The microeconomics of strategic activism

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Chapter 4

Strategic Activism in an Uncertain World

4.1 Introduction

Ethically motivated consumers face a problem when shopping for certain goods. They often cannot observe the production practices of firms whose products they contemplate buying. It could be that seemingly innocuous products have caused grave harm to the environment during the production stage or were manufactured using child labour. This informational problem is difficult to solve: even the act of consumption might not reveal the production practices the manufacturer has employed. Moreover, a firm often cannot credibly convey to consumers that it has abided by certain ethical standards. Government intervention or regulation is the natural candidate for alleviating market failures associated with such *credence goods*.[1]

Increasingly, interest groups, for instance environmental organizations, take initiative in providing consumers with information regarding firms' production practices. These interest groups (IGs) want to minimize some 'damage', for instance pollution or the use of child labour, a certain industry is causing. IGs can accomplish two things by informing consumers. In the short run they can steer consumers away from 'damaging' products towards less damaging products. In the long run they can force firms to adopt less damaging technologies by threatening to unveil firms' harmful practices.

As the literature discussion below reveals, the impact IGs can have on firms'

[1] Nelson (1970) distinguishes between *search goods* and *experience goods*. The characteristics of a search good can be inferred by inspection of the good (at the shop) prior to purchase. The characteristics of experience goods can be discovered during consumption, but not by inspection prior to purchase. Darby and Karni (1973) introduced a third category: credence goods. The characteristics of credence goods remain hidden, even after consumption.

technology choices has not passed unnoticed among scholars. However, this literature remains rather silent when it comes to some of the informational problems IGs and firms face when dealing with each other.[2] Firms need not know how problematic an IG views a certain (unethical) practice. Similarly, an IG cannot easily assess the costs a firm has to incur when adopting a less damaging technology or the future profits associated with the current technology. For example, when firms started developing genetically modified organisms to be used in pharmaceutical drugs, they did not know how much future opposition from IGs they would face. On the other hand, for IGs it is difficult to gauge the commercial value of a yet-to-be-developed drug.

As can be gathered from the literature on bargaining, uncertainty can be instrumental in delaying the resolution of conflicts, i.e. in creating *impasses*.[3] Moreover, we argue that uncertainty can also lead to futile attempts at activism: valuable resources are wasted without leading to the desired change. These consequences of uncertainty are overlooked by the existing literature. To fill this gap, we focus on the informational issues that arise when an IG tries to influence the technology choices of a firm.[4] In our game with two-sided asymmetric information an IG can request a firm to adopt a 'clean' technology instead of the damaging technology it is currently using. Both the IG and the firm are imperfectly informed about their rival's type: the IG does not know how costly it is for the firm to switch to the clean technology, whereas the firm does not know the *saliency* of the issue at stake as perceived by the IG. This saliency is either high or low. So, both the IG and the firm possess private information regarding payoff-relevant parameters. The IG threatens to initiate a campaign aimed at informing consumers about the firm's malpractice should the firm not acquiesce to its request. Consumers are heterogeneous with respect to how ethically motivated they are. If a consumer learns about the damage, then this consumer's willingness-to-pay is reduced.

The IG can reinforce its request to switch to the clean technology by trying to convey to the firm that it cares a great deal about the firm's malpractice. It can do so by, for instance, offering the firm's CEO an ostentatiously expensive report regarding the firm's conduct or by paying the firm a visit accompanied by independent experts who require hefty paychecks. In the parlance of information economics the IG can engage in *money burning* to *signal* to the firm that it is a *high type*, i.e. has a high

[2]We do not touch upon the informational problems associated with monitoring firms or their production practices or those associated with informing consumers. These problems certainly play an important role in the interactions between firms and IGs, but they are beyond the scope of the present paper.

[3]See Cramton (1992) and the references mentioned therein.

[4]See Lewis (1996) for an account of the various approaches a *regulator* trying to reduce pollution can pursue when costs and benefits of abatements are privately known.

saliency.[5] After the IG has communicated its request (possibly in conjunction with money burning) to the firm, the firm decides whether or not to switch to the clean technology. This decision is observed by the IG. If the firm does not switch, then money burning was futile and an IG campaign ensues. The more the IG cares about the issue at stake, the more effort it expends during the campaign. A more concerned IG consequently informs a larger fraction of the consumer population, leading to a larger reduction in sales and therefore in the firm's profit. We focus on equilibria in which the high type does indeed burn money, i.e. on *separating* equilibria.

