Private information about reputation*

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Abstract

In markets for products (or services) of ex-ante unverifiable quality, reputation can induce high quality of goods produced. However, producers may privately learn about the value of their reputation (i.e. their future expected cash flows). I model this problem in a dynamic production economy. I show that producers may optimally cheat consumers upon receiving negative private information about future cash flows. Large expected rents can prevent such reputation failures. Therefore, the problem is more severe as competition intensifies. Surprisingly, the presence of entry barriers increases the likelihood of reputation failures as producers anticipate profits from cheating and contemporaneously price more aggressively. Recent scandals such as the issuance of toxic mortgage products, inflated ratings and the LIBOR manipulation are consistent with the model's predictions. Skin-in-the-game based policies such as product warranty, liability of accountants and retention of CDO equity tranches can prevent these reputation failures.

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1 Introduction

The financial crisis of 2007-2009 took many people completely by surprise. Yet, in the aftermath of the crisis, several documents surfaced indicating that investment banks, credit rating agencies and mortgage originators were aware of the fact that markets could not continue along the historical growth path. Moreover, these documents crucially show that several parties in the financial industry deliberately produced products of a quality inferior to what markets at large expected them to be.[1]

The years before this crisis were characterized by deregulation of financial markets and lowering entry barriers to these markets. The perception at the time was that reputation-based self-regulation could substitute imposed regulation in a more cost-efficient way. As a result, competition in financial markets intensified, putting pressure on revenues in a permanent and structural way. At the same time, more complex products were introduced to markets and in-house research of financial markets took flight.

This paper introduces a model to analyze the effects of private information about the value of future revenue streams (reputational value) on current product or service quality in a competitive industry. In particular, I find that reputation failures may arise if producers become privately informed about negative future cash flow shocks. This reputation failure is more likely to occur as competition intensifies. The model suggests that high information asymmetry between issuing and certifying parties on the one hand and the investment community on the other hand, combined with intensified competition has (partially) caused the crisis and most likely amplified it.

While the recent period of scandals in the financial sector provides a good motivation for studying the effects of private information on reputational value, the problem is more general and growing in size. Around the world, information collection and processing technologies are implemented on an ever increasing scale, while competition in product markets intensifies due to globalization. While data collection and analysis may in general be helpful for better identifying client needs, the information advantage that producers gain over their own reputational value may

[1] Examples include alleged pressure by S&P on analysts to rush and inflate ratings (`http://www.cbc.ca/news/business/u-s-to-sue-s-p-over-mortgage-ratings-fraud-1.1312665`), Goldman allegedly defrauding or misleading investors in a CDO transaction (`http://www.sec.gov/news/press/2010/2010-59.htm`), Chuck Price's (Citigroup) quote "When the music stops, in terms of liquidity, things will be complicated. But as long as the music is playing, youve got to get up and dance.", The Icelandic banks that were aware of their weak position and the LIBOR fraud in 2008 in view of reduced bank survival probabilities.

be damaging from a welfare perspective. Ex-ante, producers may even be better off not receiving this information if the induced reputation failure translates in lower consumer demand and prices. However, when the information is produced as a costless by-product or also useful in other ways, committing ex-ante to not use such information ex-post may be hard. As such, the paper highlights one of the dark sides of big data solutions.

The mechanism at the core of this paper is valid in any product or information market where service or product quality depends on ex-ante non-verifiable effort. In such a market, a producer can be induced to exert sufficient effort by a reputation mechanism (Shapiro 1982). This gives rise to an incentive compatibility constraint, which commands that the producer should earn a reputation rent. Competition puts pressure on this mechanism by driving down prices until the incentive compatibility constraint bind. If expectations of future market volumes worsen unexpectedly, incentive compatibility will be violated, but can be restored if markets (temporarily) lower expectations for product quality as well as reservation prices. However, if producers are only privately informed about lower future market volumes, I show that it may be optimal for them to not disclose this information and deliver the lowest possible quality (as long as this is not detectable ex-ante).[2] This effect holds true despite the expected punishment in future periods. Note that it is not unlikely for a producer to have private information about future market volumes, especially since the production costs for this information have come down significantly due to technological progress.

