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IFPRI Discussion Paper 01107

August 2011

# Collective Reputation, Social Norms, and Participation

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## INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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## PARTNERS AND CONTRIBUTORS

IFPRI gratefully acknowledges the generous unrestricted funding from Australia, Canada, China, Denmark, Finland, France, Germany, India, Ireland, Italy, Japan, the Netherlands, Norway, the Philippines, South Africa, Sweden, Switzerland, the United Kingdom, the United States, and the World Bank.

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## ABSTRACT

This paper analyzes a repeated games model of collective reputation with imperfect public monitoring and perfect local peer monitoring of efforts. Even when peer monitoring is local, firms may achieve higher profits under collective reputation by decreasing the cost of maintaining customers' trust. The optimal number of firms that share a common reputation is greater when (1) trades are more frequent and public information is disseminated more rapidly, (2) the deviation gain is smaller compared to the quality premium, (3) customers' information regarding firms' quality is more precise, or (4) intragroup information about firms' quality is more global. From a positive perspective, we suggest how social norms can influence the reputation of regional products. We also offer an efficiency explanation for food scares. From a normative point of view, in our model, protection of geographical indications increases and mandatory traceability decreases welfare and incentives to provide quality without taking into account direct implementation costs.


**Keywords: collective reputation, free riding, public monitoring, peer monitoring, peer sanction**

# ACKNOWLEDGMENTS

I would like to thank anonymous reviewers and seminar participants at International Food Policy Research Institute for helpful comments and suggestions.

# 1. INTRODUCTION

In agricultural and other industries, firms sometimes sell their products under a collective brand such as a geographical indication (GI) or a group logo (Verbeke and Roosen 2009).[1] The literature that studies the economics of collective brands views them as being solutions to an information problem in the provision of quality that the consumer cannot detect before purchasing the good (Moschini, Menapace, and Pick 2008). There are several explanations for why a collective brand is more attractive than an individual brand. According to one approach, firms use collective brands to share the costs of credible auditing and certification by a central organization (Moschini, Menapace, and Pick 2008, and references therein).[2] According to another approach, a collective brand is the bearer of the collective reputation of a regional product or a group of producers that are not individually known to the consumer (Winfree and McCluskey 2005; Fishman et al. 2010).[3] In this paper, we follow the latter approach but consider a novel role for intragroup information.

Previous studies of GIs as a reputation-pooling device have suggested different mechanisms that allow a group of firms with a common reputation to overcome the free-riding problem. Fishman et al. (2010) considered a "once and for all" investment in quality and heterogeneous investment costs. They showed that the exogenous group composition, whereby all firms that participate in a collective brand have the same investment cost, provides an incentive to invest in quality that countervails the incentive to free ride. Winfree and McCluskey (2005) considered an ad hoc model of collective reputation as a common resource (a stock of consumer goodwill) with homogeneous producers and suggested that trigger strategies that prescribe collective shirking as a punishment for individual shirking can overcome free riding and sustain quality.[4] Whether this kind of *quality cartel* is implementable in a belief-based model of collective reputation is an issue that we take up in this paper.

Our main contribution is to characterize the number of firms in a group that maximizes the value of group reputation in an environment that has moral hazard and imperfect public and local peer monitoring of quality choices. From a positive perspective, we show how local social norms that prescribe peer monitoring and the end of intragroup trust as a punishment for shirking can influence the reputation of regional products and agricultural cooperatives. We also suggest an explanation for food scares as part of a mechanism that sustains customers' trust and industrywide norms. From a normative perspective, we show that collective brands improve welfare because they efficiently aggregate consumer and producer information about a group's performance; they may also save the need for costly external auditing and certification of compliance. Our model suggests that the analysis of policies that make it either easier or more difficult to maintain a fixed group membership and a commitment to sell under a collective brand, such as protection of the right to use a GI and mandatory traceability, should take into account the effects of those policies on endogenous punishment mechanisms and intragroup behavior (ERS 2011; Golan et al. 2004).

We build on the Cai and Obara (2009) model (CO model) of firm reputation and the Kandori (1992) model of social norms. Our model is a repeated games model with a group of anonymous firms

[1] Examples of products marked with geographic origin are Washington apples, Florida oranges, and Kona coffee (Babcock et al. 2008). In the European Union, GIs typically convey a certain quality and product specification (Giovannucci et al. 2009). However, a GI protected as a certification mark in the United States only certifies the geographic origin of products, and firms are entitled to use a GI to label their products by the virtue of their location within the geographic area indicated by the GI (USPTO 2011). In our setting, a GI label is a means of informing consumers that the product originates in the area indicated by the label.

[2] Geographical indications based on appellations and membership in industry organizations and food safety programs frequently involve meeting a minimum quality standard and auditing to ensure compliance (Moschini, Menapace, and Pick 2008).

[3] A large literature studies firm reputation under asymmetric information (Bar-Isaac and Tadelis 2008).

[4] Winfree and McCluskey (2005) found that an increase in the number of firms in a group reduces the incentive to provide quality. Their results suggest that, all else equal, producers should prefer to implement firm-level traceability and to sell their products under individual brands. Therefore, in the absence of exogenous fixed labeling or traceability costs, their model cannot explain why producers voluntarily "pool" their individual reputations under the umbrella of a collective brand.

that sell experience goods, meaning that customers do not directly know the individual firms and cannot observe product quality at the time of purchase. In each period, firms simultaneously choose whether to exert costly efforts that determine their products' quality in that period. Although no firm-level traceability and direct penalties for shirking, such as liability for unsafe products, exist in the model (though there is group-level traceability), customers' past consumption experience (for example, reports of unsafe products by media) and groupwide norms can provide an endogenous incentive to exert costly efforts. In order to develop a simple reputational theory of group size, we ignore auditing and certification of quality and other channels, such as provision of credit, inputs, training, and price information, as well as group-level economies of scale in production and marketing, through which producer organizations can increase members' profits.[5] Here we focus on endogenous incentives and choices at the firm level.[6]

A novel feature of our model is that customers' trust is maintained by a combination of imperfect public and local peer monitoring and punishments.[7] We characterize equilibrium in simple trigger strategies, whereby the group loses its reputation and quality premium forever once the public signal falls below a certain cut-off point.[8] In addition, in equilibrium, firms can threaten each other with a self-enforcing peer sanction for shirking—that is, if a firm detects shirking by another firm, the latter firm will subsequently shirk itself forever afterward. On the other hand, firms reciprocate and exert high efforts as long as their neighbors do not shirk and customers deem the group trustworthy. In our setting, the credibility of the "quality cartel" is based on incomplete firm-level traceability, fixed group membership, and private information that firms have about each other.[9]

We chose a specific intragroup information structure (horizontal information network) with two considerations in mind. First, this structure relaxes the assumption of perfect private information while keeping the model tractable. Second, it reflects the local nature of private information in large groups, which seems plausible in the context of agricultural markets with geographically dispersed production. We assume that firms are located around a circle and that they perfectly observe the past efforts of adjacent neighbor(s) but have no private information about more distant neighbors. So, private information is locally perfect in the sense that firms never wrongly believe that a neighbor shirks.[10] On the other hand, public information of the overall group's performance is imperfect in that sometimes customers observe a bad public signal even in the absence of shirking. Thus, in equilibrium, an eventual breakdown in cooperation among members is triggered by the loss of customers' trust rather than by the actual shirking of members. The model retains a convenient recursive structure because member payoffs and the cost of maintaining reputation depend only on the cut-off point of the public signal that is implementable in equilibrium.

In our model, collective branding has three effects on reputation: a positive peer monitoring effect, a positive information effect, and a negative free-riding effect. First, the effect of peer monitoring is positive because it deters shirking: A shirker who is monitored by peers will trigger a breakdown in

[5] Our model can be easily extended to include exogenous means of eliciting efforts, such as third-party certification of quality and liability for safety failures. The qualitative nature of our results will not change if a central organization monitors performance and punishes shirking, as long as the severity of punishments is limited (for example, by a firm's financial assets).

[6] Although auditing and enforcement of quality standards are common means of incentivizing quality provision, they are not always effective. For example, public inspections, such as pesticide residue monitoring, were considered unreliable in several developing countries (World Bank 2005). In addition, safety violations can occur despite routine inspections due to poor communication among government agencies (Mundy and Tomson 2010).

[7] It is well known in the group lending literature (Ghatak 1999; Che 2002) that internal monitoring of local production practices can overcome the free-riding problem. We do not consider exogenous peer pressure and sanctions in team production as in Barron and Gjerde (1997).

[8] That is, the group forever loses customers' loyalty and trust that the members exert high effort. As demonstrated in the Cai and Obara (2009) model, the public punishment by the permanent Nash reversion (that is, repetition of the Nash equilibrium forever) can be replaced by a temporary public punishment, whereby the firms reduce their prices until the public signal rises above a certain threshold.

[9] We consider traceability as a means of differentiating groups according to their history of quality rather than establishing liability for safety failures (Pouliot and Sumner 2009).

[10] Although we show that the group of producers can sustain discipline when each member is observed by a few (or just one) other members in the group, informational "connectedness" among members is critical for our results.

cooperation among group members, which will eventually lead to collective shirking and make the loss of customers' trust more likely. Second, we assume that member-specific idiosyncratic shocks are independent and are thus averaged out by the law of large numbers in the public signal of the overall group's performance. Therefore, the information effect is positive, because aggregating information across members makes public monitoring less noisy. With more precise public signals, reputation of high quality is easier to maintain if members exert high efforts, but it is easier to lose if members shirk. Finally, collective branding creates free-riding opportunities because a deviation by each member has less impact on the public signal in the short run (this is not true in the long run, because individual deviation will be detected by peers and will trigger collective shirking).

We find that even with *very local* peer monitoring, firms achieve higher profits under collective branding as long as they care sufficiently about the future—in that trades are sufficiently frequent or public information disseminates sufficiently rapidly—and the group size is not too small or too large. Group reputation may be easier to maintain than individual reputation because a group of firms can complement fast-working but uncertain public punishment for shirking with slow-working but certain peer punishment. The public punishment can thus be softened relative to that for an individual firm. The peer punishment works slowly in that news of the breakdown in cooperation spreads from neighbor to neighbor rather than through a common public signal. Thus, if the future is not sufficiently important or the number of firms is too small or too large, peer monitoring may not compensate for free-riding opportunities. In other words, too few firms may lack the critical mass needed to make peer punishment sufficiently severe, whereas too many firms may excessively slow the intragroup learning.

The optimal size of the group is determined by the following trade-off: On the one hand, adding another member makes it easier for customers to detect collective shirking because there is less idiosyncratic noise. On the other hand, individual shirking is more difficult to detect, and given the intragroup information structure, the average *distance* among firms increases, which slows the unfolding of peer sanction and may undermine its credibility. We show that under some conditions, the optimal size of the group is larger when trades are more frequent or when public information disseminates more rapidly, or when the deviation gain is smaller relative to reputation premium, or when customer information about firms' choices is more precise. We also find that the group maintains trust more easily when there are more information linkages among group members (that is, more global peer monitoring).

Although empirical evidence shows that price premiums for regional products depend on collective reputation (Landon and Smith 1998; Quagrainie, McCluskey, and Loureiro 2003; Castriota and Delmastro 2008), to our knowledge, no empirical studies explicitly test how such "quality cartels" are sustained. Nonetheless, some previous empirical findings are consistent with our model. For example, in an empirical study of pesticide residues on vegetables supplied by farmer organizations, Naziri et al. (2010) demonstrated that larger groups are more likely to sustain cooperation and rely on internal (but not necessarily peer) monitoring.[11] In addition, in a case study of compliance with international food safety standards by a group of smallholder farmers, Okello and Swinton (2007) found that members police each other in order to reduce the cost of external inspection of geographically dispersed farms.

A study of farmer organizations in Vietnam (Moustier et al. 2010) illustrates the key features of our model. According to the authors' findings, participation in farmer groups is voluntary and with the intention of undertaking joint social or economic activities related to production and marketing. In addition, some of the farmer groups in the sample sell most of their output directly to consumers at premium prices, label their products with group-specific logos, and are concerned with group reputation for quality. The authors concluded that farmer groups reduce transaction costs and moral hazard problems related to product quality through members' first-hand knowledge of local production practices and internal inspections of quality. Furthermore, four out of eight farmer organizations in the sample are "characterized by neighbor and/or kinship relationships between the members which allow trust to

[11] In an experimental study, Huck and Lunser (2010) found that sellers can build successful group reputations as long as groups are small but do not allow for internal group monitoring (thus, their setting corresponds to the case of no peer monitoring in our model).

develop and facilitate the control of farmer behavior" (Moustier et al. 2010, 77).

## Related Literature

Our model is closely related to the literature on collective reputation (Tirole 1996; Evans and Guinnane 2007; Levin 2009), umbrella branding (Andersson 2002; Cabral 2009; Choi 1998; Cai and Obara 2009), and incentives and social norms in groups (Kandori 1992; Spagnolo 1999; Che and Yoo 2001; Che 2002). Tirole (1996) investigated persistence of collective reputation in a model in which individual histories are imperfectly observed by the trading partners or group members and shirkers are punished by temporary or permanent exclusion. Evans and Guinnane (2007) studied the formation of common reputation among identifiable groups with a regulator who maintains the groups' quality standards. In our model, firms are endogenously incentivized by both customers and peers, rather than by explicit devices such as public certification or the threat of exclusion from the group.

Individual reputations can also be linked across products or markets via umbrella branding and horizontal integration, as in the CO model with moral hazard and imperfect public monitoring. The CO model considers a single decisionmaker before and after horizontal integration, and thus implicitly assumes that the size of a firm or a brand does not affect the decision making process within the firm. Whereas CO considered the reputation of a *single* horizontally integrated firm, we keep the size of firms unchanged and consider the reputation of a *group* of firms that have some private information about each other.[12] In the CO model, the diminishing returns to horizontal integration are due to the common component in the firm-specific noise, which limits the positive effect of information aggregation across different markets that are subject to idiosyncratic shocks. In this paper, the optimal size of the collective brand (or the collection of independent *branches* of a large firm) is finite due to partial peer monitoring among members (or branch managers) rather than to persistent noise in public monitoring (for further discussion see Section 7).

The idea that cooperation within a group can be sustained by a social norm, whereby a single act of shirking means the breakdown of trust within the entire group, was first developed in a repeated games model with random matching and local perfect observability in Kandori (1992). In a recent paper, Wolitsky (2011) shows that in a setting with continuous payoffs and network monitoring with either random or fixed matching of players who observe each others' choices, the maximum level of cooperation can be sustained in grim trigger strategies. In our model, there is local perfect observability of efforts by producers that are connected by a fixed network, but consumers *imperfectly* observe the group's performance. None of the previous studies of repeated games with community enforcement (Ellison 1994) and public good provision (Bendor and Mookherjee 1990, Pecorino 1999, Haag and Lagunoff 2007) consider a *combination* of imperfect public and private monitoring as a means of supporting cooperation, as we do in this paper.

Also, the literature on group lending and incentives in teams (Ghatak and Guinnane 1999) has explored the mechanisms through which peer sanctions can alleviate moral hazard problems in the context of joint liability contracts. Our paper is particularly closely related to Che and Yoo (2001) and Che (2002), who endogenized peer punishment behavior in a repeated game similar to ours.[13] However, their models consider contractual arrangements such that only current payoffs are contingent on the public signal, whereas the public signal affects future payoffs in our model. As a result, Che and Yoo did not consider interactions between maintaining reputation and peer sanction; they also did not allow for local peer monitoring.