As argued above, we are particularly interested in the incidence of impasses: despite the fact that the IG has conveyed to the firm that it cares a great deal, the firm continues to use the damaging technology. The IG consequently initiates a large and costly campaign that leads to a strong reduction in the firm's profit. Such situations might be particularly troublesome from a welfare point of view. Impasses occur repeatedly in practice, featuring prominently in case studies of strategic activism.[6] We find that in equilibrium impasses are less likely to occur as the saliency of the issue as perceived by the high type IG increases: a higher saliency implies that the firm has a stronger incentive to avoid the campaign by adopting the clean technology. Interestingly, the probability that an impasse occurs need not increase with the amount of uncertainty the IG faces. Detailed knowledge of the shape of the distribution from which the firm's cost of switching is drawn is thus essential for determining the likelihood that an impasse occurs.

The equilibrium amount of purely dissipative money burning the high type IG engages in increases in the saliency of the issue as perceived by this type. As the low type and high type IG become more alike (i.e. as the difference in their perceived saliencies decreases), the high type has to burn more money to separate itself from the low type. On the other hand, since knowing the IG's type plays a smaller role in the firm's technology choice the smaller the difference between the two types, the returns to burning money diminish as the difference between the two types decreases. The equilibrium amount of money burnt by the high type is therefore nonmonotonic in the 'distance' between the IG types.

[5]The role of money burning in our model is akin to the role played by costly advertising during the introductory phase of an experience good of unknown quality. See Milgrom and Roberts (1986).

[6]See for instance the case studies in Spar and La Mure (2003). The single case they discuss in which no impasse occurs deals with the pharmaceutical industry. The pharmaceutical company Novartis was keen to alter its behaviour when activists complained about the use of genetically modified organisms (GMOs). Novartis had just moved into the GMO area and it was therefore relatively easy for this firm to change its practices. Moreover, it had witnessed the fierce attacks by IGs on other pharmaceutical companies and was thus aware of the saliency of the issue. Our model indeed predicts that impasses do not occur if the firm can easily change its practices and the saliency of the issue at stake is high.

We compare the equilibrium of our model with the equilibrium of a benchmark model in which all parties involved - consumers, the firm, and the IG - are perfectly informed ex ante about the damage the firm causes, the firm's cost structure, and the IG type. Some consumers reap the benefits of perfect information: in the benchmark situation the firm charges a lower price thereby leaving some surplus to consumers who do not care much about the issue at stake. Since the IG does not have to inform consumers, it is better off in the bechmark situation. The firm is obviously worse off in the benchmark situation: it is no longer in a position to appropriate any informational rents and is forced to switch far more often than in the incomplete information setting. Total welfare can be higher or lower in the latter setting.

The above welfare comparison exposes an important aspect of the way a consumer's payoff is determined. We have modelled the damage caused by the firm as a credence attribute: a consumer's utility is only affected by the notion that the firm might be causing damage if the consumer learns about it from an outside source. Information about the damage is thus an 'eyeopener': without this information the consumer lives in blissful ignorance. Under the alternative assumption that consumers always learn about the damage *ex post*, those consumers who bought the product do experience the disutility associated with buying a product that does not meet their ethical standards. Under this alternative information structure, total welfare is unambiguously higher in the complete information benchmark situation. Yet, even if consumers always learn about the damage ex post, then still the IG does not improve the expected total welfare of market participants. The reason is that the IG blocks socially desirable trades if the firm sticks to the damaging technology.

Baron (2001) was among the first to argue that asymmetric information crucially affects strategic activism. In his model with one-sided asymmetric information the IG need not know the saliency of the issue at stake as perceived by *consumers*. The firm has private information about this saliency. In equilibrium an IG's request for change is rejected by firms with low-saliency issues.[7] In Baron's (2001) model the IG's campaign brings about an exogenous downward shift in demand. In our model this shift is endogenous and it depends on the saliency of the issue as perceived by the *IG*. In contrast to Baron (2001), we allow for costly signalling by the IG.

