that for $n > 1$, there may exist trivial equilibria in which the equilibrium price is zero and, therefore, each active firm produces at the minimum quality.[4] We seek to establish the following:

Theorem 2.2 *There exist one or more non-trivial pure-strategy equilibria, i.e. equilibria with a non-zero price, and they are interior and symmetric.*

Proof See Appendix A.

Given that non-trivial equilibrium strategies are interior and symmetric, $q_i = Q/n > 0$ and $k_i = k > 0$. Hence, we may re-write (7) and (8) as follows:

$$P(Q,k) - c(k) + \frac{Q}{n} P_1(Q,k) = 0 \tag{9}$$

and

$$\frac{P_2(Q,k)}{n} - c'(k) = 0. \tag{10}$$

While uniqueness is only assured in certain circumstances,[5] the comparative

[4]Suppose there exists $Q^0 > \bar{Q}(0)$ such that for all $Q \geq Q^0$, $P(Q,k) < c(k)$ for all $k > 0$. We know such an output will exist when $\tilde{P}_{12} \leq 0$. Now suppose each firm follows the strategy $(Q^0, 0)$, thus receiving zero profit. No firm has a profitable deviation. Given any deviation in one firm's output, total output will still weakly exceed Q^0. Therefore, the profit any firm can achieve by deviating is bounded above by zero. In other words, the specified profile of strategies is a Nash equilibrium.

[5]If one assumes that $\tilde{P}_{12} = 0$, then $\check{k}(Q)$ becomes a horizontal ray. Since $\check{Q}(k)$ is a well-defined function, there then can only be one point of intersection, i.e. a unique equilibrium. We conjecture that if $\tilde{P}_{12}$ is small (but nonzero) then one can also prove uniqueness. More generally, if we were to place certain restrictions on the signs of cross partial third derivatives we would also be able to get uniqueness.

statics and welfare considerations of the following sections hold at any non-trivial equilibrium of the game.

2.3 Regulation and Welfare

We now consider the economic welfare that is achieved under such equilibria and, more importantly, the role regulations can play in increasing welfare. We define economic welfare by:

$$W(Q,k) = \int_0^Q P(u,k)du - Qc(k). \tag{11}$$

A social planner seeking to maximize economic welfare would choose Q and k to solve:

$$P(Q,k) = c(k) \tag{12}$$

$$\int_0^Q P_2(u,k)du = Qc'(k). \tag{13}$$

Note that if additive separability is assumed ($\tilde{P}_{12} = 0$), equation (13) reduces to $P_2(Q,k) = c'(k)$. Since the left-hand side is independent of aggregate sales (Q) and strictly decreases in k while the right-hand side is strictly increasing in k, this equation uniquely defines the socially optimal quality.

Recall that in the market setting, every firm sets its quality in the Nash equilibrium to solve $P_2(Q,k) = nc'(k)$. This implies that under additive separability, the equilibrium quality level emerging in the market setting will be socially optimal under monopoly and suboptimal under oligopoly. It is, therefore, likely that the discrete change from monopoly to duopoly will be welfare improving: the induced deterioration in quality is apt to have a small adverse effect on welfare (no first-order change if n could be increased marginally), while the expansion in total output will likely have a more substantial, positive effect on welfare. However, as the market becomes less and less concentrated, the continued deterioration in quality may depress welfare and even output. Thus, if the market is highly concentrated, then it may be optimal for the government to undertake measures to increase competition. However, after a point increased competition is likely to decrease total economic welfare.

2.3.1 Positive and Normative Effects of Minimum Quality Standards (MQS)

Consider the positive and normative effects of an exogenous binding minimum quality standard (MQS) which we denote by $\bar{k}$. Since the standard marginally raises quality, its marginal impact on welfare is the following:

$$\frac{dW}{d\bar{k}} = \frac{dQ}{d\bar{k}}\{P(Q,\bar{k}) - c(\bar{k})\} + [\int_0^Q P_2(u,\bar{k})du - Qc'(\bar{k})]. \tag{14}$$

Welfare changes because (1) industry output will change (the first term) and (2), even if industry output did not change, welfare would change because of the resulting changes in the gross surplus and costs of producing the old output at a marginally enhanced quality. To calculate the marginal impact on quantity we totally differentiate equation (9) to find:

$$\frac{dQ}{d\bar{k}} = \frac{P_2(Q,\bar{k}) - c'(\bar{k}) + \frac{Q}{n}P_{12}(Q,\bar{k})}{-[P_1(Q,\bar{k})(1+\frac{1}{n}) + \frac{Q}{n}P_{11}(Q,\bar{k})]}. \tag{15}$$

The denominator is strictly positive since inverse demand is strictly decreasing and weakly concave in output. Hence, raising the MQS increases aggregate output if the numerator is strictly positive and lowers it otherwise. The sign of the numerator is ambiguous. If the standard is marginally increased, the marginal cost of an output increase rises by $c'(\bar{k})$ and the marginal benefit of an output increase rises by $P_2(Q,\bar{k}) + \frac{Q}{n}P_{12}(Q,\bar{k})$. The sign of the numerator depends on the signs and magnitudes of these respective terms. If the numerator of (15) is strictly positive, every firm would increase its output in response to the increase in the MQS. Given equations (14) and (15), we have the following results:

Theorem 2.3 *If inverse demand is additively separable,*[6] *for any binding MQS below the social optimum, a marginal increase will raise aggregate output and welfare. For any binding MQS above the social optimum, a marginal increase will decrease aggregate output and welfare.*

Given additive separability, we recall that the equilibrium quality equals the social optimum under monopoly and is strictly less than the social optimum for less concentrated market structures. This implies that an MQS is only beneficial when there is more than one firm in the market.

Proof Since inverse demand is additively separable, we have that $P_{12} = 0$. Let $\tilde{k}$ denote the socially optimal quality. That is, $\tilde{k}$ solves the equation $P_2(Q,k) = c'(k)$. So for $\bar{k} < \tilde{k}$ we have $P_2(Q,\bar{k}) > c'(\bar{k})$ and the opposite for $\bar{k} > \tilde{k}$. Looking at the numerator of equation (15), we therefore find if the

[6]Henceforth, additive separability of inverse demand implicitly implies that $\tilde{P}_{12} = 0$. Similarly, any other restrictions on the cross partial of the inverse demand function implicitly signify a restriction on $\tilde{P}(Q,R)$.

standard is below the social optimum, a marginal increase will raise output, while for a standard above the social optimum, a marginal increase will lower output.

Turning now to equation (14), the term in braces, $P(Q,\bar{k}) - c(\bar{k})$, is always strictly positive since $P(Q,\bar{k}) - c(\bar{k}) = -\frac{Q}{n}P_1(Q,\bar{k}) > 0$. Finally, by additive separability the last two terms can be rewritten as $Q[P_2(Q,\bar{k}) - c'(\bar{k})]$. Again, this expression is strictly positive for a standard below the social optimum and strictly negative for a standard above the social optimum. We conclude that welfare is strictly increasing in binding standards below the social optimum and strictly decreasing in binding standards above the social optimum. $\blacksquare$

We have shown that, given the assumption of additive separability, an MQS can improve welfare under oligopoly market settings. It turns out that an MQS can improve welfare when there is more than one firm under considerably more general inverse demand functions. To begin, we need some notation. Given unregulated equilibrium values $(Q^\star, k^\star)$, let $\zeta(u) = \frac{P_2(Q^\star,k^\star)}{Q^\star}u$. That is, $\zeta(u)$ is the line emanating from the origin and passing through the point $(Q^\star, P_2(Q^\star, k^\star))$.