The rest of this paper is organized as follows: The model is described in Section 2. In Section 3, we characterize the equilibrium with group reputation and self-enforcing peer sanction. In Section 4, we

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[12] Also related is a paper by Rob and Fishman (2005) in which a larger firm serves more consumers, which facilitates intergenerational consumer learning about the firms' performance and thus improves public monitoring.

[13] Che and Yoo (2001) considered labor contracting with binary efforts and two-member teams, and Che (2002) considered group lending in a model with continuous effort and a more general signal structure. Our paper is also related to Spagnolo (1999), who investigated the linking of social interaction and production interaction in a repeated setting with perfect information.

obtain the main results about optimal group size and examine how it is affected by the model's parameters. In Section 5, we examine the role of an intragroup information structure. In Section 6, we comment on the robustness of our results to the possibility of renegotiation. In Section 7, we discuss applications of our findings to GIs, mandatory traceability, and the theory of the firm, and consider policy implications. We conclude in Section 8.

## 2. MODEL

We adopt Cai and Obara's (2009) notation. Time is discrete and the horizon is infinite, $t = 1, 2, \ldots$ . There is a group of $n$ identical long-lived, risk-neutral firms (members of the group) that sell their products to a large number of identical risk-neutral customers. If $n = 1$, then we say that the firm sells under an individual brand; otherwise, the brand is collective.[14] We assume that the firms sell their products into a competitive downstream market with zero markup in which their products are randomly matched with buyers. Thus, under collective branding there is mutual anonymity whereby a buyer does not observe the identity of the seller and vice versa.[15] Let $\delta \in (0,1)$ denote the common discount factor.

At the beginning of each period, each firm $i$ sets its price $p_{i,t}$ for the period, and its customers decide whether to purchase one unit of the firm's products. If customers do not buy, both the customers and the firm get a payoff of zero. If customers decide to buy, the payoffs depend on the product quality which can be high or low. Each firm simultaneously decides whether to exert high effort $e_h$ or low effort $e_l$ at a cost $c_h$ or $c_l$, respectively, where $e_l < e_h$ and $c_l < c_h$. Each firm produces one unit and firm's choice of effort is fixed for the period (the effort is firm-specific), and $\Delta = e_h - e_l$ denotes the effort differential. We assume that the group's members cannot side contract or exchange payments among themselves.[16] The customers' expected per-period benefit is $v_h$ if they buy a product produced by the member who chooses $e_h$ and is $v_l$ if the member chooses $e_l$, where $v_l < v_h$. After price $p > v_l$ is posted, the stage game in the normal form is depicted below.

| | | Firm: *Low* | Firm: *High* |
|---|---|---|---|
| Customers | *Don't Buy* | 0, 0 | 0, 0 |
| | *Buy* | $v_l - p \ , p - c_l$ | $v_h - p \ , p - c_h$ |

We assume that $v_l - c_l < 0 < v_h - c_h$; in other words, trade is socially efficient when a member exerts high effort, but it becomes socially inefficient if effort is low. The unique Nash equilibrium of the stage game (*Don't Buy*, *Low*) is Pareto-dominated by the outcome (*Buy*, *High*) for any $p \in (c_h, v_h)$. In the absence of credible auditing and certification of quality, the efficient outcome can still be attained when firms are concerned with customers' future trust.

As in the CO model, we assume that the purchasing decision of a single buyer has no impact on sellers' profits; thus, each customer will buy if and only if buying generates a nonnegative payoff in the current period. In order to focus on reputation effects, we assume that the market is long on the buyers' side, so that, provided trading takes place, each firm sets the price that equals consumers' willingness to pay. Let $\tau = \frac{c_h - c_l}{p - c_h} (= \frac{c_h - c_l}{v_h - c_h})$ denote the ratio of the cost savings from shirking to the firm's current period payoff when efficient trade takes place at price $p = v_h$. For $\tau < \frac{\delta}{1-\delta}$, the first-best outcome is achieved in the standard reputational model with perfect public information, if in each period firms set $p = v_h$ and

[14] For simplicity, we ignore any fixed costs or direct economies of scale associated with forming a group or collective brand.

[15] For example, supermarkets sell fruits and vegetables produced by a large number of growers, and farmer marketing cooperatives sell livestock and crops on behalf of their members.

[16] Although this assumption may not adequately capture the organization and functions of some producer groups, it seems reasonable in the context of collective brands, such as geographical indications, as participants typically do not exchange payments contingent on the results of peer monitoring.

choose high effort and if all customers buy as long as none of the firms exerted low effort in the past.[17] Note that under perfect public information, peer monitoring by group members cannot increase payoffs, because customers can punish shirking without mistakes.

## Public Information

As discussed in the CO model, public information of a firm's effort can be noisy for many reasons, such as unobservable inputs in production, interference with other products in consumption, and noisy communication of experience among customers.[18] With this in mind, we assume that customers observe

$$e_{i,t} + \varepsilon_{i,t}$$

for each firm $i = 1,...,n$, but without knowing its identity, where $e_{i,t}$ is the effort chosen by firm $i$ in period $t$, and $\varepsilon_{i,t}$ are mean-zero normally distributed noise terms with variance $\sigma^2$ that are independent across firms and time periods. Although firm-level information of the effort choice is available, given random matching and anonymity between buyers and sellers, the average signal

$$y_t = \frac{1}{n}(\sum_{i=1}^{n} e_{i,t} + \varepsilon_{i,t}) \tag{1}$$

is a sufficient statistic for the effort choice of any group member. Therefore, the public information of the effort choices made by the members of the group in period $t$ is given by the noisy signal (1).

Note that customers ignore signals of the individual performance of group members as long as customers can commit not to exclude from the group firms that produced low quality in the past. Otherwise, individual quality histories will matter, because customers will anticipate future changes in group membership as a result of imperfect public monitoring. The commitment to nonexclusion of underperformers (either by customers or by the members of the group) is credible when a product cannot be traced to its firm of origin within the group and when firms' private information is unverifiable.

Note that with the following (inconsequential) parametric restrictions, we can interpret $e_{i,t} + \varepsilon_{i,t}$ as the utility of consumption and $v_h = E[e_h + \varepsilon] = e_h$ and $v_l = E[e_l + \varepsilon] = e_l$ as the willingness of risk-neutral consumers to pay for high- and low-quality products. In particular, $e_{i,t} + \varepsilon_{i,t}$ can represent a quality attribute, such as food safety, wherein $e_h$ denotes the adoption of food safety practices (ex ante safe food), $e_l$ denotes the nonadoption of food safety practices (ex ante unsafe food), and noise terms $\varepsilon_{i,t}$ are the contamination risks (food safety incidents). Thus, ex ante safe food can become contaminated due to a negative shock. Similarly, ex ante unsafe food can actually pose no hazard to human health due to a positive shock.

For simplicity, we ignore group-specific noise that, for example, may arise due to shocks to product quality at the retail level or the use of common inputs by the members of the group. Adding group-specific noise to the public signal will slightly complicate the notation but will not change the qualitative nature of the results. In contrast to the CO model of reputation of a *single* large firm serving many markets, our theory of the optimal group size is not predicated upon the existence of common production noise. A common component in the noise terms limits the impact of the aggregation of

[17] Note that $\tau < \frac{\delta}{1-\delta}$ is equivalent to $\frac{p-c_h}{1-\delta} > p - c_l$—that is, the present value of the firm's payoffs over the infinite horizon is greater than the one-time deviation gain.

[18] For example, in the case of a recent *E. coli* outbreak, it was finally determined that German bean sprouts caused the outbreak rather than Spanish cucumbers, which were initially considered to be the cause of the outbreak (Stevens 2011).

individual signals on the informativeness of the public signal in (1), thus reducing the advantages conferred by size. Instead we focus on how peer and public monitoring interact as a group of firms builds collective reputation.[19]

### Intragroup Information

Each firm has some private information about the efforts chosen by the other firms. We consider a special class of intragroup information structures whereby each firm $i$ observes the past effort choices of all firms in its *z*-firm neighborhood, that is, of all firms $j \in \{|i-z|_n, ..., |i+z|_n\}$, where $|x|_n = n - x$ if $x \leq 0$, $|x|_n = x - n$ if $x \geq n+1$, and $z \in \{1, ..., n-1\}$. An interpretation is that firms are located around a circle, and each firm *perfectly* observes the efforts chosen by its $z$ neighbor(s) to the left and $z$ neighbor(s) to the right, but it does *not* observe the effort choices of its more distant neighbors.

So, for periods $t = 2,3,...$, the public history $\mathrm{H}_t$ of the game is the sequence of the public signal realizations $\{y_s\}_{s=1}^{t-1}$ and prices $\{\mathrm{p}_s\}_{s=1}^{t-1}$, where $\mathrm{p}_t = \{p_{i,t}\}_{i=1}^{n}$. Firm $i$ 's private history of the game is the sequence of the efforts $\{\mathrm{e}_{i,s}^{z}\}_{s=1}^{t-1}$ chosen by all firms in its *z*-firm neighborhood, where $\mathrm{e}_{i,s}^{z} = \{e_{|i-z|_n,s}, ..., e_{i,s}, ..., e_{|i+z|_n,s}\}$. We assume that customers base their period $t$ decisions on $(\mathrm{H}_t, \mathrm{p}_t)$. The pricing decision of each firm in periods $t = 2,3,...$ depends on ($\mathrm{H}_t$, $\{\mathrm{e}_{i,s}^{z}\}_{s=1}^{t-1}$), and its effort decision depends on ($\mathrm{H}_t$, $\{\mathrm{e}_{i,s}^{z}\}_{s=1}^{t-1}$, $p_{i,t}$).

### Trigger Strategies

Even though this game admits many equilibria, including a repetition of the Nash equilibrium of the stage game in which all customers and firms choose (*Don't Buy*, *Low*), we focus on a *cut-off grim trigger strategy* equilibrium, in which both customers and firms adopt the following strategies: Each firm and its customers choose (*Buy*, *High*) in the first period at price $v_h$.[20] All customers continue to choose *Buy* as long as $y_t$ stays above some threshold $\tilde{y}$ and the price does not exceed $v_h$; they choose *Don't Buy* forever at any price greater than $v_l$ once $y_t$ falls below the threshold $\tilde{y}$. In other words, customers who are offered a product at $p_{i,t}$ in period $t$ play

$$\begin{array}{l} \textit{Buy}, \text{if } p_{i,t} \leq v_h \text{ and } y_s \geq \tilde{y} \text{ for } s = 1, ..., t-1, \text{or } p_{i,t} \leq v_l; \\ \textit{Don't Buy}, \text{if otherwise} \end{array} \tag{2}$$

Each firm continues to choose *High* as long as $y$ stays above the threshold $\tilde{y}$ and all of its neighbors chose *High* in all of the previous periods; each firm chooses *Low* forever once either $y$ falls below the threshold $\tilde{y}$ or the firm itself or at least one of its neighbors chose *Low* in the past. That is, each firm $i$ chooses its level of effort in period $t = 2,3,,...$ in accordance with

$$e_{i,t} = \begin{cases} e_h, \text{if } y_s \geq \tilde{y} \text{ and } \mathrm{e}_{i,s}^{z} = \{e_h, ..., e_h\} \text{ for } s = 1, ..., t-1; \\ e_l, \text{if otherwise} \end{cases}. \tag{3}$$

[19] The existence of a common trait is explored in a repeated games model in Evans and Guinnane (2007).
[20] For example, traditions and social ties among group members or a central organization may help "select" this equilibrium.

Note that the strategy in (3) calls for the most severe endogenous peer sanction for shirking.

We first characterize perfect equilibria with grim trigger strategies in (2) and (3) that maximize the per-firm payoff given a fixed number of firms $n$. Then we characterize the number of firms $n^*$ that maximizes the greatest average equilibrium payoff for each firm in the group. For some values of parameters (for example, sufficiently low $\delta$), the unique equilibrium for any number of firms is the repetition of the Nash equilibrium of the stage game (*Don't Buy*, *Low*), in which case $n^*$ is trivially indeterminate. Then we set $n^*=0$ as the number of firms that has no effect on the equilibrium outcome.

## 3. COLLECTIVE REPUTATION WITH PUBLIC AND PEER PUNISHMENTS

We refer to a *stationary cut-off grim trigger strategy* equilibrium with peer monitoring as a *reputation by cooperation* equilibrium. The periods in which the group's reputation is good and consumers are willing to pay up to $v_h$ are called the *reputation-by-cooperation phase*; the periods in which the group's reputation is good but some (or possibly all) firms exert low efforts (on an out-of-equilibrium path) is called the *peer punishment phase*; finally, the periods during which the group's reputation is bad are called the *public punishment phase*.

As in the CO model and Cabral (2009), the pricing decision is straightforward.[21] When the group's reputation is good, each firm is to provide high effort in the current period and sets the price $p = v_h$ (the customer's expected valuation). If the group loses its reputation and each firm is to provide low effort forever, then its price has to be at least $c_l$ to cover the cost. Because customers expect that firms will choose low effort, they will only buy if the price does not exceed $v_l$, which, by assumption, is not sufficient to cover $c_l$. Therefore, whenever customers expect the firms to choose low effort, the equilibrium outcome is (*Don't Buy*, *Low*) for all firms, and price is indeterminate. If a firm provides low effort while the group's reputation is good, it will continue to set the price equal to $v_h$, because a price below $v_h$ decreases the firm's profit in the current period and does not, by itself, alter the behavior of customers and the other firms in the future. The firm never sets the price above $v_h$ because then there will be no trade in the current period, which cannot be optimal when the group's reputation is good.

It is convenient to let $k = \frac{y-e_h}{\sigma/\sqrt{n}}$ denote the normalized public signal (henceforth, we will refer to $k$ rather than $y$ as the public signal).[22] Then, by (1), (2), and (3), the probability of reputation by cooperation continuing conditional on all firms exerting effort $e_h$ is $1-\Phi(k)$ because, by assumption, $\frac{y-e_h}{\sigma/\sqrt{n}} = \frac{\sum_{i=1}^{n}\varepsilon_{i,t}}{\sigma\sqrt{n}} \sim N(0,1)$, where $\Phi$ is the standard normal distribution function. In addition, let $\tilde{k}$ denote the cut-off signal used in the equilibrium. Then the per-firm average payoff when reputation is good and all members exerted high efforts in the past satisfies the following familiar recursive equation:

$$\pi_{n,0} = (1-\delta)(p-c_h) + \delta(1-\Phi(\tilde{k}))\pi_{n,0}, \tag{4}$$

where the subscript "*n*, 0" stands for the number of members in the group (*n*) and the number of current shirkers (0). To simplify notation, we adopt the convention of the repeated games literature and measure a firm's payoff as its expected profit averaged over the infinite horizon (that is, the sum of discounted profits multiplied by $1-\delta$), instead of as its total discounted expected profits. This convention permits an easy comparison between repeated and stage-game payoffs, as they are both measured in the same "payoff per period" units. Equation (4) says that the member's per-period value in the equilibrium is the

[21] We ignore the possibility that firms may use prices or some other form of communication to signal their identity and establish their firm-specific reputation with buyers. Equilibria in which firms signal their identity to customers via prices can be easily ruled out, because each firm can mimic prices chosen by other firms as long as prices are included in the public history of the game. It is worth pointing out that even though in equilibrium firms collude on the monopoly price, our concern is not whether collective branding helps firms exercise market power but whether it endogenously provides incentive to exert high effort. The model can be easily extended to allow for a price (or quantity) competition among firms, though this is at the cost of obscuring how the group's structure interacts with its reputation.