Feddersen and Gilligan (2001) consider a setting with two price-taking firms supplying imperfect substitutes. An IG can investigate one firm and convey to consumers whether the firm's production practices (a credence attribute) are damaging or clean. Because the IG does not incur any costs and prices are exogenous, Fed-

[7] Note that in our model both the IG and the firm know how consumers respond to information about the damage.

dersen and Gilligan's IG wields considerable power. The IG's threat can therefore induce one firm or both firms to adopt the more expensive clean practices. The IG in Heijnen (2007) does incur costs. Specifically, in his model an IG can burn money in an attempt to convince consumers that a monopolist firm is using a very damaging technology. Just like in Feddersen and Gilligan (2001), there is no uncertainty regarding cost functions or the saliency of the issue. Heijnen (2007) shows that the IG can support equilibria in which the firm chooses a less damaging technology. Both Feddersen and Gilligan (2001) and Heijnen (2007) consider one-sided asymmetric information and their analyses do not feature impasses.

The remainder of this paper is organized as follows. In the next section we introduce the model. Section 4.3 contains the derivation of equilibria and comparative statics results. The welfare analysis can be found in Section 4.4. Section 4.5 concludes. Some proofs are relegated to the appendix.

4.2 The Model

An interest group (IG) is concerned about some externality caused by a monopolistic firm producing a single good. For the sake of brevity we call the extent of the externality the amount of damage. To combat the damage the IG can contact the firm and request the latter to change its behaviour. The firm can do so, but this is costly. Specifically, it can adopt a new, 'clean' technology with associated constant marginal cost of production of $c \geq 0$. This choice is denoted $\delta = 1$. It can also ignore the IG's request and continue using the current, damaging technology ($\delta = 0$). The costs of the damaging technology are normalized to zero. The IG does not know c, but it does know that c is drawn from a distribution with full support $[0, 1]$. The associated cumulative distribution function (c.d.f.) is denoted F.

The firm has no reason to switch to the new technology should the IG refrain from any further action. The IG can, however, initiate a campaign. This campaign is aimed at reducing the attractiveness of the firm's product for consumers. During the campaign the IG informs some of the consumers about the damaging aspects of the firm's production practices. This information reduces a consumer's willingness-to-pay for the firm's product. Specifically, an uninformed consumer has a willingness-to-pay of 1, whereas an informed consumer has a willingness-to-pay of $1 - \theta$. The parameter θ varies among consumers and captures the disutility an individual consumer experiences from buying a good from a firm causing the externality under consideration. We assume that there is a unit mass of consumers and that a consumer buys one unit of the product or refrains from buying. A consumer's θ is a draw from the uniform distribution with support $[0, 1]$. The IG does not know the θ of individual consumers and is thus unable to target consumers who would experience a relatively large disutility associated with the externality. So, the average θ of informed consumers ($\frac{1}{2}$) is the same as the average θ of uninformed consumers.

Observe that the firm fully extracts consumers' surplus by charging a price of 1 and selling one unit to each consumer if there is no campaign, irrespective of the technology that is being used. On the other hand, if the firm sticks to the old technology and the IG manages to inform a fraction γ of the consumers, then demand for the product is

$$q(\gamma) = \gamma(1 - p) + 1 - \gamma, \tag{4.1}$$

as long as $p \leq 1$.

Informing consumers is costly. If the IG informs a fraction γ of the consumers, then it incurs a cost of γ^2. We call the fraction of the consumers the IG informs the *campaign size*. The optimal campaign size, γ^*, depends on the saliency a of the issue at stake (as perceived by the IG). This saliency is either high, $a = \bar{a}$, or low, $a = \lambda\bar{a}$ for some $\lambda \in (0, 1)$, where λ measures the distance between the high type IG and the low type IG.[8] We assume that $\bar{a} < 1$. If the IG is only slightly concerned about the damaging aspects of the firm's behaviour ($a = \lambda\bar{a}$), then γ^* will be small. Conversely, an outraged IG ($a = \bar{a}$) will inform a considerable part of the population. The utility function of the IG if the old technology is used (for given a), G_a, captures this relation:

$$G_a(\gamma) = -aq(\gamma) - \gamma^2. \tag{4.2}$$

The first part of (4.2) captures the IG's disutility associated with the damage the firm causes. Note that this disutility increases in the saliency a. The IG has a utility of 0 if the new technology is used.