Theorem 2.4 *Suppose that $n \geq 2$ and the unregulated equilibrium admits values $(Q^\star, k^\star)$. If $P_{12} < 0$ and $|P_{12}|$ sufficiently small, then an MQS which just binds will marginally increase output and hence welfare. If $P_{12} > 0$ and $\int_0^{Q^\star}[P_2(u,k^\star) - \zeta(u)]du > 0$, then a MQS which just binds will marginally increase output and hence welfare.*

Proof Since $P_2(Q^\star, k^\star) = nc'(k^\star)$ in equilibrium and the MQS just binds, i.e. $\bar{k} = k^\star$, we can reduce equation (15) to:

$$\frac{dQ}{d\bar{k}} = \frac{P_2(Q^\star, k^\star)(1 - \frac{1}{n}) + \frac{Q^\star}{n} P_{12}(Q^\star, k^\star)}{-[P_1(Q^\star, k^\star)(1 + \frac{1}{n}) + \frac{Q^\star}{n} P_{11}(Q^\star, k^\star)]}. \tag{16}$$

For $n > 1$, the first term in the numerator of (16) is strictly positive. If $P_{12} < 0$ and $|P_{12}|$ is sufficiently small, $\frac{dQ}{d\bar{k}} > 0$. Therefore, the first term in equation (14) is strictly positive. As for the second term in that equation, when $P_{12} < 0$ it is also strictly positive since in that case

$$\int_0^{Q^\star} P_2(u, k^\star) du > Q^\star P_2(Q^\star, k^\star) = nQ^\star c'(k^\star) > Q^\star c'(k^\star). \tag{17}$$

Suppose instead that $P_{12} > 0$. Equation (16) then implies that $\frac{dQ}{d\bar{k}} > 0$. Thus, the first term in (14) is strictly positive. As for the second term in (14), when $\int_0^{Q^\star} [P_2(u, k^\star) - \zeta(u)] du > 0$, that term is strictly positive (for $n > 1$) since

$$\int_0^{Q^\star} P_2(u, k^\star) du > \int_0^{Q^\star} \zeta(u) du = \frac{Q^\star}{2} P_2(Q^\star, k^\star) \geq \frac{Q^\star}{n} P_2(Q^\star, k^\star) = Q^\star c'(k^\star). \tag{18}$$

Thus, by equation (14), welfare marginally increases in either case. ∎

At first glance, the lower bound on the integral $\int_0^{Q^\star} P_2(u, k^\star) du$ in the case of $P_{12} > 0$ may appear quite restrictive since it incorporates the output and quality level of the unregulated equilibrium. However, there is a large class of inverse demand functions which will satisfy this assumption automatically. Indeed, if P_2 is constant, linearly increasing, or increasing and strictly concave in Q, the assumption will be satisfied. The function could also be strictly convex in certain regions as well, as long as it spends a sufficient amount of "time" above the ray defined by $\zeta(u)$.

2.3.2 Department of Justice Criticism of MQS

Recall the objection of the Department of Justice to quality standards on agricultural produce such as Michigan cherries. Presumably, the Department disregarded the suboptimal quality which arises when consumers cannot trace a basket of cherries to the farm which produced it.

In a world where consumers care nothing about quality, the Department of Justice's reasoning makes sense. Suppose that $P_2(Q, R) = 0$ for all (Q, R) and maintain all other assumptions.[7] It is straightforward to verify existence of a Nash equilibrium.

Theorem 2.5 *There exists a unique Nash equilibrium which is symmetric and in which each firm produces a positive amount of the minimum quality.*

Proof See Appendix B.

An increase in the MQS raises the per unit cost of every firm and reduces every firm's output. Since output of *unregulated* oligopolists is suboptimal, this policy lowers social welfare. This can be verified formally by re-examining equations (14) and (15). Since $P_2 = P_{12} = 0$, these equations imply that $\frac{dQ}{dk} < 0$ and $\frac{dW}{dk} < 0$ for any $\bar{k} > 0$. Thus, a minimum quality standard only serves to lower both output and economic welfare, which is exactly what the Department of Justice forewarns.

[7] Since $P_2 = 0$ it follows that $P_{12} = 0$ as well.

Why might firms nonetheless press the government to impose an MQS? Such standards raise per unit costs of every firm. Seade (1985) identified a necessary and sufficient condition for a cost increase to raise the profit of every firm in an industry of Cournot competitors. Kotchen and Salant (2009) demonstrate that this condition is equivalent to local convexity of the total revenue function. If this condition holds and an equilibrium exists, firms would have an incentive to press for an MQS even if consumers cared nothing about quality. If consumers do value quality, firms benefit from an MQS not merely because of the price increase induced by the reduction in aggregate output but because of the increase in price induced by the improvement in quality. Assuming that a Nash equilibrium exists in our model under the Seade condition, that condition would be sufficient (but no longer necessary) for firms to profit from an MQS.

2.3.3 Additional Policy Results

See Appendix C for additional policy considerations, including minimum quantity standards, taxes, and subsidies.

3 International Trade

Until now, we have assumed that consumers have no information about the source of the experience good. In many applications, however, consumers can distinguish the region (country, state, or province) of origin. In this section, we show how our benchmark case can be modified to take account of this alternative specification.

Suppose there are N countries. In country j, n_j firms produce the experience good. The country in which a firm is located is known to consumers. Consumers form a view about the quality of the goods emanating from the particular country but cannot trace a good to a particular firm within that country.

The players in the game are the $\sum_{j=1}^{N} n_j$ firms. Each of them sets quality (k_{ij}) and quantity (q_{ij}) simultaneously. Since consumers cannot distinguish firms within country j, every firm in a given country sells its experience good at the same price (P^j) and their merchandise has the same reputed quality (R^j). Given the strategy profile, $\{k_{ij}, q_{ij}\}$ for $i = 1, \ldots, n_j$ and $j = 1, \ldots, N$, firms in country j develop a reputation for quality equal to the quantity-weighted average of their qualities:

$$R^j = \sum_{i=1}^{n_j} \frac{q_{ij}}{Q^j} k_{ij}. \tag{19}$$

We specify consumer utility to generate an inverse demand curve for each country which is strictly increasing in that country's reputed quality, strictly decreasing and strictly concave in world output of the experience good, and additively separable in the two variables. In particular, assume every consumer gets net utility u from purchasing one unit of the experience good of reputed quality R at price p: $u = \theta R - p$. Consumers can purchase a substitute which provides a reservation utility, and they buy the experience good if and only if it provides higher net utility than the outside option. Consumers have the same θ but differ in their reservation utilities.

Consumers observe each country's reputation for quality. The price they pay depends on the worldwide supply of the experience goods. Suppose that, given the distribution of reservation utilities, a utility of $U(Q)$ must be offered to attract Q customers to the experience good. We assume that $U(Q)$ is strictly increasing, strictly convex, and twice differentiable and that $U(0) = 0$.[8] Price adjusts in each country so consumers are indifferent about the country from which they import the experience good. Every purchaser receives net utility $U(Q)$. Inframarginal buyers strictly prefer the experience good to their outside option while the marginal buyer is indifferent between the experience good and the outside option since both yield net utility $U(Q)$.