[22] Note that $\sigma^2/n$ is the variance of the public signal in (1).

sum of its current period profit averaged out over time, $(1-\delta)(p-c_h)$, plus the expected average value from continuation, $\delta(1-\Phi(\widetilde{k}))\pi_{n,0}$.

During the out-of-equilibrium peer punishment phase, when $m \geq 1$ adjacent firms exert low efforts in the current period, the average payoff for a shirker satisfies the following equation:[23]

$$\pi_{n,m} = (1-\delta)(p-c_l) + \delta(1-\Phi(\widetilde{k} + \tfrac{\Delta}{\sigma\sqrt{n}} m))\pi_{n,\min[m+2z,n]} \,. \tag{5}$$

Equation (5) says that during the peer punishment phase, the per-period value of the firm that shirks is the sum of its current period profit averaged out over time, $(1-\delta)(p-c_l)$, plus the expected average value from continuation, $\delta(1-\Phi(\widetilde{k} + \tfrac{\Delta}{\sigma\sqrt{n}} m))\pi_{n,\min[m+2z,n]}$. In accordance with (3), if $m$ adjacent firms shirk in the current period, then $\min[m+2z,n]$ firms will shirk in the following period while the peer punishment phase lasts. As the peer punishment phase unfolds, there will be at most 2*z* additional firms (*z* firms to the left and *z* firms to the right of the subgroup of shirkers) that no longer believe that the reputation-by-cooperation phase would continue.

So, during the reputation phase, each firm achieves a higher payoff by choosing $e_h$ if the following incentive compatibility (no-shirking) constraint is satisfied

$$\pi_{n,0} \geq \pi_{n,1} \,. \tag{6}$$

In addition, we need to verify that the threat of peer punishment is credible (sequentially optimal). Specifically, a member that detects shirking by its neighbor for the first time achieves a higher payoff by subsequently choosing $e_l$ itself if

$$\pi_{n,m} \geq (1-\delta)(p-c_h) + \delta(1-\Phi(\widetilde{k} + \tfrac{(m-1)\Delta}{\sigma\sqrt{n}}))\pi_{n,\min[m+2z-1,n]} \text{ for } m = \min[n,1+2z],\ldots,n \,, \tag{7}$$

where $m$ is the feasible number of adjacent shirkers. The right side of (7) is the sum of time-averaged current payoffs from exerting a high effort plus the continuation value when there are $m-1$ shirkers in the current period and $\min[m+z+z-1,n]$ shirkers in the next period.

A repeat shirker (a member who knows that the peer punishment phase has started) will achieve higher profits by continuing to shirk if

$$\pi_{n,m} \geq (1-\delta)(p-c_h) + \delta(1-\Phi(\widetilde{k} + \tfrac{(m-1)\Delta}{\sigma\sqrt{n}}))\pi_{n,\min[m+2z,n]} \text{ for } m = \min[n,1+2z],\ldots,n \,. \tag{8}$$

The difference between (7) and (8) is that a repeat shirker cannot slow the unfolding of the peer punishment phase because, in accordance with the effort strategy in (3), all immediate 2*z* neighbors of the repeat shirker continue to shirk, regardless of that shirker's choice of effort.

As in the CO model, by (4), the average payoff in the reputation-by-cooperation equilibrium is given by

[23] Note that, respectively, customers and each firm have imperfect information about the changes in effort choices of the entire group and all firms outside that firm's *z*-neighborhood. Nonetheless, the posterior beliefs of customers and firms that are yet to detect shirking by their neighbors are not affected by ongoing shirking, because, initially, the prior beliefs of both customers and firms put probability 1 on the equilibrium behavior (that is, that all firms provide high effort).

$$\pi(\widetilde{k}) = \frac{(1-\delta)(p-c_h)}{1-\delta(1-\Phi(\widetilde{k}))}. \tag{9}$$

Because (9) is decreasing in $\widetilde{k}$, in an equilibrium that yields the greatest per firm average payoff the cut-off point of the public signal is given by the smallest $\widetilde{k}$, denoted by $k_n$, such that the incentive compatibility constraints (6)–(8) are satisfied. Instead of characterizing the range of parameters for which a reputation-by-cooperation equilibrium exists, we identify more restrictive conditions under which (6)–(8) are satisfied *and* under which firms achieve higher payoffs from collective branding than from individual branding.

The case of individual reputation with $n = 1$ is analyzed in the CO model, and it serves as a benchmark to determine the participation criterion here. Under individual reputation, there is trivially no peer monitoring, and the effort strategy in (3) takes the following form:

$$e_{i,t} = \begin{cases} e_h, \text{if } \frac{y_s - e_h}{\sigma} \geq \widetilde{k} \text{ for } s = 1,\ldots,t-1, \text{or } t = 1; \\ e_l, \text{if otherwise} \end{cases}. \tag{10}$$

Cai and Obara (2009) show that under individual branding in the perfect public equilibrium that yields the greatest average payoff for the firm (and welfare) in the class of all perfect public equilibria, consumers buy in accordance with (2) and the firm sets $p_{i,t} = p(= v_h)$ and chooses effort in accordance with (10) provided that discount factor $\delta$ is sufficiently close to 1 (so called best equilibrium).[24] In this equilibrium, the cut-off point $k_1 < 0$ is the smallest root of the binding incentive compatibility constraint

$$\pi_{1,0} = (1-\delta)(p-c_h) + \delta(1-\Phi(k_1))\pi_{1,0} = (1-\delta)(p-c_l) + \delta(1-\Phi(k_1 + \tfrac{\Delta}{\sigma}))\pi_{1,0}, \tag{11}$$

where $\pi_{1,0}$ is the equilibrium payoff, and the more firm cares about the future the more likely it is to remain trustworthy, that is $\lim_{\delta \to 1} k_1 = -\infty$.

As in the CO model, the key variable in the analysis is the continuation probability during the reputation phase. So, by (9) and (11), in order to evaluate whether collective branding is optimal, that is,

$$\pi_{1,0} \leq \pi_{n,0} = \pi(k_n),$$

we simply need to check whether $k_n \leq k_1$ for some $n > 1$. Section 4 explores conditions under which it is easier to maintain a good reputation under a collective brand than under an individual brand, and the determinants of the optimal number of firms participating in the collective brand.

[24] A perfect public equilibrium is a profile of purchasing and effort strategies (such as (2) and (10)) that depend only on the public history $\mathrm{H}_t$ and that, beginning at any period $t$ and given any public history $\mathrm{H}_t$, form a Nash equilibrium from that period on.

## 4. OPTIMAL NUMBER OF FIRMS WITH LOCAL PEER MONITORING

To simplify the presentation, we first consider the case with *very local* peer monitoring, $z = 1$. The polar cases with $z = 0$ (no peer monitoring) and $z \geq n - 1$ (global peer monitoring) are considered in Section 5.

Our main result is that even with very local peer monitoring, firms achieve higher profits by pooling reputations when the discount factor is sufficiently close to 1.[25]

**Proposition 1** *For each set of values* $\Delta / \sigma$ *and* $\tau$ *, there exists a threshold discount factor* $\hat{\delta} < 1$ *such that for all* $\delta \geq \hat{\delta}$ *, collective branding is optimal, i.e.* $n^* > 1$ *.*

When the future is sufficiently important, there exists a group in which peer punishment is credible and collective public punishment can be softened relative to individual public punishment. In particular, we consider a group with $n = \lfloor (\frac{\sigma}{\Delta} k_1)^2 \rfloor$ members and a cut-off point of the public signal $\widetilde{k} = k_1$, which is the optimal cut-off point under an individual brand that solves equation (11). The proof consists of showing that for a sufficiently large discount factor, the incentive compatibility constraints (6)–(8) are satisfied for the chosen values of $n$ and $\widetilde{k}$, which implies that there exists an equilibrium with collective branding in which collective public punishment is triggered less frequently relative to the equilibrium with individual public punishment.

Consider first the no-shirking constraint in (6). This constraint may be difficult to satisfy when the unraveling of cooperation (as more firms find out that other firms have started shirking) takes many periods, because $n \approx (\frac{\sigma}{\Delta} k_1)^2 \to \infty$ for $\delta \to 1$. This tends to reduce the threat of peer punishment, as a large share of firms will not know about the ongoing shirking for a long time. Nonetheless, given our choices of the size of the group $n$ and the cut-off point $\widetilde{k}$, peer punishment will eventually reduce the continuation probability enough to offset the long time it takes before a large fraction of members start shirking. To see why, note that the long-run continuation probability during the peer punishment phase (that is, when all firms shirk) is given by $1 - \Phi(\widetilde{k} + \frac{\sqrt{n}\Delta}{\sigma}) \approx 1 - \Phi(0) = \frac{1}{2}$. This number is significantly less than the continuation probability in the best equilibrium under individual reputation with a single shirking firm, because $1 - \Phi(k_1 + \frac{\Delta}{\sigma}) \to 1$ as $\delta \to 1$.[26]

Second, we need to verify that the upward deviation (that is, credibility) constraints in (7) and (8) hold. An asymmetry between the no-shirking and peer sanction credibility constraints is worth pointing out: When a firm contemplates shirking for the first time, it believes that it will trigger a peer punishment phase. However, during a peer punishment phase, each firm has a relatively smaller impact on the behavior of the other firms, because the (out-of-equilibrium) shirking is believed to be irreversible, as no firm can unilaterally prevent the punishment phase from evolving (beyond slowing it down). So, as the group becomes larger, each member has less individual impact on the evolution of the punishment phase, and thus the credibility constraints are easier to satisfy. Given our choice of $n$, an increase in $\delta$ affects both the importance of the future rents, which makes the credibility constraints more difficult to satisfy, and the size of the group, which makes the credibility constraints easier to satisfy. Yet, even as $\delta \to 1$,

[25] Because we assume that each firm observes the effort choices of at most *two* other firms, $n^*$ takes only odd values. A deviating firm triggers a more severe punishment when two other firms start deviating rather than one. When $n > 1$ is odd, each deviating firm is, in fact, punished by two other firms during the beginning of the peer punishment phase. When $n$ is even, some firms expect to cause just one more firm to switch to low effort during the unfolding of the peer punishment phase.

[26] As shown in the CO model, in equilibrium and with individual reputation, the firm's continuation payoff is the same whether or not it shirks, because the no-shirking incentive compatibility constraint binds.

the size effect dominates, because the individual effort's impact on the continuation probability is temporary and vanishingly small, since $\frac{1}{n} \approx (\frac{\sigma}{\Delta} k_1)^{-2} \to 0$.

However, just as a group that is too small may not generate a threat of collective shirking that deters individual shirking more effectively than individual public punishment, a group that is too large can also weaken the threat of collective shirking. Even though collective shirking is easier to detect in larger groups, the threat of triggering peer punishment fades when shirking takes too long to spread among firms. In fact, we next demonstrate that too many members cannot sustain collective reputation of high quality.

**Proposition 2** *For each set of values $\delta$, $\Delta/\sigma$, $\tau$, the optimal size $n^*$ is finite.*

Proposition 2 shows that the reputation-by-cooperation equilibrium may exist only if the number of firms is not too great.[27] As the case with global peer monitoring in Section 5 makes clear, the *bigger, the better* result does not hold, because private monitoring among the members of the group is local, since, by assumption, each firm only observes choices of its nearest neighbors. Thus, the disadvantage of a large group is that a member that contemplates shirking anticipates that it will take a long time before many of the more distant firms realize that cooperation is unraveling. Since the future payoffs are discounted, the threat of collective shirking evaporates when the number of firms in the group is too large, because individual shirking will effectively be unnoticed by too many members for too many periods.[28]

### Comparative Statics

Next we will investigate how the optimal group size and reputation depend on the parameters of the model. We show that $n^*$ (weakly) and $1-\Phi(k_{n^*})$ increase in $\delta$ and $\Delta/\sigma$ but decrease in $\tau$ for sufficiently small values of $n^*$ and large values of $\tau$. When the cost savings from shirking are large relative to the quality premium—that is, when $\tau = \frac{c_h - c_l}{p - c_h}$ is large—the credibility constraints (7) and (8) are easily satisfied, unlike the no-shirking constraint (6).[29] Thus, for sufficiently large $\tau$ at optimum with a positive average payoff, two conditions must hold: (a) the no-shirking constraint (6) binds; and (b) all else equal, either group expansion or contraction increases the average payoff from shirking (which makes the no-shirking constraint more difficult to satisfy). In addition, note that the (out-of-equilibrium) full unraveling of the reputation-by-cooperation equilibrium takes at most $\frac{1}{2z} n^*$ periods, though it may unravel sooner if the public signal falls below the cut-off point. Thus, the average payoff in the beginning of the peer punishment phase $\pi_{n^*,1}$ is easier to calculate for small $n^*$ because it converges to its stationary value after only a few periods.

**Proposition 3** *The optimal size $n^*$ is nondecreasing and the cut-offpoint $k_{n^*}$ is decreasing in $\delta$ and $\Delta/\sigma$; $n^*$ is nonincreasing and $k_{n^*}$ is increasing in $\tau$ for sufficiently large $\tau$ and small $n^*$.*

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[27] That is, for sufficiently large $n$, the unique perfect equilibrium is the repetition of (*Don't Buy*, *Low*) in every period.

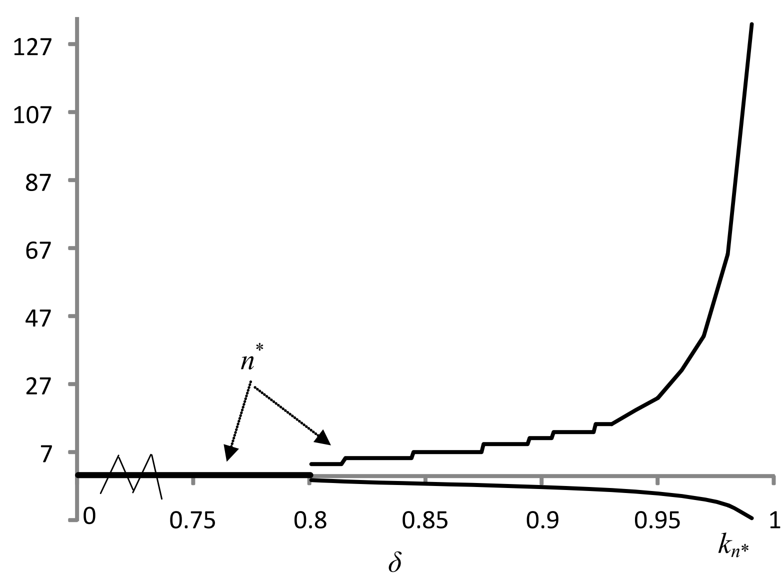
[28] Fishman et al. (2010) do not obtain the *bigger, the better* result, because in their model the marginal contribution of an individual member's investment to the brand's reputation becomes too small to compensate for the incentive to free ride when the number of firms in the group is too large.

[29] It is possible that (7) rather than (6) binds in equilibrium. For example, for $\tau = 0.8$, $\delta = 0.67$ ,and $\Delta/\sigma = 4$, the optimal number of firms is $n^* = 3$, the optimal cutoff point is $k_{n^*} = -5.0913$, and the shirking (credibility) constraint (7) binds.