Clearly, a more concerned IG initiates a larger campaign should the firm ignore the IG's demands. Consequently, if the firm knew the saliency a, then it would be more inclined to switch to the clean technology if a were large. However, just like the IG, the firm does not know its opponent's type. The firm merely knows that a equals $\bar{a}$ with probability ϕ and $\lambda\bar{a}$ with the complementary probability $1 - \phi$. Consequently, the firm only switches to the more expensive clean technology if it suspects a to be relatively large compared to its marginal cost c.

The IG can try to signal a large a by 'burning money'. To give an example, the IG could present an ostentatiously expensive report regarding the firm's conduct to the firm. If the firm does believe that a must be large after having received such a

[8] Any future reference to low types or high types pertains to IG types unless stated otherwise.

report, then it is more inclined to switch to the clean technology, i.e. preempt the IG's campaign. Burning money can therefore be optimal for the IG. Obviously, this mechanism is only present if burning money is truly costly for the IG and therefore only used by high types, i.e. only if $a = \bar{a}$. We denote the amount (in utils) of money burnt by $m = m(a)$. So, if the IG burns an amount m, then its payoff is $G_a(\gamma) - m$ if the firm does not switch and its payoff is $-m$ if the firm does switch.

The firm and the IG are involved in a game with two-sided asymmetric information. This game consists of five stages. In the first stage Nature draws a (the private information of the IG) and c (the private information of the firm). In the second stage the IG requests the firm to alter its behaviour. It can opt to reinforce its arguments by burning money. The firm subsequently chooses in the third stage whether or not to switch to the new technology. If the firm decided to stick to the damaging technology, then the IG initiates a campaign in the fourth stage. If the firm adopted the clean technology, then nothing happens in the fourth stage. In the last stage the firm sets a price, sells its product, and payoffs are realized. If the IG campaigned in the fourth stage, then demand in this stage is governed by (4.1). If the IG refrained from campaigning, then total sales equal 1.

In the next section we look for perfect Bayesian Nash separating equilibria (see for instance Fudenberg and Tirole, 1991, chapter 8) in pure strategies of this game (loosely called equilibria of the game). Strategies must thus be best responses given the history of play and given beliefs and beliefs are updated using Bayes' Rule whenever applicable.[9] Of course, an equilibrium must be consistent with backward induction. An equilibrium is supported by a second stage amount of money burnt $m^*(a)$, a third stage switching rule $\delta^*(m, c)$, a campaign size $\gamma^*(a)$ if $\delta = 0$, and a pricing rule $p^*(\gamma)$ if the IG initiates a campaign (recall that the firm charges a price of 1 if no campaign ensues). Throughout we assume that the interest group 'wins' any ties.[10] We focus on equilibria which meet Cho and Kreps's (1987) Intuitive Criterion.

4.3 Analysis

Suppose the firm continues to use the old, damaging technology. If the IG opts for a campaign size γ in the fourth stage, then in the next stage the firm's price choice

[9] Note that since the IG's payoff does not depend on the firm's type c, we can ignore any updating the IG engages in.

[10] This tie-breaking rule only affects probability zero-events.

equals

$$\operatorname*{argmax}_{p\le 1} p(1-\gamma p),$$

resulting in:

$$p^* = \begin{cases} 1 & \text{if } \gamma \le \frac{1}{2} \\ \frac{1}{2\gamma} & \text{if } \gamma > \frac{1}{2}. \end{cases}$$

The associated equilibrium sales read $1-\gamma$ if $\gamma \le \frac{1}{2}$ and $\frac{1}{2}$ if $\gamma > \frac{1}{2}$. The equilibrium campaign size consequently solves

$$\max\left\{ \max_{\gamma\le\frac{1}{2}} -a(1-\gamma)-\gamma^2, \sup_{\gamma>\frac{1}{2}} -a\times\tfrac{1}{2}-\gamma^2 \right\}.$$

This program yields $\gamma^*(a) = \frac{a}{2}$, a number which never exceeds $\frac{1}{2}$. The equilibrium price thus always equals 1.[11] The firm's equilibrium profit with the old, damaging technology equals

$$\pi(a) = 1-\frac{a}{2}. \tag{4.3}$$

The above calculations reveal that the firm simply gives up on informed consumers. By charging a price of 1 it is able to fully extract the surplus of uninformed consumers, but at the same time loses every single informed consumer. As long as the uninformed part of the market is larger than the informed part, ignoring informed consumers costs less than reducing the price to attract informed consumers, leaving uninformed consumers with some rents. It is not surprising that the IG enforces this outcome. If γ were such that the firm's price choice would depend on γ, i.e. if $\gamma > \frac{1}{2}$, then the effect of the IG's campaign on sales would be fully offset by the pricing behaviour of the firm. Informing half the population has exactly the same effect on sales and thus the same effect on the amount of damage as informing more than half the population (equilibrium sales equal $\frac{1}{2}$ for all $\gamma \ge \frac{1}{2}$).