In the presence of these private information shocks, two types of equilibria are possible. In the first type, customers may be willing to restore incentive compatibility in all states by paying additional premia. Such equilibria are socially preferred if future market declines are frequent, only small in size and/or customers suffer badly from reputation failures. In the second type of equilibrium, customers accept an occasional reputation failure and equilibrium prices drop because for producers the anticipated future value of cheating increases (and for consumers the expected value of the product drops). Such equilibria are socially preferred if future market declines are infrequent, large in size and/or if customers do not suffer much from purchasing dysfunctional products. As a result, one may observe interesting price

[2]Any negative private information on the value of future profits can resort such effects. These include private information on entry of competitors, production costs, financing costs, regulatory costs, fines, lawsuits, financial distress costs and the like. For tractability reasons, I model these effects with private information shocks about future market size.

patterns in a society that tries to coordinate on a welfare maximizing equilibrium. As potential future shocks become more severe, equilibrium prices and rents will initially rise in order to maintain incentive compatibility. At some point however, the price premium becomes so high that customers prefer to accept an occasional reputation failure and equilibrium prices drop.

If the market had been served by a (replaceable) monopolist, the market would have had a much stronger resiliency to such private information shocks. After all, the reputation of a monopolist is so valuable that it needs a much bigger shock to risk it. Hence, competitive pressure adds to instability in markets by undermining reputational mechanisms.

Because of the reputation failure described above, markets may be expected to become less competitive in the future when entry is limited. The prospect of a potentially less competitive market in the future does not solve the problem of unexpected reputation failure. On the contrary, the prospect of a future less competitive market induces producers to price more aggressively in equilibria with cheating. This makes such equilibria contemporaneously more appealing for customers. As a result, customers will be less willing to pay a premium price for guaranteed quality and avoid coordinating on cheating-proof equilibria.

Finally, I explore what can be done to contain such problems. In (consumer) product or service markets, the solution is very simple and effective. One can just implement warranty (or a no-cure-no-pay guarantee), as long as it is not too costly to claim it. I show that with warranty, there are equilibria in which high quality does not depend on reputation because incentives are contemporaneously well aligned. Yet, in order for these equilibria to arise, a price premium is required and producers pocket rents in a competitive environment.

In corporate and financial markets matters may be more difficult. Accounting firms are liable for any irregularities they missed in corporate accounts; this again is reasonably effective in disciplining them. Complex financial products such as structured pools of sub-prime mortgages performed relatively well if their originators held on to the first loss piece. However, at some point, issuers got away with selling first-loss pieces and problems started. Finally, credit rating agencies are among the hardest parties to discipline. While very similar to accountants, they certify a relative probability of default rather than an absolute certificate of perfect quality. As a result, disciplining mechanisms such as legal liability are hard to implement and enforce.

The paper primarily contributes to the existing literature on reputation in markets for products and services of ex-ante non-verifiable quality, started by Klein and Leffler (1981). Bar-Isaac and Tadelis (2008) provide an excellent review of this body of literature. The setup used in the paper is slightly simpler than in most existing papers, as effort is ex-post perfectly verifiable (as opposed to e.g. Benabou and Laroque (1992)) and there are no intrinsically different types of producers as in for example Kennan and Wilson (1993). A specific and very small strand of literature this paper connects to very closely is on the interaction of competition and reputation. The interaction between competition and reputation can have several effects (Hörner (2002), Bar-Isaac (2005)). First, competition can lower expected future profits or rents and hence make reputation less valuable. Second, competition can provide outside options for customers, making it easier to abandon a non-performing producer. Finally, competition could increase contemporaneous production costs, adding to the incentive to cheat customers. The effects spelled out in this paper are different and depend mostly on competition undermining reputation by reducing future rents. I do however also show that monopolistic producers are more resilient, but not immune to the effect.

The paper coming closest to mine is the one by Kranton (2003). She develops a model in which competition drives down prices and hence future rents. Market share in her model is however imperfectly and to some degree randomly linked to the value provided to customers. As a result, producers that contemporaneously attract a disproportionately large market share due to random fluctuations have an incentive to cheat customers. The reason for this is that future market shares are expected to be lower and hence incentive compatibility is violated at market-wide equilibrium prices. Crucial in her model is that customers select producers before products are produced. By contrast, my paper depends on private information available to a producer before production, which may cover more than just realized market shares. In particular, market shares in my model may be at their long run averages and misbehavior can result entirely from private information about negative market-wide trends. In addition, producers in my setting have the opportunity to share their private information with their customers before products are sold, but choose optimally to not do so. Hence, producers in my model more consciously choose to cheat customers than in Kranton (2003).