More formally, let $\tilde{P}^j(Q, R^j) = \theta R^j - U(Q)$, for $j = 1, \ldots, N$. Then, the inverse demand of country j is given by:

$$P^j(Q, R^j) = \begin{cases} \tilde{P}^j(Q, R^j); & \text{if } Q < U^{-1}(\theta R^j) \\ 0; & \text{if } Q \geq U^{-1}(\theta R^j). \end{cases} \tag{20}$$

Hence, we can see that the inverse demand curve is additively separable over the set $\{(Q, R^j) | Q < U^{-1}(\theta R^j)\}$.

Consider the game where each firm i ($i = 1, \ldots, n_j$) in country j ($j = 1, \ldots, N$) simultaneously chooses its output and quality to maximize the following payoff function:

$$q_{ij}[P(q_{ij} + Q_{-ij}, R^j) - c(k_{ij})]. \tag{21}$$

We define firm i's profit whenever it is inactive ($q_{ij} = 0$) as zero. This

[8] Formally, let μ be a σ-finite measure on $[0, \infty)$. Define $Q(U) = \int_0^U d\mu$. We assume that $Q(0) = 0$ and that $Q(U)$ is twice differentiable, strictly increasing, and strictly concave. Let $U(Q) \equiv Q^{-1}(U)$.

assignment never conflicts with (21) since that equation, evaluated at $q_{ij} = 0$, gives the same result when $Q_{-ij} > 0$ and is undefined when $Q_{-ij} = 0$.

Since firm i maximizes profits, its decisions must satisfy the following pair of complementary slackness (denoted c.s.) conditions for $Q_{-ij} > 0$:

$$q_{ij} \geq 0,\ P(Q, R^j) - c(k_{ij}) + q_{ij} P_1^j(Q, R^j) + q_{ij} P_2^j(Q, R^j) \frac{\partial R^j}{\partial q_{ij}} \leq 0,\ \text{c.s.} \quad (22)$$

$$k_{ij} \geq 0,\ q_{ij}[P_2^j(Q, R^j) \frac{\partial R^j}{\partial k_{ij}} - c'(k_{ij})] \leq 0,\ \text{c.s.} \quad (23)$$

where, from (19), $\frac{\partial R^j}{\partial k_{ij}} = q_{ij}/Q^j$ and $\frac{\partial R^j}{\partial q_{ij}} = (k_{ij} - R^j)/Q^j$. First-order conditions (22) and (23) are the counterparts in the international case of equations (7) and (8) in the benchmark case. We again assume that the profit function of each firm, given the other firms' strategies, is pseudoconcave.[9] We can establish the following counterpart to Theorem 2.2:

Theorem 3.1 *In the international model, there exist non-trivial Nash equilibria.*[10] *Each includes at least one active country. Across all equilibria, the same countries are active. Moreover, in each active country j, every producer of the experience good sells the same unique, strictly positive amount ($q_j > 0$) with the same unique strictly positive quality ($k_j > 0$).*

Proof See Appendix D.

In contrast to the benchmark case, uniqueness of the output and quality choice within active countries is assured here because the inverse demand curve is assumed to be additively separable.

[9] Although we have assumed a specific functional form, this should be satisfied as long as $U(Q)$ and $c(k)$ are sufficiently convex.

[10] Again, trivial equilibria are those in which firms receive a price of zero for the product.

Replacing the inverse demand curve and its partial derivatives by equivalent expressions and utilizing the fact that every firm within country j makes the same choices, we can re-write the first-order conditions (22) and (23) as follows:

$$\theta R^j - U(Q) - c(k_j) - q_j U'(Q) = 0 \tag{24}$$

and

$$\theta \frac{1}{n_j} - c'(k_j) = 0. \tag{25}$$

Equations (24) and (25) are the counterparts of equations (9) and (10) in the benchmark case.

Equation (25), which holds for firms in each country j, implies that a country with a larger number of firms exporting the experience good (the "larger country") will export lower- quality goods. Since prices adjust so that consumers are indifferent about the source of their imports, the exports of larger countries must sell for lower prices. This in turn insures that every exporter in a larger country has lower profit and output as the following argument shows. In the equilibrium any firm offering quality k earns profit per unit of $\theta k - U(Q) - c(k)$. Since this function is strictly concave in quality and peaks at k^*, the implicit solution to $\theta = c'(k^*)$, in equilibrium every firm will choose a quality $k_j < k^*$. Therefore, the profit per unit at each firm in a group rises if the common quality of every firm in that group increases. It follows that firms in larger countries will have lower profit per unit. But equation (24) implies that any firm with a lower profit per unit produces less output and hence earns lower total profit.[11]

[11] In this model, it is assumed that firms producing in one country cannot disguise

In the limiting case where every country has the same number of firms, quality, price, output, and profit are the same at every firm regardless of its location.

3.1 Two Policy Implications

In the international case, unlike the benchmark case, consumers are assumed to observe the country of origin of the experience good although not the identity of the firm which produced it. This raises a fundamental question: what are the positive and normative effects of giving each consumer the information with which to classify more finely the source of the imported good? For simplicity, we assume that before consumers receive the finer information, every one of N groups (or "countries") contains $n_j = n$ firms; after the new information arrives, these same nN firms are divided equally among $N' > N$ groups so that each new group contains fewer firms.

Theorem 3.2 *Suppose a labeling program permits consumers to classify firms into more groups of equal size, each with fewer firms. Then quality, quantity, and profit will increase at every firm and the utility of every consumer of the experience good will increase as well.*

---

their products as originating in another country where firms have a better reputation and earn higher profits. Presumably this implicitly requires that the government identify and prohibit such deceptions since they would be profitable. "Under EU law, for example, use of the word Champagne on wine labels is intended exclusively for wines produced in the Champagne region of France under the strict regulations of the region's Appellation of Controlled Origin ... Customs agents and border patrols throughout Europe have seized and destroyed thousands of bottles in the last four years illegally bearing the Champagne name, including product from the United States, Argentina, Russia, Armenia, Brazil and Ethiopia." http://www.reuters.com/do/emailArticle?articleId=US208562+10-Jan-2008+BW20080110

Proof If every firm is a member of a smaller group, world production must increase. For, suppose it decreased. Then fewer consumers would buy the good, and it must provide lower utility. But since each firm shares its collective reputation with fewer competitors, every firm will increase its quality, and hence the reputed quality of its group will increase. But since profit per unit is increasing in the common quality of the group, the sum of the first three terms in equation (24) must increase. Since the second factor of the last term decreases, however, that equation would hold only if each firm's output (q_j) increased. But then world output would increase, contradicting our hypothesis.

Consequently, world sales of the experience good must strictly increase and hence so must production at each firm. Since each firm belongs to a smaller group, each firm will increase its quality. As for profitability, since both factors in the last term of equation (24) increase, net profit per unit (the first three terms of that equation) must increase. Therefore profit at every firm will rise. To absorb the increased production, the utility each consumer receives from the experience good must increase by enough to attract the requisite number of consumers away from their outside options. ∎

Profits, and hence social welfare, would be higher if every consumer recognized not only that a product was imported from a particular country but also that it was made by someone in a particular region of that country (or, better yet, by a particular ethnic group within that region). For, the smaller the number of firms in a category recognized by every consumer, the less incentive each firm will have to shirk in the provision of quality.