In stage three the firm decides to switch to the clean technology if the resulting profit, which is $1-c$, is at least as large as its expected profit with the damaging technology, where the expectation is taken with respect to the firm's belief regarding a. Note that $G_a(\gamma^*(a)) = -a(1-\frac{a}{4})$ decreases in a. In other words, the payoff of the IG should the firm not switch to the clean technology decreases in the saliency a. Consequently, if money burning does occur in equilibrium, then the high type burns weakly more than the low type. In fact:

Lemma 4.1 *In any separating equilibrium the high type IG burns a strictly positive amount of money and the low type IG does not burn money.*

[11] Because the firm also sets a price of 1 if it does not cause any damage or if no consumer learns about the externality, uninformed consumers cannot infer from the firm's equilibrium pricing strategy that something is wrong with the firm's production practices.

Proof. Suppose the contrary, i.e. $m^*(\lambda\bar{a}) > 0$ in some separating equilibrium. Note that from the low type's perspective, the worst beliefs the firm could entertain after observing an out-of-equilibrium move (i.e. be convinced that the IG is a low type) do not differ from those the firm entertains along the equilibrium path of a separating equilibrium. This immediately implies that the low type has an incentive to deviate to burning nothing, thereby destroying the equilibrium. If the high type does not burn money, then the equilibrium cannot be separating. ■

Consider a separating equilibrium. In such an equilibrium the firm infers that the IG is a high type after observing money burning. The firm subsequently switches to the clean technology if $1 - c \geq 1 - \frac{\bar{a}}{2}$ or, equivalently, if $c \leq \frac{\bar{a}}{2}$. On the other hand, if no money burning occurs, then the firm is convinced that it deals with a low type. The firm then only switches if $c \leq \frac{\lambda\bar{a}}{2}$. For the high type it can thus only be worthwile to burn an amount x if:

$$-(1 - F(\tfrac{\bar{a}}{2})) \times \bar{a}(1 - \tfrac{\bar{a}}{4}) - x \geq -(1 - F(\tfrac{\lambda\bar{a}}{2})) \times \bar{a}(1 - \tfrac{\bar{a}}{4}),$$

where we have used the fact that the high type IG experiences a disutility of $G_{\bar{a}}(\gamma^*(\bar{a})) = -\bar{a}(1 - \frac{\bar{a}}{4})$ should the firm not meet the IG's demands. To avoid the low type from mimicking the high type x must be such that:

$$-(1 - F(\tfrac{\bar{a}}{2})) \times \lambda\bar{a}(1 - \tfrac{\lambda\bar{a}}{4}) - x \leq -(1 - F(\tfrac{\lambda\bar{a}}{2})) \times \lambda\bar{a}(1 - \tfrac{\lambda\bar{a}}{4}). \qquad (4.4)$$

Note that since $a(1 - \frac{a}{4})$ strictly increases in a and $\lambda < 1$, these two conditions for existence of a separating equilibrium hold simultaneously for some non-empty, closed interval of x-values. Combining these observations with the preceding analysis yields:

Proposition 4.1 *For each*

$$x \in X := \Big[\big(F(\tfrac{\bar{a}}{2}) - F(\tfrac{\lambda\bar{a}}{2})\big) \times \lambda\bar{a}(1 - \tfrac{\lambda\bar{a}}{4}), \big(F(\tfrac{\bar{a}}{2}) - F(\tfrac{\lambda\bar{a}}{2})\big) \times \bar{a}(1 - \tfrac{\bar{a}}{4})\Big]$$

there exists a separating equilibrium supported by the following strategies:[12]

- *Second stage money burning rule:* $m^*(a) = \begin{cases} 0 & \text{if } a = \lambda\bar{a} \\ x & \text{if } a = \bar{a} \end{cases}$,

[12] One easily verifies that no IG type has an incentive to deviate from the specified rules if the firm attaches probability 1 to the IG being of low type after observing an amount of money burnt $m \in [0, x)$. The set of equilibrium outcomes emanating from the equilibria presented in this proposition is not exhaustive. Pooling equilibria in which neither IG type burns money or in which both types burn money also exist. These are supported by beliefs of the firm which attach sufficient probability weight to the low type should an out-of-equilibrium move occur.