The second part of the analysis on warranty as a solution to overcome reputation failure relates to the literature on warranties started by Grossman (1981). Yet, opposed to Grossman (1981), I introduce a friction in the form of a positive probability of a failure to claim warranty. Moreover, as in Bongaerts (2014), I exploit the fact that warranty-based discipline does not require reputation rents. However, as opposed to Bongaerts (2014), this paper considers a private information problem relating to future business volume rather than product quality.

2 Setup

Consider a very simple production economy that consists of an infinitely repeated game. There are two types of agents in this economy: customers and producers. Every stage game, there are $N > 1$ homogeneous customers that live for only one period. Every customers c derives utility from consuming a product. Customers utility is increasing linearly in the quality $e \in [0,1]$ of the product with coefficient ν and linearly decreasing in the price p paid for the product; the coefficient on price is normalized to negative one. More formally, we have

$$U^c = \nu e - p. \tag{1}$$

Product quality is not verifiable ex-ante, but ex-post perfectly observable. There are M infinitely lived homogeneous producers in this economy that each have an identical production technology at their disposal. For tractability, I initially assume that M is fixed and finite, but that a new entrant immediately replaces an established producer when it drops out. Later this assumption will be relaxed. To produce a good of quality e, a producer needs to spend effort and resources equal to ζe^2. Producers have constant productivity to scale. Finally, every producer k discounts future payoffs with an annual discount rate r. Producer utility is given by

$$U_t^P = V_t = p - \zeta e^2 + \frac{E(V_{t+1})}{1+r}. \tag{2}$$

The major friction in the model is that every period there is a small probability q that market demand for the product may structurally shrink to only a fraction $g \in [0,1)$ of current demand.[3] Similarly, with (unconditional) probability z, there will be an upward shock to market size next period such that the market is $x > 1$ times as large.[4] Otherwise, market demand will stay constant. I impose that $z(x-1) = q(1-g)$ such that the unconditionally expected market size is constant.[5] This allows

[3]One could for example think about the market being satisfied, product life to exceed product life expectancy, aggregate wealth shocks to customers or the invention of a superior technology

[4]Naturally, these two events are mutually exclusive.

[5]This follows from rewriting the equation $qg + xz + 1 - q - x = 1$.

for solving in terms of steady state equilibria. Conditional on a market decline in the next period, each producer has a probability ϕ to privately learn that the impeding market decline will take place.[6] Such private information shocks are not unlikely to occur as producers may for example have short lines to their customers and conduct market research. In the base case of the model, the probabilities of receiving private information shocks in stage game t will be independent across producers, while in later extensions, there could be commonality in the information shocks.

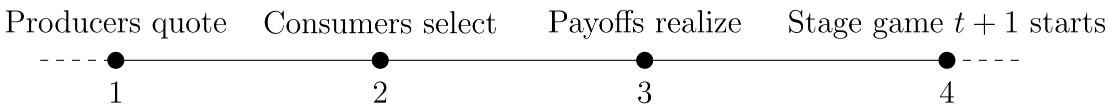

Figure 1: Time line of a stage game.

All players observe the complete history $\mathcal{F}_{t-1}$ of all previous stage games.

In 1., producers publicly quote prices for their products and privately choose their effort.

In 2., consumers select whether to buy products and if so, from which producer. They can base their decision on prices quoted and the observed history of producer performance.

In 3., payoffs realize publicly and perfectly, which means that effort is ex-post verifiable for producers with strictly positive market share.

Finally, all agents in the economy are fully rational and know all model parameters.

2.1 First best outcome

A social planner would trade-off production effort with consumer utility. Optimal allocation of resources and consumption is only achieved if this allocation is efficient in every stage game. Hence, we can solve a static optimization problem.

Proposition 1. *In the first best outcome, producers produce products of quality* $e = \min\left(\frac{\nu}{2\zeta}, 1\right)$*, leading to a social welfare of* $\min\left(\nu - \zeta, \frac{\nu^2}{4\zeta}\right)$.

Proof. See appendix. □

[6] Different ways of allowing for multiple informed producers are possible, leading to different outcomes and possibly crises. Those are explored in later sections.

Hence, it is always socially optimal to produce goods with strictly positive quality and the socially optimal quality level is independent of shocks to future market demand.

3 Base case equilibrium

In practice, obtaining the first best outcome is unlikely. Therefore, we need to resort to an equilibrium analysis. In this paper, I will focus on (sub-game perfect) steady state Nash equilibria. As the main point of the paper is quite general, I can address the problem of multiple equilibria in a general way and show robustness.