We conclude our discussion of the international case by showing why a government should want to impose a minimum quality standard on the quality of the experience good its firms export. Suppose one country imposes such a standard, while other countries choose not to regulate. We assume that the standard ($\bar{k}$) is binding but is not set as high as a firm would choose if it were the only domestic producer and hence its products could be readily identified by consumers. That is, we assume $\bar{k} < k^*$, where k^* solves $\theta = c'(k^*)$. We establish that:

Theorem 3.3 *The imposition of a minimum quality standard by one country raises the output and profits of its exporters while lowering the output and profits of unregulated exporters elsewhere. Overall, world output expands. Quality rises in the country with regulation and remains unchanged elsewhere. Imposition of the minimum quality standard benefits every consumer of the experience good.*

Proof The imposition of the standard must strictly increase world production of the experience good. For, suppose the contrary. Suppose aggregate quantity falls or remains constant. Then the utility which consumers get from the experience good must weakly decrease. In every country with *unregulated* firms, exporters would maintain quality since equation (25) still holds. So if their exports provide weakly less net utility, the prices of their exports ($P^j = \theta k_j - U(Q)$) must weakly increase. Since the per unit profit ($P^j - c(k_j)$) would then weakly increase, equation (24) implies that output at each regulated firm must weakly increase. As for the *regulated* firms, their per unit profit must *strictly* increase since the standard raised quality and, by assumption, was not excessive ($\bar{k} < k^*$). Equation (24) then implies that output at each regulated firm strictly increases. But then we have a contradiction: aggregate output cannot weakly decrease as we hypothesized since that implies the sum of the individual firm outputs would strictly increase.

So the imposition of a minimum quality standard in one country must cause world output of the experience good to strictly increase and hence must cause the net utility of every consumer of the good to increase. Since the quality of the unregulated firms does not change, their prices, profit per unit, output and total profits must fall. Since aggregate output expands despite the contraction at every unregulated firm, output at every *regulated* firm must increase. But, as equation (24) implies, regulated firms would expand output only if their profit per unit also increased. Hence, their total profits would also increase. Since profit per unit increases at each regulated firm, its price per unit must increase by more than enough to offset the increased cost per unit of producing the higher quality mandated by the minimum quality standard. ∎

Intuitively, the minimum quality standard imposed by one country creates a competitive advantage for its firms since it reassures buyers about the quality and safety of products originating there.

4 Conclusion

In this paper, we considered markets where consumers cannot discern a product's quality prior to purchase and can never identify the firm which produced the good. We considered both the benchmark case where consumers do not know the country of origin of the experience good and the international case in which consumers do know it. When buyers who care about the quality and safety of the products they purchase are informed about the country of origin of the experience goods available to them, firms in those countries are motivated to improve the quality and safety of their merchandise. As a result, both profits and welfare increase. An MQS can secure further benefits. In the absence of such regulations, a country with a larger number of producers of the experience good will export shoddier products at lower prices. If one country imposes such regulations, consumers benefit not only from the enhanced quality of that country's exports but from the opportunity to buy other countries' exports which sell for diminished prices despite their unchanged quality. The minimum quality standard imposed by one country raises the profits of the firms compelled to obey them and reduces the profits of competing exporters with the misfortune to be located in countries without such regulations.

Department of Economics, Harvard University, *tmcquade@fas.harvard.edu*

Department of Economics, University of Michigan and Resources for the Future (RFF), *ssalant@umich.edu*

Program in Sport Management, University of Michigan, *jwinfree@umich.edu*

A Proof of Theorem 2.2

We proceed as follows. We first demonstrate that there exists at least one symmetric Nash equilibrium of the game. We then show that any Nash equilibrium (symmetric or otherwise) of the game must be interior. Finally, we show that there can be no asymmetric Nash equilibria.

Lemma A.1 *There exists a non-trivial symmetric equilibrium.*

Proof Assume each firm chooses the same pair (q, k). Given this symmetry, we can write the Kuhn-Tucker conditions as:

$$q \geq 0, \ P(Q, k) + qP_1(Q, k) - c(k) \leq 0, \ \text{c.s.} \tag{26}$$

$$q = Q/n, \tag{27}$$

and

$$k \geq 0, \ q[P_2(Q, k) - nc'(k)] \leq 0, \ \text{c.s.} \tag{28}$$

where $R = k$.

To begin, for $Q < \bar{Q}(0)$ we let $\hat{k}(Q)$ be the unique solution to the equation $P(Q, k) = c(k)$. We know that there exists a unique solution since $P(Q, 0) > 0$, $c(0) = 0$, inverse demand is strictly concave in quality, and the cost function is strictly convex in quality. We see that:

$$\frac{d\hat{k}}{dQ} = \frac{P_1(Q, \hat{k})}{-[P_2(Q, \hat{k}) - c'(\hat{k})]}. \tag{29}$$

But for all $Q < \bar{Q}(0)$, the unit margin is strictly decreasing at $(Q, \hat{k}(Q))$, which implies that $P_2(Q,\hat{k}) - c'(\hat{k}) < 0$. Since inverse demand is strictly decreasing in Q, we conclude that $\frac{d\hat{k}}{dQ} < 0$.

Next, we consider equations (26) and (27). Given a particular quality k, we would like to study the solution to these complementary slackness conditions, which we denote by $(\breve{q}(k), \breve{Q}(k))$. Note that if $k \geq \hat{k}(0)$, then $P(Q,k) - c(k) \leq 0$ for all Q and the solution to (26) and (27) is $\breve{Q}(k) = \breve{q}(k) = 0$. Now suppose that $k < \hat{k}(0)$. Then $P(0,k) - c(k) > 0$. Moreover, since $P(Q,k) = 0$ for all $Q \geq \hat{Q}(k)$, where $P(\hat{Q}(k),k) = c(k)$, the solution to (26) is $q = 0$ for all $Q \geq \hat{Q}(k)$. Finally, by totally differentiating equation (26) with respect to Q, we find that for all $Q < \hat{Q}(k)$:

$$\frac{dq}{dQ} = -\frac{P_1(Q,k) + qP_{11}(Q,k)}{P_1(Q,k)} < 0. \tag{30}$$

So consider the function $f(Q) = nq(Q)$ where $q(Q)$ is the solution to (26) given Q. We are looking for a fixed point of this function. We know that this continuous function strictly decreases from $f(0) > 0$ to $f(\hat{Q}(k)) = 0$ and $f(Q) = 0$ for all $Q \geq \hat{Q}(k)$. This implies that the curve will cross the 45^o line at some $0 < Q < \hat{Q}(k) < \bar{Q}(k)$. Then $(Q/n, Q)$ defines the desired solution. We conclude that we have solution curves $\breve{Q}(k)$ and $\breve{q}(k) = \breve{Q}(k)/n$ which are defined for $0 \leq k \leq \hat{k}(0)$. Since $P_1(Q,k)(1 + \frac{1}{n}) + \frac{Q}{n}P_{11}(Q,k) < 0$ at each solution, it follows from the implicit function theorem that these curves are continuous over this interval. Putting everything together, we note that $\breve{Q}(k)$ is bounded above by some constant M.