Consider the advantages and disadvantages of increasing the group's size when the no-shirking constraint (6) binds. The benefit of adding a member to the group is that collective shirking is easier for consumers to detect because signal (1) becomes less noisy, which makes peer sanction a more powerful deterrent. The costs of adding a member to the group are twofold: (a) the consequences of individual shirking appear less severe as the reputation-by-cooperation equilibrium unravels more slowly; and (b) the continuation probability, when all else is equal, is less sensitive to individual shirking. As a result, peer sanction and public punishment become less powerful deterrents in the short run.

As the future becomes more important (or as trades occur more frequently), the no-shirking constraint (6) is easier to satisfy, and, keeping group size fixed, the cut-off point of the public signal can be reduced. In addition, the long-run benefits of expansion increase relative to the short-run costs of expansion, and the optimal size of the group increases, which allows for an even softer public punishment. The relationships among the discount factor, the optimal group size, and the cut-off point are depicted in Figure 4.1 (recall that $n^* = 0$ means that (*Don't Buy*, *Low*) is the unique equilibrium in every period).[30]

**Figure 4.1—Group size, cut-off point, and discount factor for $\tau = 1$ and $\Delta / \sigma = 1$**

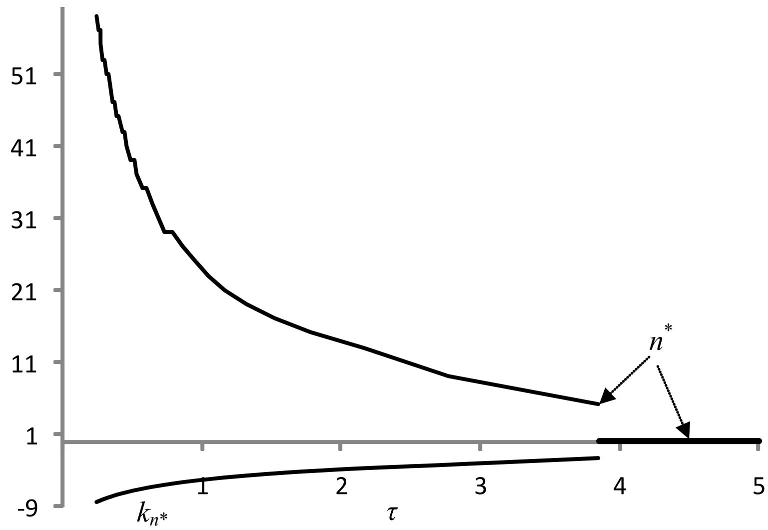



Source: Author's numerical analysis.

In the case of either a small decrease in the cost savings from shirking or an increase in the quality premium, the intuition is similar. As the ratio $\tau$ increases, constraint (6) is more difficult to satisfy, which necessitates a more severe public punishment—that is, a larger $k_{n^*}$. In addition, the long-run value of reputation (or the present value of expected quality premium) decreases relative to the one-time deviation gain. This, in turn, decreases the long-run marginal benefit of size (due to collective shirking) relative to its short-run marginal cost (due to slower unraveling of cooperation and less-conspicuous individual shirking), and the optimal group size falls (Figure 4.2).

[30] Plotting the survival probability $1 - \Phi(k_{n^*})$ is perhaps more intuitive. We plot $k_{n^*}$ instead because the survival probabilities are too close to 1 when $n^* > 1$.

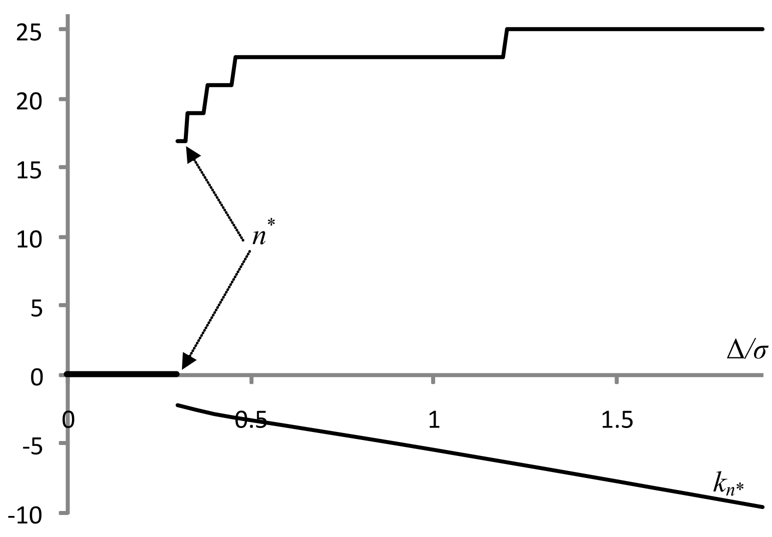
**Figure 4.2—Group size, cut-off point, and relative gain from shirking for $\delta = 0.95$ and $\Delta / \sigma = 1$**




Source: Author's numerical analysis.

A public signal that is more precise (higher $1/\sigma$) or more sensitive to an individual effort (higher $\Delta$) allows for a softer public punishment (lower $k_{n^*}$) because public monitoring is more accurate. A more informative public signal also raises the long-run benefit of adding another member, because collective shirking is more likely to lead to the public punishment phase. It also reduces the short-run costs of adding another member because, all else equal, the continuation probabilities during the unraveling of the peer punishment phase decrease and the sensitivity of the public signal to individual shirking increases. The effects of the informativeness of the public signal on the optimal cut-off point and group size are illustrated in Figure 4.3.

**Figure 4.3—Group size, cut-off point, and precision of public information for $\delta = 0.95$ and $\tau = 1$**




Source: Author's numerical analysis.

After inspecting Figures 4.1–4.3, it is worth noting that the optimal group size is considerably less sensitive to changes in the informativeness of the public signal in comparison with that for the other parameters (that is, the discount factor and the relative gain from shirking). This is explained by the customer information structure, whereby the effort (ex ante quality) is observed with additive (white Gaussian) noise with a thin-tail distribution. This property can be useful in an empirical application of our model because, as Figure 4.3 demonstrates, there is no need to precisely estimate $\Delta / \sigma$ as long as customers have enough information about firms' performance (for example, for $\delta = 0.95$ and $\tau = 1$, an equilibrium in which high quality is provided exists only if $\Delta / \sigma > 0.3$). For a reasonable range of the other parameters—$\delta \in (0.8, 0.99)$ and $\tau \in (0.3, 3.85)$—the optimal group size is between 3 and 133 members. However, if we further restrict the discount factor—$\delta \in (0.85, 0.95)$—and the relative gains from shirking—$\tau \in (0.3, 1)$—the optimal group size is between 7 and 51 members. These numerical examples indicate that for $z = 1$, producer groups that cannot rely on exclusion and external sanctions to punish shirkers must be rather small to be successful.

The analysis above applies to groups with local peer monitoring: each member observes and is observed by a small number of other members. We next investigate how the intragroup information structure affects the optimal number of firms in the group. Because the effect of a marginal increase in $z$ (the size of the neighborhoods in which firms observe one another's efforts) is somewhat cumbersome to evaluate, we proceed by investigating the extreme cases with no peer monitoring and with global peer monitoring.

## 5. INTRAGROUP INFORMATION

We now consider two polar intragroup information structures: no private information ( $z=0$ ) and perfect private information about all other members' effort choices ( $z \geq n-1$ ).

### No Peer Monitoring

For $n>1$ and $z=0$, firms have no private information about other firms' choices, and the effort strategy in (3) coincides with that under individual reputation in (10). Note that without peer monitoring, there are no implementable peer sanctions decoupled from the public punishment. Therefore, by (10), the no-shirking constraint (6) is simply given by

$$\pi_{n,0} = (1-\delta)(p-c_h) + \delta(1-\Phi(\widetilde{k}))\pi_{n,0} \geq (1-\delta)(p-c_l) + \delta(1-\Phi(\widetilde{k} + \tfrac{\Delta}{\sigma\sqrt{n}}))\pi_{n,0} \,. \qquad (12)$$

As before, in the equilibrium that maximizes the firms' average payoff, the cut-off point of the public signal $k_n$ is the smallest $\widetilde{k}$ such that the no-shirking constraint (12) holds. If there are no $\widetilde{k}$ such that (12) holds, then in equilibrium, (*Don't Buy, Low*) is played in every period, and $\pi_{n,0} = 0$.

**Proposition 4** *If firms do not observe one another's choices, then* $n^* \leq 1$.

Collective reputation that is not complemented by peer monitoring gives an opportunity to free ride on other members' efforts, and the incentive to free ride increases with the group's size, because the sensitivity of the public signal to the individual choice of effort diminishes with size at rate $\frac{\Delta}{\sigma\sqrt{n}}$. In the absence of peer monitoring, there is no upside to sharing a common reputation since firms can base their punishment only on the public signal. Because customers and firms have the same information about the overall effort, firms can do no better than exert high effort when customers are willing to buy and play (*Don't Buy*, *Low*) if they are not willing to buy at a price above $v_l$. Therefore, because of the incentive to free ride on common reputation, the no-shirking constraint is necessarily more difficult to satisfy, and the public punishment must be made harsher relative to that under individual reputation (that is, the cut-off point of the public signal must increase) in order to restore the members' incentive to exert high effort.

Hence, as long as firms do not have private information about each other, they can achieve a higher average payoff under individual branding than under collective branding in the cut-off trigger strategy equilibrium. In fact, using the technique in the CO model, it can be shown that in the absence of peer monitoring, a perfect public equilibrium that yields the highest average payoffs for a group of *n* firms is the trigger strategy equilibrium with the smallest cut-off point $k_n$ that satisfies the no-shirking constraint (12). Thus, an even stronger result is true that firms can achieve greater average payoffs under individual reputation than the highest payoff under collective reputation in any perfect public equilibrium without peer monitoring. Next we show that firms always benefit from collective reputation in a sufficiently large group, provided that each firm has perfect information about past choices of all the other firms in the group.

### Perfect Global Peer Monitoring

We now suppose that all firms observe one another's efforts, that is, $z \geq n-1$. In accordance with the effort strategy in (3), shirking is now subjected to maximally intense peer punishment with only a one-period delay.

**Proposition 5** *If* $\tau < \frac{\delta^2}{1-\delta^2}$ *and each firm observes past efforts of all other firms, then* $n^* \to \infty$.

Under perfect global peer monitoring, the information aggregation and peer monitoring effects dominate the free-riding effect in a sufficiently large group.[31] Peer punishment is *fast working* in the sense that there is just a one-period delay (due to the simultaneity of effort choices in the stage game) before all members start shirking collectively following a one-member deviation. In addition, as $n \to \infty$, peer punishment in equilibrium entails a nearly certain loss of customers' trust, because customers can easily detect collective shirking.

To understand condition $\tau < \frac{\delta^2}{1-\delta^2}$, let us rewrite it as $\frac{v_h - c_h}{1-\delta} > (v_h - c_l)(1+\delta)$. In this form, it says that the present value of the social surpluses over the infinite horizon (the maximum firm's payoff) is greater than the present value of the deviation gains today and tomorrow (the gain from shirking under perfect public monitoring with a two-period lag). Although in a large group that maintains trust with its customers and among its members, individual shirking has little effect on the public signal today, it is almost certain to cause the group to lose its reputation tomorrow. Therefore, the above condition is necessary for the no-shirking constraint (6) to be satisfied when $z \geq n-1$ and $n \to \infty$.

Furthermore, under perfect global peer monitoring, as $n \to \infty$, collective reputation allows firms to attain the average payoff of $v_h - c_h$, which is the highest attainable payoff under *perfect public* monitoring (that is, when the past effort choices are known not only to the firms but also to all customers). Therefore, in an equilibrium with collective reputation and trigger purchasing and effort strategies (2) and (3), a sufficiently large group of perfectly globally privately informed firms can achieve a higher average payoff than that in any other perfect equilibrium with fewer firms. To recap, propositions 4 and 5 demonstrate that the intragroup information structure plays a critical role in a group's ability to establish a good collective reputation and in determining the optimal group size.

Our comparative statics results generate empirically testable hypotheses about the relationship between participation in collective brands such as GIs and characteristics of the product and producers. Even though the real-world structure of GIs is not necessarily optimal due to fixed natural boundaries and geography, data on long-lasting and successful GIs (that is, GIs that happen to apply to a group of producers with appropriate characteristics that enable building cooperation and trust) should still exhibit patterns predicted by our model. Propositions 3–5 suggest that the size of GIs should be greater when GI-labeled products are sold more frequently, when cost savings from providing low quality are smaller relative to price premium for high quality, and when producers who are entitled to use a GI label are more familiar with each other (including closer social ties, more cooperative culture, and geographical proximity).

[31] Che (2002) obtained a similar *the bigger, the better* result in a setting with group lending. In addition, Bernheim and Whinston (1990) showed that in the perfect monitoring setting, two firms may find it easier to collude if they interact in multiple markets. Matsushima (2001) considered the setting of imperfect monitoring and proved that two firms can approach perfect collusion when the number of market contacts goes to infinity.

## 6. ROBUSTNESS TO RENEGOTIATION

### Renegotiation between Customers and the Group

We assume that customers and firms do not try to renegotiate the implicit agreements to punish each other following a bad public signal. Recall that after the public signal falls below the cut-off point, the equilibrium strategies (2) and (3) call for Nash reversion (*Don't Buy*, *Low*) during the public punishment phase. However, this is not an efficient outcome, and both customers and the group of firms have a strong incentive to renegotiate their implicit (self-enforcing) agreement to play (*Don't Buy*, *Low*). The CO model demonstrates that in a single (horizontally integrated) firm, there exists an efficient renegotiation-proof equilibrium that replaces the infinite repetition of Nash reversion, with a temporary public punishment that consists of low prices offered by the firm until the public signal exceeds a certain threshold. This construction naturally extends to collective reputation and a group of firms, because the implicit contract between customers and the single firm in the CO model is identical to the implicit contract between customers and the group of firms in our model.

### Renegotiation among the Group Members

We also assumed that shirking by one firm triggers subsequent shirking by its neighbors forever afterward, and that this is the sequentially optimal response. However, firms that know that the unraveling of the reputation-by-cooperation equilibrium is underway (or is complete) will have a strong incentive to renegotiate their implicit (self-enforcing) agreement to shirk. To check whether the reputation-by-cooperation equilibrium is robust to renegotiation among firms during the peer punishment phase, we need to consider two cases.

Suppose that the no-shirking constraint (6) binds in equilibrium. Then, keeping the customers' strategy fixed, equilibrium is renegotiation-proof according to the criterion derived in Abreu, Pearce, and Stachetti (1993)—that is, there are no other self-enforcing agreements among firms that never give each shirker a lower continuation value after any history. This is because the no-shirking constraint (6) binds given that the firms anticipate the *worst* sequentially optimal punishment—shirking forever. Therefore, there can be no other subgame perfect equilibria in which customers follow the trigger strategy with the prescribed cut-off point, because the no-shirking constraint will necessarily not be satisfied.