In order to induce producers to exert a strictly positive effort level e, current gains for producers from slacking (i.e. set $e =$) should be more than offset by the expected loss of future income. Hence, customers should employ punishment strategies based on past (mis)behavior. In the equilibrium below, I use a grim-trigger punishment strategy as that maximizes the incentives for producers to exert effort (Abreu 1988). Later on, I show robustness to other punishment strategies in a reduced form way.

Let us, as a a benchmark, first consider the equilibrium with constant market size (i.e. where declines are impossible).

Proposition 2. *Let us assume that $q = 0$. The following set of strategies then constitutes and equilibrium:*

1. *All producers that have ever quoted a price below p^* or have ever exerted effort e below e^* quote p^* and exert effort $e = 0$*
2. *All producers that have always quoted a price of at least p^* and have never exerted effort e below e^* quote p^* and exert effort $e = e^*$*
3. *Customers choose randomly among the producers with the lowest price quote that have always quoted a price of at least p^* and have never exerted effort e below e^* quote p^* and exert effort $e = e^*$*

where

$$p^* = (r+1)\zeta(e^*)^2 \tag{3}$$
$$e^* = \frac{\nu}{2(1+r)\zeta}. \tag{4}$$

Proof. See appendix. □

The equilibrium price p^* in Proposition 2 is determined by making the incentive compatibility constraint bind as a result of product market competition. Equilibrium effort e^* can then be derived by substituting equilibrium price as a function of effort into customer utility and maximizing towards e.

In the equilibrium of Proposition 2, producers earn reputation rents that are increasing in their discount rate. These reputation rents reduces equilibrium product quality compared to first best.

Now consider what happens when market size is subject to shocks (i.e. $q, z > 0$). If producers have no private information about shocks to future market size, then Proposition 2 still applies as the expected market size is unaffected and profits scale linearly with market size in equilibrium.

Now consider the situation where producers can receive private information shocks about future market declines. Let us call producers that have received an information shock 'informed producers'. With the strategies employed in Proposition 2, the incentive compatibility constraint of an informed producer would be violated. This is because he knows that the present value of future profits is insufficient to induce exerting effort today. Such reputation failures would lead to exceptional profits for the producer at the expense of the consumers.

Market participants can handle this potential reputation failure in two different ways. One way would be for the market to ensure incentive compatibility in all states of nature. In order to achieve this, prices need to increase compared to the base case. In this case, producer rents go up at the expense of the consumers, while equilibrium effort declines (because effort becomes more expensive). The other way would be that all market participants recognize and accept that occasional reputation failures take place in equilibrium. As a result, customers' willingness to pay should decline, while producers would anticipate exceptional profits at some point in time and therefore require lower rents. As a result, equilibrium prices should be lower compared to the benchmark equilibrium. equilibrium effort would drop compared to the base case due to insufficient discipline.

Which of the two equilibrium types customers would try to coordinate on mainly depends on the frequency and severity of private information shocks. If private information shocks are large and/or infrequent, ensuring incentive compatibility in all states of nature is relatively costly and tolerating occasional reputation failure would be optimal. If on the other hand information shocks are small and/or frequent, the additional rents are small compared to welfare losses resulting from reputation failure. Hence, in those cases premium prices would maximize customer welfare.

The following proposition formalizes the intuition explained above.

Proposition 3. *Let us assume that $q > 0$. The following set of strategies then constitutes and equilibrium:*

1. *All uninformed producers that have ever quoted a price below p^* or have ever exerted effort e below e^* quote p^* and exert effort $e = 0$*
2. *All uninformed producers that have always quoted a price of at least p^* and have never exerted effort e below e^* quote p^* and exert effort $e = e^*$*
3. *All informed quote p^* and exert effort $e = 0$ if $g \leq \underline{g}$ and quote p^* and exert effort $e = e^*$ otherwise*
4. *Customers choose randomly among the producers with the lowest price quote that have always quoted a price of at least p^* and have never exerted effort e below e^* quote p^* and exert effort $e = e^*$*

where

$$p^* = \begin{cases} (1 + rg^{-1})\zeta(e^*)^2 & \text{if } g \geq \underline{g}, \\ (1 + r - q\phi(1-g))\zeta(e^*)^2 & \text{otherwise}, \end{cases} \tag{5}$$

$$e^* = \begin{cases} \frac{\nu}{2(1+rg^{-1})\zeta} & \text{if } g \geq \underline{g}, \\ \frac{(1-q\phi)\nu}{2(1+r-q\phi(1-g))\zeta} & \text{otherwise}, \end{cases} \tag{6}$$

$$\underline{g} = \frac{-(r + q\phi - (q\phi)^2) + \sqrt{(r + q\phi - (q\phi)^2)^2 + 4(1-q\phi)^2 rq\phi}}{2q\phi}. \tag{7}$$