Let us consider the solution curve $\breve{k}(Q)$ to the equation (28). If the firm is inactive ($q = 0$), then any quality choice solves equation (28). However, we will assume (without, as we will show, loss of generality) that $\breve{k}(0) = \lim_{Q\to 0} \breve{k}(Q)$. Thus, $\breve{k}(Q)$ is continuous at $Q = 0$. Next, note that for any $Q \in (0, \bar{Q}(0))$, the left hand side of (28) is strictly positive at $k = 0$ since $P_2(Q, 0) > 0$ and $c'(0) = 0$; strictly negative for $k \to \infty$; and continuous. Hence, there is at least one root. Moreover, since the left-hand side is strictly decreasing in k, there is exactly one root for any $Q \in (0, \bar{Q}(0))$. Therefore, $\breve{k}(Q)$ is a well-defined positive function for all $0 \le Q < \bar{Q}(0)$. Since $P_{22}(Q, k) - nc''(k) < 0$, by the implicit function theorem it is continuous. Finally, note that for all $Q \in [0, \bar{Q}(0))$, at the point $(Q, \hat{k}(Q))$ the cost curve must be steeper than the price curve since the cost function is strictly increasing and strictly convex away from 0, while inverse demand is strictly increasing and concave in quality. In particular, this means that $\breve{k}(Q) < \hat{k}(Q) < \hat{k}(0)$ for all $0 \le Q < \bar{Q}(0)$.

For $Q \ge \bar{Q}(0)$, things are somewhat trickier. We first ignore the zero solution to equation (28). Now consider the equation $\tilde{P}_2(\bar{Q}(\tilde{k}), k)) = c'(k)$ and the corresponding solution curve $\bar{k}(\tilde{k})$. If this curve has a fixed point, denote the minimal one by k^0.[12] Since $\bar{k}(0) > 0$ and the curve is continuous, it follows that $\bar{k}(\tilde{k}) > \tilde{k}$ for all $0 \le \tilde{k} < k^0$. This in turn implies that for $Q \in [\bar{Q}(0), \bar{Q}(k^0))$, equation (28) has a non-trivial solution, which we denote $\breve{k}(Q)$. Therefore, $\breve{k}(Q)$ exists and is continuous for all $0 \le Q < \bar{Q}(k^0)$. Moreover, $\breve{k}(Q) \to k^0$ as $Q \to \bar{Q}(k^0)$.

To complete the proof, we define $T(Q) = \breve{Q}(\breve{k}(Q)) - Q$. We need to consider two cases. First suppose that $\bar{k}(\tilde{k})$ does not have a fixed point. Then $\breve{k}(Q)$ exists and is continuous for all Q, which means that $T(Q)$ is

[12] Note that if $\tilde{P}_{12} \le 0$, then $\bar{k}(\tilde{k})$ will have a unique fixed point.

continuous for all Q. Now $\breve{k}(0) < \hat{k}(0)$, which implies $T(0) = \breve{Q}(\breve{k}(0)) > 0$. Since $\breve{Q}(k)$ is bounded above, it follows that $\lim_{Q\to\infty} T(Q) = -\infty$. Therefore, by the intermediate value theorem, we conclude that $\breve{Q}(\breve{k}(Q))$ has a fixed point $Q^\star$ and an associated image $k^\star = \breve{k}(Q^\star)$. Next consider the case where $\bar{k}(\tilde{k})$ does have a fixed point. We again know that $T(0) > 0$. We also know that $\breve{Q}(k^0) < \bar{Q}(k^0)$ and $\breve{k}(Q) \to k^0$ as $Q \to \bar{Q}(k^0)$. Consequently, we can conclude that $\lim_{Q\to\bar{Q}(k^0)} T(Q) = \breve{Q}(k^\star) - \bar{Q}(k^\star) < 0$. Again, by the intermediate value theorem, we conclude that $\breve{Q}(\breve{k}(Q))$ has a fixed point $Q^\star$ and an associated image $k^\star = \breve{k}(Q^\star)$.

Hence, in both cases we are able to find a fixed point of the function $\breve{Q}(\breve{k}(Q))$. Pseudoconcavity of the profit functions therefore implies that a firm's strategy $(Q^\star/n, k^\star)$ is profit-maximizing and hence the profile of these strategies forms a symmetric Nash equilibrium. ∎

The following two lemmas demonstrate that any non-trivial Nash equilibrium must be interior.

Lemma A.2 *There can be no non-trivial equilibrium (symmetric or otherwise) in which a firm produces a positive quantity of the minimum quality.*

Proof If it is optimal to produce at minimum quality ($k_i = 0$), then since $c'(0) = 0$ condition (8) requires that $P_2(Q, R)\frac{q_i}{Q} \leq 0$. But each of the factors to the left of this inequality is strictly positive since, by hypothesis, $q_i > 0$ and we are considering non-trivial equilibria. So the inequality can never hold. Therefore, every firm with $q_i > 0$ must have $k_i > 0$. ∎

Intuitively, since the cost function is flat at the origin but inverse demand is strictly increasing in quality when the price is non-zero, an active firm producing a minimal quality can always increase his profit by marginally increasing his quality choice. At the margin, costs will remain the same but the price will increase.

Lemma A.3 *There can be no non-trivial equilibrium (symmetric or otherwise) in which some firm is inactive.*

Proof First, suppose that all the other firms produce nothing ($Q_{-i} = 0$). If firm i also produces nothing, it would earn a payoff of zero. But this cannot be optimal. For, by unilaterally setting $k_i = 0$ and $0 < q_i < \bar{Q}(0)$, its payoff would increase to $q_i P(q_i, 0) > 0$. So there can be no Nash equilibrium with $q_i = 0$ when $Q_{-i} = 0$. [13]

Nor can there be a non-trivial Nash equilibrium with $q_i = 0$ when $Q_{-i} > 0$. In that case, one or more of the rival firms is producing a strictly positive amount. Label as firm j the active firm with the smallest quality. Hence, $k_j - R \leq 0$. Since firm j produces a strictly positive amount, its first-order condition in (7) must hold with equality. Since the terms $q_j P_1(Q, R)$ and $q_j P_2(Q, R)(k_j - R)/Q$ are respectively strictly and weakly negative, (7) implies $P(Q, R) - c(k_j) > 0$. But since the cost function is strictly increasing, $P(Q, R) - c(0) > 0$ and this same complementary slackness condition (7), which must hold for firm i as well, implies that $q_i > 0$, contradicting the hypothesis that $q_i = 0$. ∎

From the two lemmas above, we conclude that the symmetric equilibria found previously must be interior. We conclude the proof of the theorem

[13] Our discarding of all but one value for $\breve{k}(0)$ when a firm is inactive could have resulted in the elimination of additional fixed points. However, since every fixed point is a Nash equilibrium and we have just established from first principles that there are no Nash equilibria with any firm inactive, in fact we could not have eliminated any equilibria.

by demonstrating that in no non-trivial equilibrium do any two firms choose different qualities or different quantities.