However, if in the reputation-by-cooperation equilibrium, an upward deviation (credibility) constraint (7) binds, then the equilibrium is not renegotiation-proof according to that criterion. In this case, a weaker renegotiation-proof self-enforcing peer punishment can be constructed while satisfying the no-shirking constraint with the given cut-off point of the public signal. For example, a weaker peer punishment can be implemented using strategies that prescribe firms to shirk for a given number of periods and then to revert back to exerting high efforts.[32]

[32] Strategies with temporary punishment phases are used to construct equilibrium with imperfect public monitoring in Green and Porter (1984).

## 7. WELFARE AND POLICY IMPLICATIONS

Note that in the absence of institutions that provide legal protection for the right to use a GI label, such as the system of certification marks in the United States that certify the area of production (USPTO 2011), the entire industry (appropriately defined) can be thought of as a collective brand. Suppose there are $N \le M$ firms in the industry, where $M$ is the measure of the mass of consumers. The size of the industry is exogenously fixed (for example, due to a resource constraint), and peer monitoring is local—that is, $z = 1$. Consider a trigger-strategy equilibrium in which *N* firms participate in the collective brand, and the cut-off point is $k_N$ (which yields the highest payoff for firms when there are *N* firms in the group). In this equilibrium, the time-averaged (per period) social welfare is given by

$$W(k_N) = N\frac{(1-\delta)(v_h - c_h)}{1-\delta(1-\Phi(k_N))}.$$

The simplifying assumption that the firms set the price equal to the customers' willingness to pay and extract the entire surplus from trade implies that $W(k_N) = N\pi(k_N)$ and that maximizing the industry's profits also maximizes social welfare. Therefore, we can evaluate the effects of collective branding on equilibrium payoffs by comparing $\pi(k_N)$ and $\pi(k_{n^*})$, where we assume that $N/n^*$ (that is, the number of collective brands in the industry) is an integer. Because $k_N \ge k_{n^*}$, it must be that group branding increases firms' payoffs, since socially efficient trade lasts longer when there are several smaller collective brands (rather than one large collective brand with $n = N$). Thus, collective branding (weakly) increases welfare because

$$W(k_N) = N\pi(k_N) \le N\pi(k_{n^*}) = W(k_{n^*}).$$

Next we show that profit-maximizing collective brands also increase welfare when consumers retain some of the surplus from trade. For example, suppose that in addition to *N efficient* firms, the high-quality products are also competitively supplied by *inefficient* firms that use a costlier technology with the constant marginal cost $c_0 \in (c_h, v_h)$ and that can freely enter and exit the industry.[33] Our previous analysis remains unchanged except that now the efficient firms charge at most $p_{i,t} = c_0 < v_h$, so that the relative one-time gain from deviation $\tau_0 = \frac{c_h - c_l}{c_0 - c_h} > \frac{c_h - c_l}{v_h - c_h} = \tau$ increases. When the high-quality products are inelastically supplied at price $c_0$, the privately optimal group size is smaller—$n^*(\delta, \tau_0, \Delta/\sigma, z) \le n^*(\delta, \tau, \Delta/\sigma, z)$, where the inequality follows by Proposition 3. Again, for simplicity, we suppose that $N/n^*(\delta, \tau_0, \Delta/\sigma, z)$ is an integer and that there is a $k_N$ that satisfies (6)–(8) for $p = c_0$ and *n* = *N*. Because the alternative technology is costlier—that is, $c_0 > c_h$—the product is (initially) supplied by *N* efficient firms, and the remainder of the demand ($M - N$) is satisfied by the competitive fringe. The effect of collective branding on social welfare is still positive because

$$W(k_N) = N\frac{(1-\delta)(v_h - c_h) + \delta\Phi(k_N)(v_h - c_0)}{1-\delta(1-\Phi(k_N))} + (M - N)(v_h - c_0)$$

[33] The additional costs can be due to third-party monitoring and enforcement of compliance with a quality standard.

$$\leq N\frac{(1-\delta)(v_h-c_h)+\delta\Phi(k_{n^*})(v_h-c_0)}{1-\delta(1-\Phi(k_{n^*}))}+(M-N)(v_h-c_0)=W(k_{n^*})\,.$$

The inequality follows because the efficient firms (while group reputation is good) generate more social surplus than the inefficient firms do, and the efficient firms remain trustworthy and trade with customers longer when they can form smaller groups.

This result can be applied to GIs. Legal protection of the right to use a GI was debated during the recent rounds of multilateral trade negotiations (ERS 2011). One argument against the protection of GIs is that regional brands can make it easier to sustain a "quantity cartel" and reduce competition. In our model, less legal protection for the right to use a GI effectively amounts to an increase in the number of firms (as well as likely loss of "informational connectedness" among them) that participate in the collective brand and that share a common reputation. Thus, protection of GIs can raise welfare by making it easier for firms to maintain customers' trust, because peer monitoring is ineffective in a group that is too large or that lacks "informational connectedness." [34] Note that in our model, the mechanism through which GIs raise welfare is very different from the one based on fixed certification costs and groupwide economies of scale in Moschini, Menapace, and Pick (2008).

### Traceability and Food Scares

Although participation in GIs is voluntary, mandatory firm-level traceability *directly* affects producers' commitment to remain unknown to their customers and belong to the group, because producers with a history of low quality can now be punished by exclusion from the group. The threat of exclusion effectively puts customers *in charge* of punishing individual producers. It also makes it more difficult for groupwide norms that incentivize the provision of quality by prescribing collective shirking as a punishment for individual shirking. Therefore, in our setting, mandatory traceability may decrease welfare even without taking into account the direct costs of the policy's implementation (Golan et al. 2004).[35]

Our model has a lack of firm-level traceability within a group (for example, it is prohibitively costly to identify the member of the group that supplied a particular product after it is purchased and consumed), but intergroup traceability is perfect in that consumers can (at no cost) verify the identity of the group in which the product originated. Therefore, $\frac{1}{n}\in(0,1]$—the probability that a given product is supplied by firm $i$—measures the *degree of traceability* (in the sense that each product can be traced back to *n* potential firms of origin) in an industry with *N* firms and *N/n* collective brands.[36] Suppose that the industry cooperatively chooses the degree of traceability to maximize industrywide profits. We showed that in the industry with internal knowledge of production practices, *incomplete* traceability is optimal; in this case, there is perfect traceability at the group level but no firm-level traceability within the group of $n^*$ firms. Thus, a mandatory increase in the degree of traceability (up to firm-level traceability) from $1/n^*$ to $1/n$, for $1\leq n\leq n^*$, *decreases* both welfare and the incentives to increase the level of food safety:

$$W(k_n)\leq W(k_{n^*})\ \text{ for } 1\leq n\leq n^*,$$

because punishment of individual shirking by collective shirking is ineffective in a group that is too small.

---

[34] In a complementary contribution, Fishman et al. (2010) also showed that GIs and state trading enterprises can increase quality and welfare.

[35] Note that although there is no direct liability for low quality in our model, (noisy) exogenous punishment for shirking will not qualitatively change our results. Pouliot and Sumner (2008) studied a model in which producers are liable for safety lapses and found that a greater degree of traceability increases producers' incentives to provide a high level of food safety.

[36] Pouloit and Sumner (2009) modeled the degree of traceability as the probability of identifying the firm of origin of a particular product. Note that individual (firm-level) brands cannot differentiate firms with good and bad reputation as long as buyers cannot ex post relate their consumption experience with the product to its firm of origin.

Furthermore, the model explains why a frequently observed long-lasting decrease in demand and a loss of public confidence in the industry following the news of isolated incidents of food contamination (so called *food scares*) may, in fact, be efficient.[37] Suppose the parameters are such that the industry's profits are maximized when all firms participate in a single collective (industry) brand—that is, $k_N \leq k_n$ for all $n \leq N$. In our model, food scares are consistent with an equilibrium response of consumers when the public signal falls below the cut-off point because one firm in the group performed very poorly. This happens when $e_h + \varepsilon_{i,t}$ is very low (an isolated food safety incident) for firm $i$ and when $e_h + \varepsilon_{j,t}$ are high (no food safety problems) for the other firms $j \neq i$. The intuition is that such food scares (that is, the loss of customers' trust in the entire industry due to an ex post bad performance by one member) are efficient because they also *scare* producers and sustain industrywide norms of compliance. Producers who are peer monitored and anticipate a long-lasting loss of reputation as a result of a single food safety incident anywhere in the industry provide safety not only to retain customers but also to convince other producers that they are willing to cooperate with them in earning and maintaining customers' trust.

### Firm Size

Our model also contributes to the theory of the optimal firm size. A group of firms selling products under the umbrella of a collective brand can be seen as an extreme case of a horizontally integrated firm with decentralized management of its branches and affiliates. (As before, we ignore any direct linkages across branches and economies of scale.) With this interpretation of our model, it is worth noting that our comparative statics results are the *opposite* of those in the CO model of the firm's reputation. In the CO model, the degree of horizontal integration (that is, the firm's size) is *smaller* when (1) the future is more important and information is disseminated more rapidly, or (2) the deviation gain is smaller relative to the reputation premium, or (3) the customer's information about firms' quality choices is more precise. The difference in the comparative statics is explained by the different mechanisms through which size affects the cost of maintaining trust under horizontal integration (one owner) and collective branding (many owners). In the CO model, although there is no free-riding problem, it is difficult for customers to punish partial deviations by a large firm that maintains high overall quality while offering low quality to a subset of customers. In our model, the threat of a breakdown in cooperation curbs free riding; however, it can do so only in a group (that is, a firm with decentralized management) of an appropriate size.

Our findings suggest that peer monitoring can align the interests of independent firms and substitute for horizontal integration. Combining our results with those of the CO model generates an empirically testable hypothesis: All else equal, branch managers should be more independent in large firms that trade more frequently, that are subject to more public scrutiny, and whose reputation premiums are greater relative to the cost savings from shirking.

[37] There are many examples of food scares involving eggs, fresh produce, peanuts, pistachios, pet food, and dairy—as well as scares related to nonagricultural products such as toys and drywall—in which isolated safety incidents affected sales of the entire industry (Pouliot and Sumner 2009). Furthermore, some empirical evidence suggests that the effect of food scares on consumption persists after the source of contamination has been identified and media coverage has declined (Mazzocchi 2006).

# 8. CONCLUSION

In this paper, we analyzed a simple model of collective reputation in which customers have imperfect information about the overall choice of effort and in which firms perfectly observe choices of (possibly just a few) other firms in the group. The model contributes to the theory of the firm, and we used it to study the optimal number of firms in the collective brand and to derive comparative statics results that can be empirically tested against the real-world patterns of geographic-origin labeling. Our analysis explains how local social norms can help sustain the reputation of regional products, as well as why food scares may be a necessary disciplining device. We also show that an assessment of welfare effects of GIs and traceability in value chains with multiple upstream suppliers should take into account intragroup behavior.

The advantage of collective reputation that is sustained by groupwide social norms, rather than by a minimum quality standard enforced by external auditing, is that it relies on the private information of group members and does not require additional expenditures on the monitoring of compliance (Borgen 2001; Lyon and Porter 2009).[38] The disadvantage is that such a "quality cartel" is sustainable only if certain conditions are met. Both group characteristics, such as size and internal structure, and producer and market characteristics, such as frequency of trades, customer information, quality premium, and production costs, may influence the group's ability to achieve a reputation for high quality using trigger strategies and the end of trust within the group as a punishment for individual shirking.

Our model suggests how verification costs that involve a variable cost of monitoring compliance (which increases with output) and a fixed cost of quality certification (which is independent of aggregate output) may determine the size and nature of a group that represents the cost-minimizing arrangement (Moschini, Menapace, and Pick 2008). On the one hand, a small group, in which members are *close* to each other, can use peer monitoring to save on external inspection and enforcement costs. The disadvantage of a small group is that the fixed certification costs are spread over fewer members. On the other hand, a large group can spread the fixed certification costs over a large base. The disadvantage of a large group is that it cannot rely on social norms when there is too little familiarity and interaction among its members, and it needs to incur the full cost of external auditing in order to signal quality.

For example, many industry food safety programs, such as Leafy Greens Marketing Agreement, rely on third-party inspections and explicit punishments for shirking (LGMA 2011).[39] Their diverse memberships likely make it difficult to sustain group norms, and the large fixed costs of credible certification (which includes expertise in food safety practices) give rise to significant economies of scale (Hardesty and Kusunose 2009). On the other hand, small farmer groups (studied in Moustier et al. 2010) are efficient, because quality requirements are group specific and internal inspections offer a cheap way of monitoring quality when members are similar and are located in close proximity to each other.

For tractability, we made a restrictive assumption that firms have perfect (local) private information about other firms. A more realistic and natural assumption is that firms' observations of the choices and product quality of other firms in a group are noisy but perhaps less so than that of their customers. Although infinitely repeated games with imperfect private monitoring lack a tractable recursive structure (see, for example, Kandori 2002), some conditions under which a combination of noisy collective public punishment and peer sanctions is superior to a noisy individual public punishment can perhaps be identified. Our model can also be extended in a number of other ways, such as allowing for heterogeneous costs and firm sizes, asymmetric informational linkages, endogenous peer monitoring effort, imperfect traceability, punishment by member exclusion, and simultaneous use of both individual and collective brands to establish a reputation for quality. These extensions and empirical studies that structurally estimate determinants of collective reputation in a model with Bayesian learning, such as the one analyzed in this paper, await future research.

[38] Minimum quality standards and exclusion for noncompliance in agricultural cooperatives have been discussed in Babcock and Weninger (2004), Hirschauer and Musshoff (2007), and Fatas, Jimenez-Jimenez, and Morales (2010).

[39] We are thankful to an anonymous reviewer for pointing this out.

## APPENDIX: PROOFS OF PROPOSITIONS

To simplify notation, we let $\overline{\Phi} = 1 - \Phi$ .