Proof. See appendix. □

In the equilibrium of Proposition 3, equilibrium prices p^* are set to make incentive compatibility bind in expectation or in the worst case for $g \geq \underline{g}$ and $g > \underline{g}$, respectively. Equilibrium effort e^* is obtained by substituting p^* as a function of e into customer utility and maximizing towards e. The optimal equilibrium type for customers in this market is determined by comparing customer utility between the two equilibrium types. This difference is a monotone function of g on the support of g and hence, the switching point can be determined by solving for the unique value of g for which customers would be indifferent between the two.

A thing to notice here is that with information asymmetry on future sales volumes, equilibrium product quality uniformly deteriorates. Hence, while big data solutions can provide producers with useful information on their customer preferences, the market trend analyses that such systems allow for put pressure on quality.

In contrast to a competitive setting, a monopolistic setting offers much more resiliency to large private information shocks. After all, the monopoly position is too valuable to be risked lightly. Hence, a monopolist is able to withstand the temptation of cheating after a moderate private information shock. For very large private information shocks, also the monopolist will yield to temptation.

Proposition 4. *Let us assume that $q > 0$, $r < 1$ and that $M = 1$. The following set of strategies then constitutes and equilibrium:*

1. *The monopolistic producer quotes p^* and exerts effort $e = 0$ if it has ever quoted a price below p^* or has ever exerted effort e below e^**

2. *The monopolistic producer quotes p^* and exerts effort $e = e^*$ if it is uninformed and has always quoted a price of at least p^* and has never exerted effort e below e^**

3. *If the monopolistic producer is informed, it quotes p^* and exerts effort $e = 0$ if $I_g = 1$ and quotes p^* and exerts effort $e = e^*$ otherwise*

4. *Customers buy from the producer if it has always quoted a price of at least p^* and has never exerted effort e below e^**

where

$$p^* = \nu(1 - q\phi I_g)e^*, \tag{8}$$

$$e^* = \min\left(\frac{\nu}{2\zeta}, 1\right), \tag{9}$$

and I_g is and indicator function taking the value of 1 if $g < r$.

Proof. See appendix. □

As is usual in a monopolistic setting, the monopolist can capture all surplus in the economy and therefore captures rents. Absent private information shocks, a monopoly would therefore lead to first best (one can set $\phi = 0$ in 8 to see this). Even in the presence of private information shocks, a monopolist's incentive compatibility constraint holds in all states of nature as long as the anticipated market decline does not more than offset excess monopoly rents. As it turns out, excess monopoly rents are more than offset by g when $g < r$.

4 Entry barriers and anticipated competition

When private information shocks are producer specific and not common across the industry, one could think that entry barriers could generate expectations about future rents that may prevent reputation failure. In particular, one might suspect that the prospect of having a less competitive industry going forward may prevent producers from misbehaving. As I will show below, the opposite is the case. The intuition is as follows.

In an equilibrium in which producers occasionally cheat, producers have a prospect of attaining a valuable monopoly position in the future.[7] As a result, producers can achieve incentive compatibility in normal times at lower equilibrium prices.[8] This makes cheating equilibria contemporaneously more attractive for customers as prices charged before the monopoly materializes are lower. As a result, customers will be more inclined to coordinate on equilibria with reputation failures (in other words, $\underline{g}$ increases). In addition, customers will demand higher quality (i.e. e^* increases compared to Proposition 3), because quality becomes cheaper. While this intuition holds generally, it is most easily shown when $M = 2$, as is done in Proposition 5. In that case, a monopoly remains upon one producer leaving the market.

Proposition 5. *With entry barriers, $\underline{g}$ increases and hence cheating equilibria arise with smaller private information shocks. In those equilibria, equilibrium market prices are reduced by an amount that reflects the value of a potential future monopoly.*

Proof. See appendix. □

5 Applications and preventive measures

5.1 Warranty

Product warranty can effectively avoid such misbehavior provided that the probability of successful claiming warranty is high enough.[9] To this end, we extend the model by introducing a warranty that can be claimed with success probability $1 - \psi$

[7] This happens when all other producers have cheated.