Lemma A.4 *There exist no pure strategy asymmetric non-trivial Nash equilibria.*

Proof Since any equilibrium must be interior, the pair of first-order conditions for each firm must hold with equality. These imply that the following equation must hold in any equilibrium:

$$[k_i - (R - \frac{QP_1(Q,R)}{P_2(Q,R)})]c'(k_i) + \{P(Q,R) - c(k_i)\} = 0. \qquad (31)$$

Define the left-hand side as $\Gamma(k_i; Q, R)$. For each equilibrium, there may be a different (Q, R). But given those aggregate variables, every firm $(i = 1, \ldots, n)$ will have $\Gamma(k_i; Q, R) = 0$. However, this equation cannot have more than one root. We see $\frac{\partial \Gamma}{\partial k_i}(k_i; Q, R) = [k_i - (R - \frac{QP_1(Q,R)}{P_2(Q,R)})]c''(k_i)$ and (31) requires that at any root, the first factor in $\frac{\partial \Gamma}{\partial k_i}(k_i; Q, R)$ must be strictly negative.[14]

Hence, there can be no more than one root. So, for any given equilibrium with its (Q, R) a unique k_i satisfies equation (31). But since equation (31) must hold for *every* firm, each firm must choose the same quality in this equilibrium. Denote it $k(Q, R)$. Moreover, since every firm will be active and reputed quality will equal $R = k(Q, R)$, equation (7) implies that $q_i = \frac{P(Q,R) - c(k(Q,R)}{-P_1(Q,R)}$. Since the right-hand side of this equation is independent of i, every firm will produce the same quantity in this equilibrium. Denote it $q(Q, R)$. ∎

[14] The term in braces in (31) must be strictly positive since $q_i > 0$ (from Lemma A.3), condition (26) therefore holds with equality, and $P_1 < 0$ by assumption.

B Proof of Theorem 2.5

First note that there can be no equilibrium in which any active firm sets its quality above the minimum ($k = 0$). This follows since such a firm could strictly reduce its costs while preserving its gross revenue by dropping its quality to the minimum. Hence, the only candidates for equilibria are strategy profiles where every active firm produces at the lowest quality level. Standard treatments in the Cournot oligopoly literature establish that there exists a unique symmetric equilibrium when every firm has the identical constant marginal cost ($c(0)$ in our case). In equilibrium, every firm produces $q_i = Q^*/n$, where Q^* solves: $P(Q, 0) + \frac{Q}{n} P_1(Q, 0) - c(0) = 0$. To verify that the strategy profile $\{k_i = 0, q_i = Q^*/n\}$ for $i = 1, \ldots, n$ forms a Nash equilibrium when firms choose quality as well as quantity, we must check that no firm could profitably deviate by raising quality above the minimum and altering quantity at the same time. Since consumers do not value quality, such a deviation affects price only because it alters total output. Since increases in quality raise costs, the firm can do better by simply changing output and keeping quality at its minimum level; but, as the standard proofs establish, no such deviation is ever profitable. Therefore, the strategy profile in which each firm produces an output $Q^\star/n$ of minimum quality forms a Nash equilibrium. ∎

C Additional Policy Results

We begin with binding minimum quantity standards. Suppose the regulator wants a total industry output of $\bar{Q}$. Then, in practice, the regulator will set the standard at $\bar{Q}/n$. We note that firms will set quality such that $P_2(\bar{Q}, k) = nc'(k)$. Given this, we find:

$$\frac{dk}{d\bar{Q}} = \frac{P_{12}(\bar{Q}, k)}{nc''(k) - P_{22}(\bar{Q}, k)}. \tag{32}$$

Thus, if inverse demand is additively separable quality is unchanged. If $P_{12} > 0$ quality increases and if $P_{12} < 0$ quality decreases. These results are quite intuitive. Let us now think about welfare. We see that:

$$\frac{dW}{d\bar{Q}} = \{P(\bar{Q}, k) - c(k)\} + \frac{dk}{d\bar{Q}}[\int_0^{\bar{Q}} P_2(u, k)du - \bar{Q}c'(k)], \tag{33}$$

Let $k^\star$ denote the quality of the unregulated equilibrium. If inverse demand is additively separable, the regulator can set $\bar{Q}$ to solve $P(Q, k^\star) = c(k^\star)$. This will maximize the welfare achievable under a minimum quantity standard. If $n = 1$, it will coincide with the welfare achieved by a social planner. If $P_{12} < 0$, we know by the reasoning above that for any $\bar{Q}$ set, $\int_0^{\bar{Q}} P_2(u, k)du - \bar{Q}c'(k) > 0$. Thus as long as the standard is such that firms do not shut down, i.e. the unit margin is positive, any further marginal increase will result in a welfare gain from the higher output, but a welfare loss from the consequent degraded quality. Finally, if $P_{12} > 0$ and the standard again is set such that firms do not shut down, marginal increases in the regulation will result in marginally higher welfare as long as $\int_0^{\bar{Q}} P(u, k)du > 0$. As previously noted, this will occur if P_2 is sufficiently concave in Q.

Last but not least, we consider the role of taxes and subsidies. Since command and control regulations tend to have large enforcement costs associated with them, it is important to understand if similar effects could be achieved through the use of fiscal regulation. Given a tax T, the firm's first order conditions are:

$$P(Q,k) - c(k) - T = -\frac{Q}{n}P_1(Q,k) \tag{34}$$

$$P_2(Q,k) = nc'(k). \tag{35}$$

Implicitly differentiating, we find that an increase in the rate has the following impact on quality:

$$\frac{dk}{dT} = \frac{P_{12}(Q,k)\frac{dQ}{dT}}{nc''(k) - P_{22}(Q,k)}. \tag{36}$$

Now let:

$$A(Q,k) = P_1(Q,k)(1+\frac{1}{n}) + \frac{Q}{n}P_{11}(Q,k) \tag{37}$$

$$B(Q,k) = \frac{P_{12}(Q,k)}{nc''(k) - P_{22}(Q,k)}[(n-1)c'(k) + \frac{Q}{n}P_{12}(Q,k)]. \tag{38}$$

After some tedious calculations, we find that the marginal impact on industry output is given by:

$$\frac{dQ}{dT} = \frac{1}{A(Q,k) + B(Q,k)}. \tag{39}$$

Given these results, we can think about optimal policy. We include government revenues in the welfare function, so that the expression for welfare is unchanged. If $P_{12} = 0$, then neither a tax nor a subsidy has any effect on quality. Consequently, firms should be subsidized so as to achieve the socially optimal output. Let us now suppose that $P_{12} < 0$. Note that $A(Q,k) < 0$. When $|P_{12}|$ is small, $B(Q,k) < 0$. Thus, imposing a tax will shrink output but increase quality. Subsidies will have the opposite effect. In both cases, there will be welfare effects moving in opposite directions. For instance, when a tax is imposed there will be a welfare loss from the reduced output, but a welfare gain from the enhanced quality. Interestingly, for P_{12} sufficiently negative, a tax may actually increase industry output. In this case, enhancing quality must be achieved through a subsidy. We turn finally to $P_{12} > 0$ and suppose that P_2 is sufficiently concave in Q so as to recognize welfare gains from increases in quality. For a small P_{12}, welfare gains must be achieved through subsidy, while for P_{12} sufficiently large, a tax must be utilized. We conclude that fiscal regulation can certainly improve welfare. However, regulators must accurately measure demand since the optimal policy is sensitive to the magnitude of the cross partial. This is especially true when $P_{12} > 0$ and there are not competing welfare effects.

To conclude, it appears that an MQS offers the best regulatory option. Indeed, they result in enhanced quality and increased output for a wide range of inverse demand functions, including those with a sufficiently small negative cross partial. This is significant since no other regulatory option considered can achieve both increased output and enhanced quality with then cross partial is negative. Rather, regulations will always lead to competing welfare effects. However, minimum quality standards and taxes/subsidies become viable options when the cross partial is non-negative, noting of course then inverse demand is additively separable, such measures have no impact on quality. Yet when the cross partial is positive, these regulations can increase both output and quality, just as in the case of an MQS. Consequently, if regulators feed that command and control regulations are too costly for the government to implement and have estimated inverse demand to have a positive cross partial, fiscal regulation should be seriously considered. As discussed, though, the key to a successful policy is to get an accurate measure of demand. Given the magnitude of the cross partial in relation to other quantities, either a subsidy or a tax should be implemented.