### Proof of Proposition 1

We start by showing that the incentive compatibility constraints (6)–(8) are satisfied when $n = \lfloor (\frac{\sigma}{\Delta} k_1)^2 \rfloor$ and $\tilde{k} = k_1$ for sufficiently large $\delta$ . First, we verify the no-shirking constraint (6). In order to show that condition (6), that compares the payoff from cooperating and choosing high effort with the payoff from shirking, holds it will be convenient to bound the payoff from shirking and starting the peer punishment phase as follows:

$$
\begin{aligned}
\pi_{n,1} &= (1-\delta)(v_h - c_l) + \sum_{t=1}^{\infty} \delta^t \prod_{s=0}^{t} \overline{\Phi}(\tilde{k} + \min[1+2s, n]\tfrac{\Delta}{\sigma\sqrt{n}})(1-\delta)(v_h - c_l) \qquad \text{(A1)} \\
&< (1-\delta)(v_h - c_l)(1 + \sum_{t=0}^{\lceil (n-2)/2 \rceil} \delta^{t+1} \prod_{s=0}^{t} \overline{\Phi}(\tilde{k}) + \delta^{\lfloor (n-1)/2 \rfloor} ( \prod_{s=0}^{\lceil (n-2)/2 \rceil} \overline{\Phi}(\tilde{k})) \frac{\delta \overline{\Phi}(\tilde{k} + \sqrt{n}\,\frac{\Delta}{\sigma})}{1 - \delta \overline{\Phi}(\tilde{k} + \sqrt{n}\,\frac{\Delta}{\sigma})}) \\
&= \frac{(1-\delta)(v_h - c_l)}{1 - \delta \overline{\Phi}(\tilde{k})} (1 - (\delta \overline{\Phi}(\tilde{k}))^{\lfloor (n-1)/2 \rfloor} (1 - \frac{\delta \overline{\Phi}(\tilde{k} + \sqrt{n}\,\frac{\Delta}{\sigma})}{1 - \delta \overline{\Phi}(\tilde{k} + \sqrt{n}\,\frac{\Delta}{\sigma})})) .
\end{aligned}
$$

Substituting $n = (\frac{\sigma}{\Delta} k_1)^2$ (and treating $n$ as a continuous variable) and $\tilde{k} = k_1$ and using (A1), the no-shirking constraint (6) assuredly holds if

$$
\frac{(1-\delta)(v_h - c_h)}{1 - \delta \overline{\Phi}(k_1)} \geq \frac{(1-\delta)(v_h - c_l)}{1 - \delta \overline{\Phi}(k_1)} (1 - (\delta \overline{\Phi}(k_1))^{\lfloor ((\frac{\sigma}{\Delta} k_1)^2 - 1)/2 \rfloor} (1 - \frac{\delta(1 - \delta \overline{\Phi}(k_1))}{2 - \delta})) \text{, or}
$$

$$
\frac{1}{1+\tau} \geq 1 - (\delta \overline{\Phi}(k_1))^{\lfloor ((\frac{\sigma}{\Delta} k_1)^2 - 1)/2 \rfloor} (1 - \frac{\delta(1 - \delta \overline{\Phi}(k_1))}{2 - \delta}),
$$

where $\overline{\Phi}(\tilde{k} + \sqrt{n}\,\frac{\Delta}{\sigma}) = \overline{\Phi}(k_1 + \sqrt{(\frac{\sigma}{\Delta} k_1)^2}\,\frac{\Delta}{\sigma}) = \overline{\Phi}(k_1 - k_1) = \frac{1}{2}$ is used to obtain the first inequality. The last inequality must hold for sufficiently large $\delta$ because taking the limit as $\delta \to 1$ , the right side converges to 0. To see why, note that by equation (11) that determines the optimal cut-offpoint for $n = 1$ , we have

$$
\lim_{\delta \to 1} \delta \overline{\Phi}(k_1) = 1 \text{ and}
$$

$$
\lim_{\delta \to 1} (\delta \overline{\Phi}(k_1))^{\lfloor ((\frac{\sigma}{\Delta} k_1)^2 - 1)/2 \rfloor} = 1 .
$$

The last equality can be verified, again using (11), as follows:

$$
\begin{aligned}
\lim_{\delta \to 1} \ln((\delta \overline{\Phi}(k_1))^{\frac{1}{2}(\frac{\sigma}{\Delta} k_1)^2}) &= \lim_{\delta \to 1} \tfrac{1}{2} \frac{\ln(\delta \overline{\Phi}(k_1))}{(\frac{\sigma}{\Delta} k_1)^{-2}} = -\lim_{\delta \to 1} \tfrac{1}{4} (\tfrac{\sigma}{\Delta})^2 \frac{\frac{d\delta}{dk_1} - \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}k_1^2}}{k_1^{-3}} \\
&= \lim_{k_1 \to -\infty} \frac{1}{4} (\tfrac{\sigma}{\Delta})^2 \tfrac{1}{\sqrt{2\pi}} \frac{\frac{v_h - c_h}{c_h - c_l} e^{-\frac{1}{2}(k_1 + \Delta/\sigma)^2} - \frac{v_h - c_l}{c_h - c_l} e^{-\frac{1}{2}k_1^2} + e^{-\frac{1}{2}k_1^2}}{k_1^{-3}}
\end{aligned}
$$

$$= \lim_{k_1 \to -\infty} \frac{1}{4} (\tfrac{\sigma}{\Delta})^2 \, \tfrac{1}{\sqrt{2\pi}} \, \tfrac{v_h - c_h}{c_h - c_l} \, \frac{e^{-\frac{1}{2}(k_1 + \Delta/\sigma)^2} - e^{-\frac{1}{2}k_1^2}}{k_1^{-3}} = 0\,,$$

where we applied l'Hôpital's rule to obtain the second equality, treating the optimal cut-off point under individual reputation $k_1$ as a function of the discount factor $\delta$, and where we implicitly differentiated the binding incentive compatibility constraint (11) to find its derivative $dk_1 / d\delta$ and to obtain the third equality.

Second, we verify the upward deviation (the credibility of peer punishment) constraints (7) and (8). Note that (8) is implied by (7), because the average payoff of a firm that shirks during the peer punishment phase $\pi_{n,m}$ decreases with the number of shirkers $m$. Therefore, we only need to verify that the constraints in (7) are satisfied. Let us rewrite (7) as follows:

$$\sum_{t=0}^{\infty} \delta^{t+1} \Big(\prod_{s=0}^{t} \overline{\Phi}(\widetilde{k} + \min[m-1+2s, n]\tfrac{\Delta}{\sigma\sqrt{n}}) - \prod_{s=0}^{t} \overline{\Phi}(\widetilde{k} + \min[m+2s, n]\tfrac{\Delta}{\sigma\sqrt{n}})\Big) \le \frac{\tau}{1+\tau} \quad \text{(A2)}$$

for $m = \min[3, n], ..., n$. Substituting $n = (\frac{\sigma}{\Delta} k_1)^2$ and $\widetilde{k} = k_1$, the inequalities in (A2) become

$$\sum_{t=0}^{\lfloor ((\frac{\sigma}{\Delta}k_1)^2 - m)/2 \rfloor} \delta^{t+1} \Big(\prod_{s=0}^{t} \overline{\Phi}(k_1 - \tfrac{(m-1+2s)\Delta^2}{\sigma^2 k_1}) - \prod_{s=0}^{t} \overline{\Phi}(k_1 - \tfrac{(m+2s)\Delta^2}{\sigma^2 k_1})\Big)$$

$$+ \delta^{\lfloor ((\frac{\sigma}{\Delta}k_1)^2 - m)/2 \rfloor + 1} \Big( \prod_{s=0}^{\lfloor ((\frac{\sigma}{\Delta}k_1)^2 - m)/2 \rfloor} \overline{\Phi}(k_1 - \tfrac{(m-1+2s)\Delta^2}{\sigma^2 k_1}) - \prod_{s=0}^{\lfloor ((\frac{\sigma}{\Delta}k_1)^2 - m)/2 \rfloor} \overline{\Phi}(k_1 - \tfrac{(m+2s)\Delta^2}{\sigma^2 k_1})\Big) \frac{\delta}{2-\delta} \le \frac{\tau}{1+\tau}\,.$$

But the left side converges to 0 as $\delta \to 1$ for each $m = \min[3, n], ..., n$.

Hence, continuity implies that there exists an optimal cut-off point of the public signal $k_n < k_1$ such that the incentive compatibility constraints (6)–(8) are satisfied for $n = \lfloor (\frac{\sigma}{\Delta} k_1)^2 \rfloor > 1$ and $\widetilde{k} = k_n$. Therefore, sharing a common reputation is optimal, that is, $n^* > 1$, for all sufficiently large $\delta < 1$.

*Q.E.D.*

### Proof of Proposition 2

It suffices to show that the no-shirking constraint (6) cannot hold for sufficiently large $n$—that is,

$$\lim_{n\to\infty} \sum_{t=0}^{\infty} \delta^{t+1} \Big(\prod_{s=0}^{t} \overline{\Phi}(\widetilde{k}) - (1+\tau) \prod_{s=0}^{t} \overline{\Phi}(\widetilde{k} + \min[1+2s, n]\tfrac{\Delta}{\sigma\sqrt{n}})\Big) - \tau = -\frac{\tau}{1 - \delta\overline{\Phi}(\widetilde{k})} < 0 \text{ for all } \widetilde{k}\,.$$

*Q.E.D.*

The following well-known property of single-crossing functions will be useful in the proof of Proposition 3.

**Lemma** Suppose that (a) function $g(t)$, $t = 0,1,2,...$, is single-crossing—that is, if $g(t) \ge 0$, then $g(t') > 0$ for all $t' > t$; and (b) $\sum_{t=0}^{\infty} \delta^t g(t) = 0$. Then $d(\sum_{t=0}^{\infty} \delta^t g(t)) / d\delta > 0$.

### Proof of Lemma

Conditions (a) and (b) imply that there exists $\hat{t} \geq 1$ such that $g(t) \leq 0$ for all $t = 0,1,...,\hat{t}$ and $g(t) > 0$ for all $t = \hat{t}+1, \hat{t}+2,...$. So, we have

$$\frac{d(\sum_{t=1}^{\infty} t\delta^{t-1} g(t))}{d\delta} = \sum_{t=1}^{\infty} t\delta^{t-1} g(t) > \hat{t} \sum_{t=0}^{\infty} \delta^{t} g(t) = 0 .$$

*Q.E.D.*

### Proof of Proposition 3

By (9), the group size that maximizes the reputation-by-cooperation equilibrium payoff $\pi_{n,0}$ also minimizes $k_n$—that is, it solves the following problem:

$$\min_{n \geq 2} \widetilde{k} \text{ s.t. (6)–(8).} \tag{A3}$$

As was pointed out earlier, (8) is implied by (7). Also, note that (6) can be rewritten as

$$(1-\delta\overline{\Phi}(\widetilde{k}))(1+\sum_{t=0}^{\infty}\delta^{t+1}\prod_{s=0}^{t}\overline{\Phi}(\widetilde{k}+\min[1+2s,n]\tfrac{\Delta}{\sigma\sqrt{n}}) \leq \frac{1}{1+\tau} . \tag{A4}$$

Because the right side of (A2) is increasing in $\tau$ and the right side of (A4) is decreasing in $\tau$, it must be that only (A4) binds at optimum for sufficiently large values of $\tau$.

To proceed, it will be convenient to let

$$f(t,k,n;\tau,\Delta/\sigma) = \frac{1}{1+\tau}\overline{\Phi}(k)^{t+1} - \prod_{s=0}^{t}\overline{\Phi}(k+\min[1+2s,n]\tfrac{\Delta}{\sigma\sqrt{n}}) \text{ and} \tag{A5}$$

$$G(k,n;\delta,\tau,\Delta/\sigma) = -\frac{\tau}{1+\tau} + \sum_{t=0}^{\infty}\delta^{t+1} f(t,k,n;\tau,\Delta/\sigma) , \tag{A6}$$

so that the incentive compatibility constraint (6) can be rewritten as $G(k,n;\delta,\tau,\Delta/\sigma) \geq 0$, and (A3) can be rewritten as

$$\min_{n} k \text{ subject to } G(k,n;\delta,\tau,\Delta/\sigma) = 0 ,$$

because by assumption, constraints (7) and (8) do not bind. We ignore the integer constraint and treat $n^*$ as a continuous variable. Then the optimality conditions for problem (A3) become

$$G(k_{n^*}, n^*;\delta,\tau,\Delta/\sigma) = 0 \text{ and} \tag{A7a}$$

$$G_n(k_{n^*}, n^*;\delta,\tau,\Delta/\sigma) = 0 , \tag{A7b}$$

where $k_{n^*}$ is the smallest root of equation (A7a) and the subscripts on function *G* denote its partial derivatives. Implicitly differentiating the system of equations (A7) yields

$$\frac{dn^*}{da} = \frac{G_{nk}G_a - G_k G_{na}}{G_k G_{nn}} \text{ and} \tag{A8a}$$

$$\frac{dk_{n^*}}{d\delta} = -\frac{G_a}{G_k} \tag{A8b}$$

where $a = \delta, \Delta/\sigma, \tau$, and we omit the arguments of function *G* to simplify notation. Next we determine the sign of $dn^*/d\delta$ and $dk_{n^*}/d\delta$ by signing each term on the right sides of (A8) separately.[40]

Note that the function $f(t, k_{n^*}, n^*; \tau, \Delta/\sigma)$ is single-crossing in $t$ because $\overline{\Phi}(k_{n^*}) > \overline{\Phi}(k_{n^*} + \min[1+2s, n^*]\frac{\Delta}{\sigma\sqrt{n^*}})$ for all $s \geq 0$. Therefore, by Lemma and (A7a), it follows that $G_\delta(k_{n^*}, n^*; \delta, \tau, \Delta/\sigma) > 0$. Also, it must be that at optimum, $G_k(k_{n^*}, n^*; \delta, \tau, \Delta/\sigma) > 0$ because $k_{n^*}$ is the smallest root of $G(k_{n^*}, n^*; \delta, \tau, \Delta/\sigma) = 0$ and $G(\infty, n^*; \delta, \tau, \Delta/\sigma) < 0$. This allows us to sign $dk_{n^*}/d\delta < 0$.

In order to sign $G_{n\delta}(k_{n^*}, n^*; \delta, \tau, \Delta/\sigma)$, we first note that the continuation probabilities during the beginning of the peer punishment phase, $\prod_{s=0}^{t}\overline{\Phi}(k_{n^*} + \frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})$, are increasing in $n$, that is,

$$\frac{\partial \prod_{s=0}^{t}\overline{\Phi}(k_{n^*} + \frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})}{\partial n} = \sum_{s=0}^{t}\left(\frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*} + \frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2} \frac{(1+2s)\Delta}{2\sigma(n^*)^{3/2}} \prod_{\substack{x=0 \\ x\neq s}}^{t}\overline{\Phi}(k_{n^*} + \frac{(1+2x)\Delta}{\sigma\sqrt{n^*}})\right) > 0$$

for all $t \leq \frac{n^*-2}{2}$. In addition, note that differentiating the long-run continuation probabilities during the peer punishment phase yields

$$\begin{aligned}
&\frac{\partial \prod_{s=0}^{t}\overline{\Phi}(k_{n^*} + \min[1+2s, n^*]\frac{\Delta}{\sigma\sqrt{n^*}})}{\partial n} \\
&= \sum_{s=0}^{\lceil \frac{n^*}{2} \rceil - 1}\left(\frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*} + \frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2} \frac{(1+2s)\Delta}{2\sigma(n^*)^{3/2}} \prod_{\substack{x=0 \\ x\neq s}}^{\lceil \frac{n^*}{2} \rceil - 1}\overline{\Phi}(k_{n^*} + \frac{(1+2x)\Delta}{\sigma\sqrt{n^*}})\right)\overline{\Phi}(k_{n^*} + \frac{\sqrt{n^*}\Delta}{\sigma})^{t - \lceil \frac{n^*}{2} \rceil + 1} \\
&- \prod_{s=0}^{\lceil \frac{n^*}{2} \rceil - 1}\overline{\Phi}(k_{n^*} + \frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})(t - \lceil \tfrac{n^*}{2} \rceil + 1)\overline{\Phi}(k_{n^*} + \frac{\sqrt{n^*}\Delta}{\sigma})^{t - \lceil \frac{n^*}{2} \rceil} \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*} + \frac{\sqrt{n^*}\Delta}{\sigma})^2} \frac{\Delta}{2\sigma\sqrt{n^*}}
\end{aligned}$$

[40] So the obtained comparative statics results hold more generally.

$$= \overline{\Phi}(k_{n^*} + \tfrac{\sqrt{n^*}\Delta}{\sigma})^{t-\lceil \frac{n^*}{2} \rceil} \{ \sum_{s=0}^{\lceil \frac{n^*}{2} \rceil -1} (\tfrac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*} + \frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2} \tfrac{(1+2s)\Delta}{2\sigma(n^*)^{3/2}} \prod_{\substack{x=0 \\ x\neq s}}^{\lceil \frac{n^*}{2} \rceil -1} \overline{\Phi}(k_{n^*} + \tfrac{(1+2x)\Delta}{\sigma\sqrt{n^*}})) \overline{\Phi}(k_{n^*} + \tfrac{\sqrt{n^*}\Delta}{\sigma})$$

$$- (t - \lceil \tfrac{n^*}{2} \rceil + 1) \prod_{s=0}^{\lceil \frac{n^*}{2} \rceil -1} \overline{\Phi}(k_{n^*} + \tfrac{(1+2s)\Delta}{\sigma\sqrt{n^*}}) \tfrac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*} + \frac{\sqrt{n^*}\Delta}{\sigma})^2} \tfrac{\Delta}{2\sigma\sqrt{n^*}} \}$$

for all $t > \frac{n^*}{2} - 1$. Because the second term in the brackets (in the last line) is decreasing in $t$, there must exist $\hat{t} > \frac{n^*}{2} - 1$ such that

$$\frac{\partial \prod_{s=0}^{t} \overline{\Phi}(k_{n^*} + \min[1+2s, n^*] \frac{\Delta}{\sigma\sqrt{n^*}})}{\partial n} < 0 \text{ if and only if } t \geq \hat{t}.$$

So, $-\dfrac{\partial \prod_{s=0}^{t} \overline{\Phi}(k_{n^*} + \min[1+2s, n^*] \frac{\Delta}{\sigma\sqrt{n^*}})}{\partial n}$ is a single-crossing function of $t$. From Lemma and (A7b), it follows that $G_{n\delta}(k_{n^*}, n^*; \delta, \tau, \Delta/\sigma) > 0$.