[8] In this case, equilibrium prices may even fall short of production costs.

[9] One can think about warranty in a broad sense. For consumer products, it refers to product warranty, while for corporate or financial services and products it could refer to for example the retention of first loss pieces, accountant liabilities, regulatory fines, litigation costs or legal settlements. For expositional purposes, I illustrate the mechanism with warranty on consumer products.

whenever production effort falls short of e^*. In case warranty is claimed, the purchase price is reimbursed to the customers in exchange for the defunct product. If ψ is high, the cost to producers is low and there is still a positive contemporaneous benefit of slacking. Producers may then still optimally cheat customers. However, as their benefit of future expected cheating is reduced by the expected warranty claims, product prices are higher than in Proposition 3 for $g \leq \underline{g}$. If ψ is close to 0 however, even contemporaneously it may not be worthwhile for a producer to cheat customers. After all, warranty claims offset a fraction $1 - \psi$ of all contemporaneous gains from cheating and on top of that make the producer forgo rents on the same fraction $1 - \psi$ of its sales.[10] If ψ is close to zero, equilibria may arise in which incentives for producers are contemporaneously well aligned and hence reputation becomes irrelevant. However, for these equilibria to work, prices cannot equal production costs as otherwise warranty claims are not costly enough for producers.

Proposition 6. *Warranty can give rise to stable equilibria that do not depend on reputation effects. Market prices and effort in such equilibria are given by*

$$p^* = \frac{\zeta(e^*)^2}{1-\psi}, \tag{10}$$

$$e^* = \frac{\nu}{2(1-\psi)\zeta}. \tag{11}$$

Proof. See appendix. □

The intuition behind the expression for p^* in (10) is as follows. In order for incentive compatibility to hold, contemporaneous expected costs should exceed cost savings. Cost savings are given by ζe^2, while expected costs are given by $(1 - \psi)p$. This inequality should bind due to competition. p^* the arises naturally. e^* is derived as before by optimizing consumer utility over e with p^* as a function of e plugged in.

[10] The second component is crucial for the warranty to work. Otherwise, cheating is just an option with little downside. Processing costs for warranty claims on the producer's side can achieve a similar goal.

6 Robustness

6.1 Other types of punishment strategies

So far I have only considered grim-trigger punishment strategies as these provide the strongest discipline. With a grimm-trigger strategy, the loss of future value essentially equals a perpetuity of future expected rents. One could also consider other punishment strategies that involve a boycot/suspension of a producer for k periods. In this case, the future value that is risked by cheating is essentially an annuity of future expected rents. Hence, in this case we can use a multiplication constant γ for the PV of future value losses where $\gamma = \left(1 - \left(\frac{1-q\phi}{1+r}\right)^k\right)$.

7 Conclusions

In the above analysis, I have highlighted a problem with recent, large-scale data solutions implemented by many producers. Their superior knowledge about their reputational value can create incentives to cheat their customers or can drive up prices to higher levels than required before the rise of big-data solutions. Both effects lead to customers choosing for lower product quality when trading off product quality against price. In line with the results in the paper, we have seen relatively many reputation failures in industries with high entry barriers such as banking and credit ratings. The main source of the problem is that producers may find it very hard to commit ex-ante to not use such information when it comes available. Ex-post it is always optimal to use the information when available.

For tractability, the current version of the paper uses a model that is as simple as possible. Possible extensions to make the model reflect reality better include imperfect ex-post verifiability, the analysis of common shocks in concentrated industries[11] and applications to specific industries.

[11] This leads to mixed-strategy equilibria that are very hard if not impossible to solve in closed form.

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A Appendix: proofs

A.1 Proof of proposition 1

Aggregate utility arising from exerted effort is given by νe, while using up production factors decreases welfare by ζe^2. Hence aggregate welfare is given by

$$WF = \nu e - \zeta e^2, \tag{12}$$

where $e \in [0,1]$. Imposing a first order condition, verifying that the second order condition is satisfied as the quadratic term enters with a negative sign and imposing the bounded support gives:

$$e = \min\left(\frac{\nu}{2\zeta}, 1\right). \tag{13}$$

Substituting these solution into (12) gives

$$WF = \min\left(\frac{\nu^2}{4\zeta}, \nu - \zeta\right), \tag{14}$$

respectively.