D Proof of Theorem 3.1

The proof follows the same structure of the proof of Theorem 2.2.

Lemma D.1 *There exists a non-trivial equilibrium in which in each country j, every producer of the experience good is either active or inactive. If a country is active, each firm sells the same unique strictly positive amount ($q_j > 0$) with the same unique strictly positive quality ($k_j > 0$). There is at least one active country.*

Proof Given the symmetry we are considering, we can write the Kuhn-Tucker conditions as:

$$q_j \geq 0, \; P^j(Q, k_j) + q_j P_1^j(Q, k_j) - c(k_j) \leq 0, \; \text{c.s.} \tag{40}$$

$$Q = \sum_{j=1}^{N} n_j q_j, \tag{41}$$

and

$$k_j \geq 0, \; q_j[P_2^j(Q, k_j) - n_j c'(k_j)] \leq 0, \; \text{c.s.} \tag{42}$$

where $R^j = k_j$.

To begin, consider the solution to equation (42) given a particular Q and q_j. If the firm is inactive ($q_j = 0$), then any quality choice will solve the equation. Now let $\tilde{k}_j = (c')^{-1}(\theta/n_j)$. If the firm is active, it is clear that for all $0 \leq Q < \bar{Q}(\tilde{k}_j)$, $\tilde{k}_j$ is the unique non-zero solution to equation (42). For $Q \geq \bar{Q}(\tilde{k}_j)$, there is no non-zero solution.

Let us now consider the system of equations given by (40) and (41) when $k_j = \tilde{k}_j$ for all j. Note that $P^j(0, \tilde{k}_j) - c(\tilde{k}_j) = \theta\tilde{k}_j - c(\tilde{k}_j) > 0$ for all j.[15] Next, define $\hat{Q}(\tilde{k}_j) < \bar{Q}(\tilde{k}_j)$ such that $P(\hat{Q}(\tilde{k}_j), \tilde{k}_j) = c(\tilde{k}_j)$. Then the solution to (40) is $q_j = 0$ for all $Q \geq \hat{Q}(\tilde{k}_j)$. By totally differentiating equation (40) with respect to Q, we find that for $Q < \hat{Q}(\tilde{k}_j)$:

$$\frac{dq_j}{dQ} = -\frac{P_1^j(Q, \tilde{k}_j) + q_j P_{11}^j(Q, \tilde{k}_j)}{P_1^j(Q\tilde{k}_j)} = -\frac{U'(Q) + q_j U''(Q)}{U'(Q)} < 0. \tag{43}$$

Now let $f(Q) = \sum_{j=1}^{N} n_j q_j(Q)$ and $Q^H = \max\{\hat{Q}(\tilde{k}_1), ..., \hat{Q}(\tilde{k}_N)\}$. Then $f(Q)$ is continuous and strictly decreases from $f(0) > 0$ to $f(Q^H) = 0$ and $f(Q) = 0$ for all $Q \geq Q^H$. Thus the curve will cross the 45^o line exactly once at some $0 < Q^\star < Q^H$. Let $k_j^\star = \tilde{k}_j$ and $q_j^\star = q_j(Q^\star)$ for all j. If $Q^\star < \hat{Q}(\tilde{k}_j) < \bar{Q}(\tilde{k}_j)$, then $q_j^\star > 0$ and if $Q^\star \geq \hat{Q}(\tilde{k}_j)$, then $q_j^\star = 0$. The profile $((k_j^\star)_{j=1}^N, (q_j^\star)_{j=1}^N, Q^\star)$ satisfies the Kuhn-Tucker necessary conditions. Note that at least one country will be active since $Q^\star < Q^H$.

Since by assumption the profit function of each firm is pseudoconcave, the specified solution constitutes a Nash equilibrium. ∎

[15] Let $\hat{k} = (c')^{-1}(\theta)$. Then since $c(0) = 0$ and the cost function is convex, we know $k - c(k)$ is maximized at $\hat{k}$. Since $\tilde{k}_j \leq \hat{k}$ for all j, it follows that $\theta\tilde{k}_j - c(\tilde{k}_j) > 0$ for all j.

The following two lemmas demonstrate that in any non-trivial equilibrium, active firms do not produce the minimum quality and active countries cannot have inactive firms.

Lemma D.2 *There can be no non-trivial equilibrium (symmetric or otherwise) in which a firm produces a positive quantity of the minimum quality.*

Proof If it is optimal to produce at minimum quality ($k_{ij} = 0$), then since $c'(0) = 0$ condition (23) requires that $P_2(Q, R^j)\frac{q_{ij}}{Q^j} \leq 0$. But each of the factors to the left of this inequality is strictly positive since, by hypothesis, $q_{ij} > 0$ and we are considering non-trivial equilibria. So the inequality can never hold. Therefore, every firm with $q_{ij} > 0$ must have $k_{ij} > 0$. ∎

Intuitively, since the cost function is flat at the origin but inverse demand is strictly increasing in quality when the price is non-zero, an active firm producing a minimal quality can always increase his profit by marginally increasing his quality choice. At the margin, costs will remain the same but the price will increase.

Lemma D.3 *There can be no non-trivial equilibrium (symmetric or otherwise) in which an active country can have an inactive firm.*

Proof Suppose that $q_{ij} = 0$ and $Q^j > 0$. In that case, one or more of the rival firms is producing a strictly positive amount. Label as firm i' the active firm with the smallest quality. Hence, $k_{i'j} - R^j \leq 0$. Since firm i' produces a strictly positive amount, its first-order condition in (22) must hold with equality. Since the terms $q_{i'j}P_1^j(Q, R^j)$ and $q_{i'j}P_2^j(Q, R^j)(k_{i'j} - R^j)/Q$ are respectively strictly and weakly negative, (22) implies $P^j(Q, R^j) - c(k_{i'j}) > 0$.

But since the cost function is strictly increasing, $P(Q, R^j) - c(0) > 0$ and this same complementary slackness condition (7), which must hold for firm i as well, implies that $q_{ij} > 0$, contradicting the hypothesis that $q_{ij} = 0$. ∎

Given the previous results, we have the following lemma.

Lemma D.4 *There exist no non-trivial pure strategy Nash equilibria in which firms in active countries produce different qualities and/or outputs.*

Proof Consider an active country j. By the two previous lemmas, the first-order conditions of each firm in this country must hold with equality. That is, the following equations must hold in equilibrium:

$$[k_{ij} - (R^j - \frac{QU'(Q)}{\theta R^j})]c'(k_{ij}) + \{\theta R^j - U(Q) - c(k_{ij})\} = 0. \tag{44}$$

Define the left-hand side as $\Gamma^j(k_{ij}; Q, R^j)$. In equilibrium, every firm ($i = 1, \ldots, n_j$) will have $\Gamma^j(k_{ij}; Q, R^j) = 0$. However, this equation cannot have more than one root. We see $\frac{\partial \Gamma^j}{\partial k_{ij}}(k_{ij}; Q, R^j) = [k_{ij} - (R^j - \frac{QU'(Q)}{\theta R^j})]c''(k_{ij})$ and (44) requires that at any root, the first factor in $\frac{\partial \Gamma^j}{\partial k_{ij}}(k_{ij}; Q, R^j)$ must be strictly negative.[16]

Hence, there can be no more than one root. So, for any given equilibrium with its (Q, R^j) a unique k_{ij} satisfies equation (44). But since equation (44) must hold for *every* firm, each firm must choose the same quality in this equilibrium. Denote it $k_j(Q, R^j)$. Moreover, since every firm will be active and reputed quality will equal $R^j = k_j(Q, R^j)$, equation (22) implies that

[16] The term in braces in (44) must be strictly positive since $q_{ij} > 0$ (from Lemma D.3), condition (40) therefore holds with equality, and $P_1 < 0$ by assumption.