To sign $G_{nk}(k_{n^*}, n^*; \delta, \tau, \Delta/\sigma)$, we rewrite (A7b) more explicitly as

$$G_n = (- \sum_{t=0}^{\lceil \frac{n^*}{2} \rceil -1} \delta^{t+1} \sum_{s=0}^{t} (\tfrac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*} + \frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2} \tfrac{1+2s}{2(n^*)^{3/2}} \prod_{\substack{x=0 \\ x\neq s}}^{t} \overline{\Phi}(k_{n^*} + \tfrac{(1+2x)\Delta}{\sigma\sqrt{n^*}})) + \qquad \text{(A9)}$$

$$- \delta^{\lceil \frac{n^*}{2} \rceil} \sum_{s=0}^{\lceil \frac{n^*}{2} \rceil -1} (\tfrac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*} + \frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2} \tfrac{1+2s}{2(n^*)^{3/2}} \prod_{\substack{x=0 \\ x\neq s}}^{\lceil \frac{n^*}{2} \rceil -1} \overline{\Phi}(k_{n^*} + \tfrac{(1+2x)\Delta}{\sigma\sqrt{n^*}})) \frac{\delta\overline{\Phi}(k_{n^*} + \frac{\sqrt{n^*}\Delta}{\sigma})}{1 - \delta\overline{\Phi}(k_{n^*} + \frac{\sqrt{n^*}\Delta}{\sigma})}$$

$$+ \delta^{\lceil \frac{n^*}{2} \rceil} \prod_{s=0}^{\lceil \frac{n^*}{2} \rceil -1} \overline{\Phi}(k_{n^*} + \tfrac{(1+2s)\Delta}{\sigma\sqrt{n^*}}) \frac{\delta \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*} + \frac{\sqrt{n^*}\Delta}{\sigma})^2}}{(1 - \delta\overline{\Phi}(k_{n^*} + \frac{\sqrt{n^*}\Delta}{\sigma}))^2} \tfrac{1}{2\sqrt{n^*}}) \tfrac{\Delta}{\sigma} = 0.$$

Differentiating (A9) yields

$$G_{nk} = \sum_{t=0}^{\lceil \frac{n^*}{2} \rceil -1} \delta^{t+1} \sum_{s=0}^{t} (\tfrac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*} + \frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2} (k_{n^*} + \tfrac{(1+2s)\Delta}{\sigma\sqrt{n^*}}) \tfrac{(1+2s)\Delta}{2\sigma(n^*)^{3/2}} \prod_{\substack{x=0 \\ x\neq s}}^{t} \overline{\Phi}(k_{n^*} + \tfrac{(1+2x)\Delta}{\sigma\sqrt{n^*}}) + \qquad \text{(A10)}$$

$$+ \delta^{\lceil \frac{n^*}{2} \rceil} \sum_{s=0}^{\lceil \frac{n^*}{2} \rceil -1} (\tfrac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*} + \frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2} (k_{n^*} + \tfrac{(1+2s)\Delta}{\sigma\sqrt{n^*}}) \tfrac{(1+2s)\Delta}{2\sigma(n^*)^{3/2}} \prod_{\substack{x=0 \\ x\neq s}}^{\lceil \frac{n^*}{2} \rceil -1} \overline{\Phi}(k_{n^*} + \tfrac{(1+2x)\Delta}{\sigma\sqrt{n^*}})) \frac{\delta\overline{\Phi}(k_{n^*} + \frac{\sqrt{n^*}\Delta}{\sigma})}{1 - \delta\overline{\Phi}(k_{n^*} + \frac{\sqrt{n^*}\Delta}{\sigma})}$$

$$- \delta^{\lceil \frac{n^*}{2} \rceil} \prod_{s=0}^{\lceil \frac{n^*}{2} \rceil -1} \overline{\Phi}(k_{n^*} + \tfrac{(1+2s)\Delta}{\sigma\sqrt{n^*}}) \frac{\delta \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*} + \frac{\sqrt{n^*}\Delta}{\sigma})^2}}{(1 - \delta\overline{\Phi}(k_{n^*} + \frac{\sqrt{n^*}\Delta}{\sigma}))^2} \tfrac{\Delta}{2\sigma\sqrt{n^*}} (k_{n^*} + \tfrac{\sqrt{n^*}\Delta}{\sigma})$$

$$-\sum_{t=0}^{\lceil \frac{n^*}{2}\rceil-1}\delta^{t+1}\sum_{s=0}^{t}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}(k_{n^*}+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2}\frac{(1+2s)\Delta}{2\sigma(n^*)^{3/2}}\frac{\partial\prod_{\substack{x=0\\x\neq s}}^{t}\overline{\Phi}(k_{n^*}+\frac{(1+2x)\Delta}{\sigma\sqrt{n^*}})}{\partial k}$$

$$-\delta^{\lceil \frac{n^*}{2}\rceil}\sum_{s=0}^{\lceil \frac{n^*}{2}\rceil-1}\left(\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}(k_{n^*}+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2}\frac{(1+2s)\Delta}{2\sigma(n^*)^{3/2}}\frac{\partial\prod_{\substack{x=0\\x\neq s}}^{\lceil \frac{n^*}{2}\rceil-1}\overline{\Phi}(k_{n^*}+\frac{(1+2x)\Delta}{\sigma\sqrt{n^*}})}{\partial k}\right)\frac{\delta\overline{\Phi}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})}{1-\delta\overline{\Phi}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})}$$

$$+\delta^{\lceil \frac{n^*}{2}\rceil}\sum_{s=1}^{\lceil \frac{n^*}{2}\rceil-1}\left(\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}(k_{n^*}+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2}\frac{(1+2s)\Delta}{2\sigma(n^*)^{3/2}}\prod_{\substack{x=0\\x\neq s}}^{\lceil \frac{n^*}{2}\rceil-1}\overline{\Phi}(k_{n^*}+\frac{(1+2x)\Delta}{\sigma\sqrt{n^*}})\right)\frac{\delta\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})^2}}{(1-\delta\overline{\Phi}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma}))^2}$$

$$+\delta^{\lceil \frac{n^*}{2}\rceil}\frac{\partial\prod_{s=0}^{\lceil \frac{n^*}{2}\rceil-1}\overline{\Phi}(k_n+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})}{\partial k}\frac{\delta\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})^2}}{(1-\delta\overline{\Phi}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma}))^2}\frac{\Delta}{2\sigma\sqrt{n^*}}$$

$$-\delta^{\lceil \frac{n^*}{2}\rceil}\prod_{s=0}^{\lceil \frac{n^*}{2}\rceil-1}\overline{\Phi}(k_n+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})\frac{(\delta\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})^2})^2}{(1-\delta\overline{\Phi}(k_n+\frac{\sqrt{n^*}\Delta}{\sigma}))^3}\frac{\Delta}{\sigma\sqrt{n^*}}.$$

From (A9), it follows that the sum of the terms in the first three lines in (A10) is negative, because

$$\sum_{t=0}^{\lceil \frac{n^*}{2}\rceil-1}\delta^{t+1}\sum_{s=0}^{t}\left(\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}(k_{n^*}+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2}(k_{n^*}+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})\frac{(1+2s)\Delta}{2\sigma(n^*)^{3/2}}\prod_{\substack{x=0\\x\neq s}}^{t}\overline{\Phi}(k_{n^*}+\frac{(1+2x)\Delta}{\sigma\sqrt{n^*}})\right)+$$

$$+\delta^{\lceil \frac{n^*}{2}\rceil}\sum_{s=0}^{\lceil \frac{n^*}{2}\rceil-1}\left(\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}(k_{n^*}+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2}(k_{n^*}+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})\frac{(1+2s)\Delta}{2\sigma(n^*)^{3/2}}\prod_{\substack{x=0\\x\neq s}}^{\lceil \frac{n^*}{2}\rceil-1}\overline{\Phi}(k_{n^*}+\frac{(1+2x)\Delta}{\sigma\sqrt{n^*}})\right)\frac{\delta\overline{\Phi}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})}{1-\delta\overline{\Phi}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})}$$

$$-\delta^{\lceil \frac{n^*}{2}\rceil}\prod_{s=0}^{\lceil \frac{n^*}{2}\rceil-1}\overline{\Phi}(k_{n^*}+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})\frac{\delta\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})^2}}{(1-\delta\overline{\Phi}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma}))^2}\frac{\Delta}{2\sigma\sqrt{n^*}}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})$$

$$=k_{n^*}\{\sum_{t=0}^{\lceil \frac{n^*}{2}\rceil-1}\delta^{t+1}\sum_{s=0}^{t}\left(\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}(k_{n^*}+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2}\frac{(1+2s)\Delta}{2\sigma(n^*)^{3/2}}\prod_{\substack{x=0\\x\neq s}}^{t}\overline{\Phi}(k_{n^*}+\frac{(1+2x)\Delta}{\sigma\sqrt{n^*}})\right)+$$

$$+\delta^{\lceil \frac{n^*}{2}\rceil}\sum_{s=0}^{\lceil \frac{n^*}{2}\rceil-1}\left(\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}(k_{n^*}+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2}\frac{(1+2s)\Delta}{2\sigma(n^*)^{3/2}}\prod_{\substack{x=0\\x\neq s}}^{\lceil \frac{n^*}{2}\rceil-1}\overline{\Phi}(k_{n^*}+\frac{(1+2x)\Delta}{\sigma\sqrt{n^*}})\right)\frac{\delta\overline{\Phi}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})}{1-\delta\overline{\Phi}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})}$$

$$-\delta^{\lceil \frac{n^*}{2}\rceil}\prod_{s=0}^{\lceil \frac{n^*}{2}\rceil-1}\overline{\Phi}(k_{n^*}+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})\frac{\delta\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})^2}}{(1-\delta\overline{\Phi}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma}))^2}\frac{\Delta}{2\sigma\sqrt{n^*}}\}$$

$$
\begin{aligned}
&+\sum_{t=0}^{\lceil \frac{n^*}{2}\rceil -1} \delta^{t+1} \sum_{s=0}^{t} \Big(\tfrac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*}+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2} \tfrac{(1+2s)\Delta}{\sigma\sqrt{n^*}} \tfrac{(1+2s)\Delta}{2\sigma(n^*)^{3/2}} \prod_{\substack{x=0\\ x\neq s}}^{t} \overline{\Phi}(k_{n^*}+\tfrac{(1+2x)\Delta}{\sigma\sqrt{n^*}})\Big) + \\
&+\delta^{\lceil \frac{n^*}{2}\rceil} \sum_{s=0}^{\lceil \frac{n^*}{2}\rceil -1} \Big(\tfrac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*}+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2} \tfrac{(1+2s)\Delta}{\sigma\sqrt{n^*}} \tfrac{(1+2s)\Delta}{2\sigma(n^*)^{3/2}} \prod_{\substack{x=0\\ x\neq s}}^{t} \overline{\Phi}(k_{n^*}+\tfrac{(1+2x)\Delta}{\sigma\sqrt{n^*}})\Big) \frac{\delta\overline{\Phi}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})}{1-\delta\overline{\Phi}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})} \\
&-\delta^{\lceil \frac{n^*}{2}\rceil} \prod_{s=0}^{\lceil \frac{n^*}{2}\rceil -1} \overline{\Phi}(k_{n^*}+\tfrac{(1+2s)\Delta}{\sigma\sqrt{n^*}}) \frac{\delta \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})^2}}{(1-\delta\overline{\Phi}(k_n+\frac{\sqrt{n^*}\Delta}{\sigma}))^2} \frac{\Delta^2}{2\sigma^2} \\
&< (k_{n^*}+\tfrac{\sqrt{n^*}\Delta}{\sigma})\Big\{ \sum_{t=0}^{\lceil \frac{n^*}{2}\rceil -1} \delta^{t+1} \sum_{s=0}^{t} \Big(\tfrac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*}+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2} \tfrac{(1+2s)\Delta}{2\sigma(n^*)^{3/2}} \prod_{\substack{x=0\\ x\neq s}}^{t} \overline{\Phi}(k_{n^*}+\tfrac{(1+2x)\Delta}{\sigma\sqrt{n^*}})\Big) + \\
&+\delta^{\lceil \frac{n^*}{2}\rceil} \sum_{s=0}^{\lceil \frac{n^*}{2}\rceil -1} \Big(\tfrac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*}+\frac{(1+2s)\Delta}{\sigma\sqrt{n^*}})^2} \tfrac{(1+2s)\Delta}{2\sigma(n^*)^{3/2}} \prod_{\substack{x=0\\ x\neq s}}^{t} \overline{\Phi}(k_{n^*}+\tfrac{(1+2x)\Delta}{\sigma\sqrt{n^*}})\Big) \frac{\delta\overline{\Phi}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})}{1-\delta\overline{\Phi}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})} \\
&-\delta^{\lceil \frac{n^*}{2}\rceil} \prod_{s=0}^{\lceil \frac{n^*}{2}\rceil -1} \overline{\Phi}(k_{n^*}+\tfrac{(1+2s)\Delta}{\sigma\sqrt{n^*}}) \frac{\delta \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma})^2}}{(1-\delta\overline{\Phi}(k_{n^*}+\frac{\sqrt{n^*}\Delta}{\sigma}))^2} \frac{\Delta}{2\sigma\sqrt{n^*}}\Big\} = (k_{n^*}+\tfrac{\sqrt{n^*}\Delta}{\sigma}) G_n(k_{n^*}, n^*;\delta,\tau,\Delta/\sigma) = 0.
\end{aligned}
$$

The sum of the rest of the terms in (A10) is also negative for sufficiently small $n^*$, which verifies that $G_{nk}(k_{n^*}, n^*;\delta,\tau,\Delta/\sigma) < 0$.

Finally, $G_{nn}(k_{n^*}, n^*;\delta,\tau,\Delta/\sigma) < 0$ by the (local) second-order conditions. This verifies that $dn^*/d\delta > 0$.