A.2 Proof of proposition 2

Given the grim-trigger strategy employed by customers, it is optimal for producers that are not trusted anymore to exert zero effort as effort is costly and positive effort under these strategies does not lead to future volume. For producers that are trusted, incentive compatibility holds when given the equilibrium strategies, the gains from shirking are more than offset by the loss of future business, or in other words

$$\zeta e^2 \leq \frac{p^* - \zeta e^2}{r}. \tag{15}$$

Competition makes this constraint bind. Solving for p^* yields

$$p^* = (1+r)\zeta(e^*)^2. \tag{16}$$

For customers, it is optimal not to purchase from a producer that can be expected to exert zero effort, as that yields negative utility. It is also optimal for customers to choose the lowest price quote from all producers that can be expected to exert e^*. Plugging (16) into the utility function of the customers and optimizing yields

$$e^* = \frac{\nu}{2(1+r)\zeta}. \tag{17}$$

A.3 Proof of proposition 3

Either of two possibilities can arise. First, we could get an equilibrium in which reputation fails every now and then. Second, we could get an equilibrium in which customers protect themselves against reputation failure by always paying a premium. We work out both equilibria below. Customers in the end coordinate for the one or the other equilibrium, based on what maximizes their utility. In the final stage of the proof I derive under which conditions which equilibrium will be chosen.

Let us first work out the equilibrium with misbehavior. Given grim-trigger punishment by customers, it is optimal for uninformed producers to exert e^* when p^* is incentive compatible. p^* is incentive compatible for an uninformed producer if the gains from shirking are more than offset by the loss of future business, or in other words

$$\zeta e^2 \leq \frac{E(V_{t+1})}{1+r}. \tag{18}$$

Realizing that an uninformed producer can be informed in the future and then cheat, we can work out $E(V_{t+1})$ as

$$\begin{aligned} E(V_{t+1}) = (1-q-z)(p^* - \zeta(e^*)^2 + \frac{E(V_{t+2})}{1+r}) + z(p^* - \zeta(e^*)^2 + x\frac{E(V_{t+2})}{1+r}) + \\ q(1-\phi)(p^* - \zeta(e^*)^2 + g\frac{E(V_{t+2})}{1+r}) + q\phi p^*. \end{aligned} \tag{19}$$

Simplifying yields

$$E(V_{t+1}) = (1-q\phi)(p^* - \zeta(e^*)^2) + (1 - q\phi g\frac{E(V_{t+2})}{1+r}) + q\phi q^*. \tag{20}$$

Forward substitution gives

$$\frac{E(V_{t+1})}{1+r} = \frac{p^* - (1-q\phi)\zeta(e^*)^2}{r + q\phi g}. \tag{21}$$

Substituting (21) into (18), we obtain conditions for regular incentive compatibility to hold. Making this IC bind due to competition and solving for p^*, we get

$$p^* = \zeta(e^*)^2 \left(1 + r - q\phi(1-g)\right). \tag{22}$$

For customers, it is optimal not to purchase from a producer that can be expected to exert zero effort, as that yields negative utility. It is also optimal for customers to choose the lowest price quote from all producers that can be expected to exert e^* in the absence of private information. Plugging (22) into the utility function of the customers and optimizing yields

$$e^* = \frac{\nu}{2(1 + r - q\phi(1-g))\zeta}. \tag{23}$$

In case of a negative future volume shock, the subjective incentive compatibility constraint for an informed producer is given by

$$\zeta e^2 \leq g\frac{p^* - (1-q\phi)\zeta(e^*)^2}{r + q\phi g}. \tag{24}$$

Substituting (22) and (23) into the subjective incentive compatibility constraint shows that given the equilibrium strategies, it is never satisfied for an informed producer. Hence, it is optimal for the producer to slack and exert effort $e = 0$.

In an equilibrium without cheating, the incentive compatibility constraint needs to hold for informed and uninformed producers. Hence, instead of (18), we always need to have that

$$\zeta e^2 \leq g\frac{E(V_{t+1})}{1+r}. \tag{25}$$

Working out $E(V_{t+1})$, we get

$$E(V_{t+1}) = \frac{p^* - \zeta(e^*)^2}{r}, \tag{26}$$

as in the case without information asymmetry. Substituting and solving for p^* gives

$$p^* = (1 + rg^{-1})\zeta(e^*)^2. \tag{27}$$

Substituting into the customers utility function and optimizing w.r.t. e^* yields

$$e^* = \frac{\nu}{2(1 + rg^{-1})\zeta}. \tag{28}$$

To find out which equilibrium customers would coordinate on, we compare customers utility for both equilibria as a function of g. Equating the two and solving for g yields $\underline{g}$. Customers utility with cheating is given by