$q_{ij} = \frac{\theta R^j - U(Q) - c(k_j(Q, R^j))}{-U'(Q)}$. Since the right-hand side of this equation is independent of i, every firm will produce the same quantity in this equilibrium. Denote it $q_j(Q, R^j)$. $\blacksquare$

References

Akerlof, George, "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism," *Quarterly Journal of Economics*, 84 (1970), 488-500.

Bingaman, Anne K., and Robert E. Litan, Call for Additional Proposals for a Marketing Order for Red Tart Cherries under the Agricultural Marketing Order Act: Comments of the Department of Justice, Antitrust Documents Group (1993), Department of Justice.

Bogdanich, Walt, "The Drug Scare That Exposed a World of Hurt," *The New York Times*, March 30, 2008.

Fabrikant, Geraldine, and Louise Story, "4 Executives are Charged over Tainted Toothpaste," *The New York Times*, March 7, 2008.

Fleckinger, Pierre, "Collective Reputation and Market Structure: Regulating the Quality vs. Quantity Trade-off," discussion paper, Ecole Polytechnique, 2007.

Gardner, Bruce, "U.S. Food Regulation and Product Differentiation: Historical Perspective," discussion paper, University of Maryland.

Klein, Benjamin, and Keith B. Leffler, "The Role of Market Forces in Assuring Contractual Performance," *Journal of Political Economy*, 89 (1981), 615-641.

Kotchen, Matt, and Stephen W. Salant, "A Free Lunch in the Commons," NBER Working Paper No. 15086, 2009.

Mas-Colell, Andreu, Michael D. Whinston, and Jerry R. Green, *Microeconomic Theory*, New York: Oxford University Press, 1995.

Olmstead, Alan L., and Paul W. Rhode, "Hog Round Marketing, Mongrelized Seed, and Government Policy: Institutional Change in U.S. Cotton Production, 1920-60," *Journal of Economic History*, 63 (2003), 447-488.

Rouvière, Elodie, and Raphael Soubeyran, "Collective Reputation, Entry and Minimum Quality Standard," FEEM Working Paper, 2008.

Seade, Jesus, "Profitable cost increases and the shifting of taxation: Equilibrium responses of markets in oligopoly." University of Warwick Research Paper Series No. 260, 1985.

Shapiro, Carl, "Premiums for High Quality Products as Returns to Reputations," *Quarterly Journal of Economics* 98 (1983), 659-80.

Spence, Michael A., "Monopoly, Quality and Regulation," *Bell Journal of Economics*, 6 (1975), 417-429.

Tirole, Jean, "A Theory of Collective Reputation (with applications to the persistence of corruption and to firm quality)," *Review of Economic Studies*, 63 (1996), 1-22.

Winfree, Jason, and Jill McCluskey, "Collective Reputation and Quality," *American Journal of Agricultural Economics*, 87 (2005), 206-213.

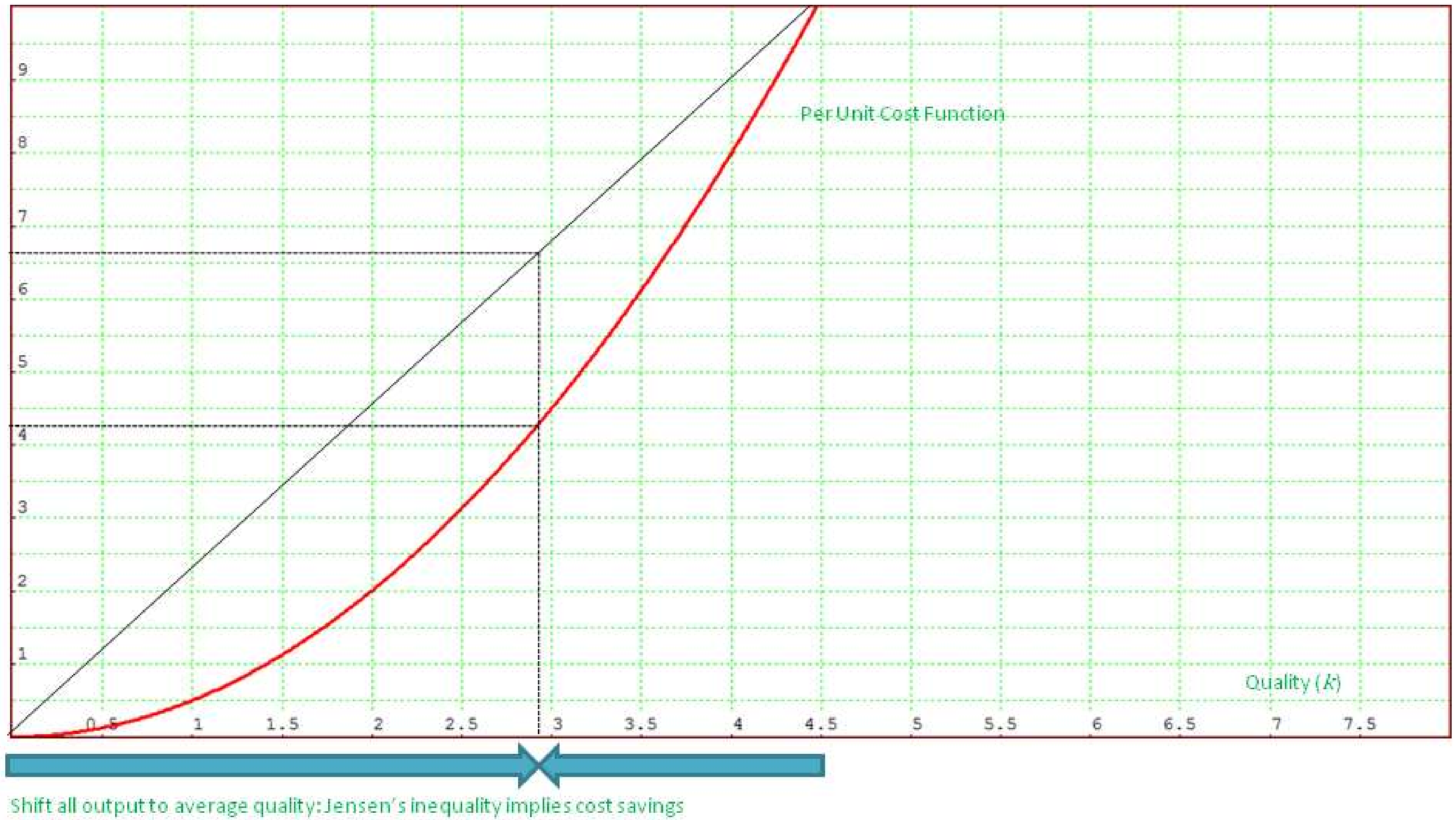

Figure 1: Strictly Convex Cost Function Insures Cost Savings When Product Line Has Diverse Qualities