Next we show that

$$\frac{dn^*}{d(\Delta/\sigma)} > 0 \text{ and } \frac{dk_{n^*}}{d(\Delta/\sigma)} < 0.$$

Note that $0 < G_k(k,n;\delta,\tau,\Delta/\sigma) < G_{\Delta/\sigma}(k,n;\delta,\tau,\Delta/\sigma)$ and $G_{nk}(k,n;\delta,\tau,\Delta/\sigma)$ $= G_{n(\Delta/\sigma)}(k,n;\delta,\tau,\Delta/\sigma)$ for $n = 1$. Therefore, for sufficiently small $n^*$ it must be that $G_{nk}G_{\Delta/\sigma}$ $- G_k G_{n(\Delta/\sigma)} \approx G_{nk}(G_{\Delta/\sigma} - G_k) < 0$ because as we showed earlier $G_{nk}(k_{n^*}, n^*;\delta,\tau,\Delta/\sigma) < 0$. By (A8), this verifies the claims. Similarly, by (A8), it follows that

$$\frac{dn^*}{d\tau} = \frac{G_{nk}G_\tau}{G_k G_{nn}} < 0 \text{ and } \frac{dk_{n^*}}{d\tau} > 0$$

because $G_\tau(k_{n^*}, n^*;\delta,\tau,\Delta/\sigma) < 0$.

*Q.E.D.*

**Proof of Proposition 4**

Suppose that $n \geq 2$ firms earn a strictly positive payoff in equilibrium. It must be that at optimum, the no-shirking constraint (12) binds because it cannot hold for $\tilde{k} \to -\infty$. Therefore, we have

$$(1-\delta)(v_h - c_h) + \delta(1-\Phi(k_n))\frac{(1-\delta)(v_h - c_h)}{1-\delta(1-\Phi(k_n))}$$
$$= (1-\delta)(v_h - c_l) + \delta(1-\Phi(k_n + \tfrac{\Delta}{\sigma\sqrt{n}}))\frac{(1-\delta)(v_h - c_h)}{1-\delta(1-\Phi(k_n))}$$
$$> (1-\delta)(v_h - c_l) + \delta(1-\Phi(k_n + \tfrac{\Delta}{\sigma}))\frac{(1-\delta)(v_h - c_h)}{1-\delta(1-\Phi(k_n))}.$$

Hence, from (11), it follows that $k_1 < k_n$, that is, a single firm can achieve a higher average payoff than any group of $n \geq 2$ firms when $z = 0$.

Now suppose that the firm earns zero payoff in equilibrium under individual reputation, that is, (*Don't Buy*, *Low*) is played in every period. The incentive compatibility constraint (11) cannot be satisfied if for all $\tilde{k}$

$$(1-\delta)(v_h - c_h) + \delta(1-\Phi(\tilde{k}))\frac{(1-\delta)(v_h - c_h)}{1-\delta(1-\Phi(\tilde{k}))}$$
$$< (1-\delta)(v_h - c_l) + \delta(1-\Phi(\tilde{k} + \tfrac{\Delta}{\sigma}))\frac{(1-\delta)(v_h - c_h)}{1-\delta(1-\Phi(\tilde{k}))}$$
$$< (1-\delta)(v_h - c_h) + \delta(1-\Phi(\tilde{k} + \tfrac{\Delta}{\sigma\sqrt{n}}))\frac{(1-\delta)(v_h - c_h)}{1-\delta(1-\Phi(\tilde{k}))}.$$

This proves that the incentive compatibility constraint (12) also cannot be satisfied for any $n \geq 2$, so that in equilibrium $\pi_{n,0} = 0$.

*Q.E.D.*

### Proof of Proposition 5

Under perfect global peer monitoring (that is, for $z \geq n-1$) in a reputation-by-cooperation equilibrium with cut-off point $\tilde{k}$, by (3), the no-shirking constraint (6) becomes

$$(1-\delta)(v_h - c_h) + \delta(1-\Phi(\tilde{k}))\frac{(1-\delta)(v_h - c_h)}{1-\delta(1-\Phi(\tilde{k}))} \tag{A11}$$
$$\geq (1-\delta)(v_h - c_l) + \delta(1-\Phi(\tilde{k} + \tfrac{\Delta}{\sigma\sqrt{n}}))\frac{(1-\delta)(v_h - c_l)}{1-\delta(1-\Phi(\tilde{k} + \sqrt{n}\tfrac{\Delta}{\sigma}))}.$$

Because all firms find out about shirking at the same time, peer punishment is self-enforcing if

$$(1-\delta)(v_h - c_l) + \delta(1-\Phi(\tilde{k} + \sqrt{n}\tfrac{\Delta}{\sigma}))\frac{(1-\delta)(v_h - c_l)}{1-\delta(1-\Phi(\tilde{k} + \sqrt{n}\tfrac{\Delta}{\sigma}))} \tag{A12}$$
$$\geq (1-\delta)(v_h - c_h) + \delta(1-\Phi(\tilde{k} + \tfrac{(n-1)\Delta}{\sigma\sqrt{n}}))\frac{(1-\delta)(v_h - c_l)}{1-\delta(1-\Phi(\tilde{k} + \sqrt{n}\tfrac{\Delta}{\sigma}))}.$$

However, it is easy to verify that both (A11) and (A12) are satisfied for $\tilde{k} = -\frac{1}{2}\sqrt{n}\frac{\Delta}{\sigma}$ as $n \to \infty$ when $\tau < \frac{\delta^2}{1-\delta^2}$. So, as $n \to \infty$, there exists a $k_n \leq -\frac{1}{2}\sqrt{n}\frac{\Delta}{\sigma}$ such that all incentive-compatibility constraints are satisfied. Furthermore, as the number of firms increases, the per-firm average payoff approaches $v_h - c_h$, or the maximum social surplus in each period over the infinite horizon. Because this is the highest achievable payoff, it must be that $n^* \to \infty$.

*Q.E.D.*

## REFERENCES


Abreu, D., D. Pearce, and E. Stachetti. 1993. "Renegotiation and Symmetry in Repeated Games." *Journal of Economic Theory* 60: 217–240.

Andersson, F. 2002. "Pooling Reputations." *International Journal of Industrial Organization* 20: 715–730.

Babcock, B., D. Hayes, J. Lawrence, and R. Clemens. 2008. "Creating a Geographically Linked Collective Brand for High-Quality Beef: A Case Study." *Innovative Marketing* 4: 16–24.

Babcock, B., and Q. Weninger. 2004. *Can Quality Revitalize the Alaskan Salmon Industry?* Discussion Paper 04-WP 359. Ames, IA: Center for Agricultural and Rural Development, Iowa State University.

Bar-Isaac, H., and S. Tadelis. 2008. "Seller Reputation." *Foundations and Trends in Microeconomics* 4: 273–351.

Barron, J., and K. Gjerde. 1997. "Peer Pressure in an Agency Relationship." *Journal of Labor Economics* 15: 234-254.

Bendor, J., and D. Mookherjee. 1990. "Norms, Third-Party Sanctions, and Cooperation." *Journal of Law, Economics, and Organization* 6: 33-63.

Bernheim, D., and M. Whinston. 1990. "Multimarket Contact and Collusive Behavior." *RAND Journal of Economics* 21: 1–26.

Borgen, S. 2001. "Identification as a Trust-Generating Mechanism in Cooperatives." *Annals of Public and Cooperative Economics* 72: 209–228.

Cabral, L. 2009. "Umbrella Branding with Imperfect Observability and Moral Hazard." *International Journal of Industrial Organization* 27: 206–213.

Cai, H., and I. Obara, 2009. "Firm Reputation and Horizontal Integration." *RAND Journal of Economics* 40: 340–363.

Castriota, S., and M. Delmastro. 2008. *Individual and Collective Reputation: Lessons from the Wine Market.* Working Paper 30. American Association of Wine Economists, New York University.

Che, Y. 2002. "Joint Liability and Peer Monitoring under Group Lending." *Contributions to Theoretical Economics* 2: Article 3.

Che, Y., and S. Yoo. 2001. "Optimal Incentives for Teams." *American Economic Review* 91: 525–541.

Choi, J. 1998. "Brand Extension and Informational Leverage." *Review of Economic Studies* 65: 655–669.

Ellison, G. 1994. "Cooperation in the Prisoner.s Dilemma with Anonymous Random Matching." *Review of Economic Studies* 61: 567-588.

ERS (Economic Research Service). 2011. *Naming Rights for "Geographical Indications."* WTO Briefing Room. Economic Research Service, U.S. Department of Agriculture. www.ers.usda.gov/Briefing/wto/geoindications.htm.

Evans, R., and T. Guinnane. 2007. *Collective Reputation, Professional Regulation, and Franchising*. Discussion Paper. New Haven, CT: Department of Economics, Yale University.

Fatas, E., F. Jimenez-Jimenez, and A. Morales. 2010. "Blind Fines in Cooperatives." *Applied Economic Perspectives and Policy* 32: 564-587.

Fishman, A., I. Finkelstein, A. Simhon, and N. Yacouel. 2010. *The Economics of Collective Brands*. Working Paper. Department of Economics, Bar-Ilan University and Hebrew University, Jerusalem.

Ghatak, M. 1999. "Group Lending, Local Information, and Peer Selection." *Journal of Development Economics* 60: 27–50.

Ghatak, M., and T. Guinnane. 1999. "The Economics of Lending with Joint Liability: Theory and Practice." *Journal of Development Economics* 60: 195–228.

Giovannucci, D., T. Josling, W. Kerr, B. O'Connor, and M. T. Yeung. 2009. *Guide to Geographical Indications*. Geneva: International Trade Center.

Golan, E., B. Krissoff, F. Kuchler, K. Nelson, and G. Price. 2004. *Traceability in the U.S. Food Supply: Economic Theory and Industry Studies*. Agricultural Economic Report No. 830. Economic Research Service, U.S. Department of Agriculture.

Green, E., and R. Porter. 1984. "Noncooperative Collusion under Imperfect Price Information." *Econometrica* 52: 87–100.

Haag, M., and R. Lagunoff. 2007. "On the Size and Structure of Group Cooperation." *Journal of Economic Theory* 135: 68-89.

Hardesty, S., and Y. Kusunose. 2009. "Growers' Compliance Costs for the Leafy Greens Marketing Agreement and Other Food Safety Programs." University of California Small Farm Program Research Brief. www.sfc.ucdavis.edu/docs/leafygreens.pdf.

Hirschauer, N., and O. Musshoff. 2007. "A Game-Theoretic Approach to Behavioral Food Risks: The Case of Grain Producers." *Food Policy* 32: 246–265.

Huck, S., and G. Lunser. 2010. "Group Reputations: An Experimental Foray." *Journal of Economic Behavior and Organization* 73: 153–157.

Kandori, M. 1992. "Social Norms and Community Enforcement." *Review of Economic Studies* 59: 63–80.

______. 2002. "Introduction to Repeated Games with Private Monitoring." *Journal of Economic Theory* 102: 1–15.

Landon, S., and C. Smith. 1998. "Quality Expectations, Reputation, and Price." *Southern Economic Journal* 64: 628–647.

Langinier, C., and B. Babcock. 2008. "Agricultural Production Clubs: Viability and Welfare Implications." *Journal of Agricultural & Food Industrial Organization* 6(1): Article 10.

Levin, J. 2009. "The Dynamics of Collective Reputation." *The B.E. Journal of Theoretical Economics* 9: Article 27.

LGMA (Leafy Greens Marketing Agreement). 2011. Leafy Greens Marketing Agreement. www.lgma.ca.gov.

Lyon, F., and G. Porter. 2009. "Market Institutions, Trust, and Norms: Exploring Moral Economies in Nigerian Food Systems." *Cambridge Journal of Economics* 33: 903–920.

Matsushima, H. 2001. "Multimarket Contact, Imperfect Monitoring, and Implicit Collusion." *Journal of Economic Theory* 98: 158–178.

Mazzocchi, M. 2006. "No News Is Good News: Stochastic Parameters versus Media Coverage Indices in Demand Models after Food Scares" *American Journal of Agricultural Economics* 88: 727–741.

Moschini, G., L. Menapace, and D. Pick. 2008. "Geographical Indications and the Competitive Provision of Quality in Agricultural Markets." *American Journal of Agricultural Economics* 90: 794–812.

Moustier, P., P. Tam, D. Anh, V. Binh, and N. Loc. 2010. "The Role of Farmer Organizations in Supplying Supermarkets with Quality Food in Vietnam." *Food Policy* 35: 69–78.

Mundy, A., and B. Tomson. 2010. "Egg Inspectors Failed to Raise Alarms." *Wall Street Journal*, September 10, B1.

Naziri, D., M. Aubert, J.-M. Codron, N. Loc, and P. Moustier. 2010. *Estimating the Impact of Small-Scale Farmers' Collective Action on Food Safety: The Case of Vegetables in Vietnam*. Working Paper. Paris, France: CIRAD-MOISA.

Okello, J., and S. Swinton. 2007. "Compliance with International Food Safety Standards in Kenya's Green Bean Industry: Comparison of a Small- and a Large-Scale Farm Producing for Export." *Review of Agricultural Economics* 29: 269–285.

Pecorino, P. 1999. "The Effect of Group Size on Public Good Provision in a Repeated Game Setting,." *Journal of Public Economics* 72: 121-134.

Pouliot, S., and D. Sumner. 2008. "Traceability, Liability, and Incentives for Food Safety and Quality." *American Journal of Agricultural Economics* 90: 15–27.

_____. 2009. *Traceability, Food Safety, and Industry Reputation.* Working Paper. Ames, IA: Department of Economics, Iowa State University.

Quagrainie, K., J. McCluskey, and M. Loureiro. 2003. "A Latent Structure Approach to Measuring Reputation." *Southern Economic Journal* 67: 966–977.

Rob, R., and A. Fishman. 2005. "Is Bigger Better? Customer Base Expansion through Word-of-Mouth Reputation." *Journal of Political Economy* 113: 1146–1161.

Spagnolo, G. 1999. "Social Relations and Cooperation in Organizations." *Journal of Economic Behavior and Organization* 38: 1–25.

Stevens, L. 2011. "Germany Now Says Sprouts Are to Blame for Outbreak." *Wall Street Journal*, June 11, B1.

Tirole, J. 1996. "A Theory of Collective Reputation (with Application to Corruption and Firm Quality)." *Review of Economic Studies* 63: 1–22.

USPTO (U.S. Patent and Trademark Office). 2011. "Geographical Indication Protection in the United States." United States Patent and Trademark Office. www.uspto.gov/web/offices/dcom/olia/globalip/pdf/gi_system.pdf.

Verbeke, W., and J. Roosen. 2009. "Market Differentiation Potential of Origin, Quality, and Traceability Labeling." *Estey Centre Journal of International Law and Trade Policy* 10(1): 20–35.

Winfree, J., and J. McCluskey. 2005. "Collective Reputation and Quality." *American Journal of Agricultural Economics* 87: 206–213.

Wolitzky, A. 2011. "Cooperation with Network Monitoring." Working Paper. Department of Economics, Massachusetts Institute of Technology, Cambridge.

World Bank. 2005. *Food Safety and Agricultural Health Standards: Challenges and Opportunities for Developing Countries Exports*. World Bank Sector Report, no. 31207, Washington, DC: World Bank.

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