$$\frac{(1-q\phi)^2\nu^2}{4(1+r-q\phi(1-g))\zeta}. \tag{29}$$

Customers utility with price premia is given by

$$\frac{\nu^2}{4(1+rg^{-1})\zeta}. \tag{30}$$

Equating the two yields a quadratic equation in g with positive coefficients on the quadratic and linear terms and a negative constant. Hence, it has only one positive root. $\underline{g}$ can then be obtained as the positive root of this equation:

$$\underline{g} = \frac{-(r+q\phi-(q\phi)^2)+\sqrt{(r+q\phi-(q\phi)^2)^2+4(1-q\phi)^2 rq\phi}}{2q\phi}. \tag{31}$$

A.4 Proof of proposition 4

Let us assume that the monopolist never cheats when $I_g = 1$. A monopolist can extract all economic surplus from customers. The utility of customers in equilibrium is given by

$$U_c = \nu(1-q\phi I_g)e^* - p^*. \tag{32}$$

Equating customers utility to zero and solving for p^* yields

$$p^* = \nu(1-q\phi I_g)e^*. \tag{33}$$

The monopolist's utility function is given by

$$U_m = \frac{p^*-(1-q\phi I_g)\zeta(e^*)^2}{r+q\phi g I_g}. \tag{34}$$

Substituting for p^*, imposing a FOC and solving for e^* yields

$$e^* = \frac{\nu}{2\zeta}. \tag{35}$$

Incentive compatibility is always achieved when

$$\zeta(e^*)^2 \leq g\frac{(1-q\phi I_g)(p^*-\zeta(e^*)^2)}{r+q\phi g I_g}. \tag{36}$$

Substituting for p^* and e^* yields that incentive compatibility always holds when

$$g \geq r, \tag{37}$$

which is exactly the condition for I_g to equal unity.

A.5 Proof of proposition 5

As before, incentive compatibility in normal times holds when (18) is satisfied. Let us define the present value of a monopoly starting in one period as

$$\xi = \frac{(1-q\phi I_g)\frac{\nu^2}{4\zeta}}{r+q\phi g I_g}, \tag{38}$$

which is obtained by substituting (33) and (35) into (34). If both parties slack conditional on private information, we have that

$$\begin{aligned} E(V_{t+1}) = (1-q(2\phi-\phi^2))(p^*-\zeta(e^*)^2) + (1-qg(2\phi-\phi^2))\frac{E(V_{t+2})}{1+r} \\ + q\phi p^* + q(\phi-\phi^2)(p^*-\zeta(e^*)^2+2g\xi). \end{aligned} \tag{39}$$

The factor $2g$ in front of the monopoly value ξ reflects the smaller market (g) that is not to be shared anymore (2). Forward substitution gives

$$E(V_{t+1}) = \frac{p^*-(1-q\phi)\zeta(e^*)^2+2q(\phi-\phi^2)g\xi}{r+qg(2\phi-\phi^2)}. \tag{40}$$

Substituting (40) into (18), we obtain conditions for regular incentive compatibility to hold. Making this IC bind due to competition and solving for p^*, we get

$$p^* = \zeta(e^*)^2(1+r-q\phi(1-2g(1-\phi))) - 2gq\phi(1-\phi)\xi. \tag{41}$$

As before, in normal times, customers effectively optimize over effort and hence, we have

$$e^* = \frac{(1-q\phi)\nu}{2(1+r-q\phi(1-2g(1-\phi)))\zeta}. \tag{42}$$

Customers utility in this case is given by

$$\frac{(1-q\phi)^2\nu^2}{4(1+r-q\phi(1-2g(1-\phi))\zeta)} + 2gq\phi(1-\phi)\xi. \tag{43}$$

In an equilibrium in which producers never cheat, the required price markup and hence customers utility is unchanged. As customers utility in the cheating is larger than before while customers utility in the price premium equilibrium has not changed, larger gs will already lead to cheating.

A.6 Proof of proposition 6

With warranty, the contemporaneous payoff of cheating customers is given by

$$\psi p^* - (p^* - \zeta(e^*)^2). \tag{44}$$

In order for incentives to be contemporaneously well aligned, this payoff should be negative. This is the case when

$$\zeta(e^*)^2 - (1-\psi)p^* \leq 0, \Rightarrow \qquad p^* \geq \frac{\zeta(e^*)^2}{1-\psi}. \tag{45}$$