- *Third stage switching rule:* $\delta^*(m,c) = \begin{cases} 1 & \text{if } c \leq \frac{\lambda\bar{a}}{2} + \frac{(1-\lambda)\bar{a}}{2} \times \mathbf{1}_{\{m \geq x\}}(m) \\ 0 & \text{if } c > \frac{\lambda\bar{a}}{2} + \frac{(1-\lambda)\bar{a}}{2} \times \mathbf{1}_{\{m \geq x\}}(m) \end{cases}$,
- *Fourth stage campaign size rule:* $\gamma^*(a) = (1-\delta)\frac{a}{2}$,
- *Fifth stage pricing rule:* $p^* \equiv 1$,

where $\mathbf{1}_A$ *is the indicator function of a set* A.[13] *The equilibrium in which an amount* x *is burnt (henceforth* equilibrium x*) is supported by updated beliefs of the firm which attach probability* 1 *to the event that the IG is a high type after an amount* $m \geq x$ *is burnt and probability* 0 *to that event if an amount* $m < x$ *is burnt.*

Clearly, the high IG type is strictly better off in equilibrium x_1 than in equilibrium x_2 for all $x_1, x_2 \in X$ such that $x_1 < x_2$. With the aid of the Intuitive Criterion of Cho and Kreps (1987) we can therefore discard all but one of the equilibria mentioned in Proposition 4.1:

Proposition 4.2 *Equilibrium* m^* *is the unique separating equilibrium satisfying the Intuitive Criterion, where*

$$m^* := \min_{x \in X} x = \left(F(\tfrac{\bar{a}}{2}) - F(\tfrac{\lambda\bar{a}}{2})\right) \times \lambda\bar{a}(1 - \tfrac{\lambda\bar{a}}{4}). \tag{4.5}$$

Proof. Consider equilibrium x for some $x > m^*$ and fix an out-of-equilibrium amount of money burnt $m \in [m^*, x)$. The low type has no incentive to deviate to m, for the resulting payoff is strictly less than its equilibrium payoff of $-(1 - F(\frac{\lambda\bar{a}}{2})) \times \lambda\bar{a}(1 - \frac{\lambda\bar{a}}{4})$ for *any* out-of-equilibrium beliefs the firm might entertain: condition (4.4) informs us that the low type is worse off after burning an amount m even if the firm is convinced to be dealing with a high type after this amount has been burnt. The Intuitive Criterion now prescribes that it is not *reasonable* for the firm to believe that the message m could possibly be sent by the low type, i.e. upon observing m the firm must be convinced to be dealing with a high type and act accordingly.[14] So, after an amount m has been burnt the firm switches to the new technology. The high type consequently has an incentive to deviate to m. Equilibrium x therefore fails to meet the Intuitive Criterion. ■

Our main interest lies in the relation between the amount of uncertainty faced by the players and the (expected) outcomes of the game. We focus in particular on the amount of money burnt by the high type and on the occurrence of *impasses*:

[13] So, $\mathbf{1}_A(x) = 1$ if $x \in A$ and $\mathbf{1}_A(x) = 0$ if $x \neq A$.

[14] An example of reasonable beliefs that meet the Intuitive Criterion reads $\Pr(a = \bar{a}|x) = \mathbf{1}_{\{x \geq m^*\}}(x)$.

Definition 4.1 *An* impasse *occurs if the firm does not switch to the new technology despite the fact that the IG has conveyed to the firm to be a high type ($a = \bar{a}$) by burning money.*

The equilibrium probability ρ^* that an impasse occurs is:

$$\rho^* = \Pr(m = m^*) \times \Pr(\delta^*(m^*, c) = 0) = \phi(1 - F(\tfrac{\bar{a}}{2})). \tag{4.6}$$

Money burning and impasses are phenomena which (in the present framework) only occur in the presence of informational asymmetries. The amount of money burnt and the ex ante probability that an impasse occurs therefore indicate the impact of such asymmetries. These measures depend on the distribution of types. The distribution of IG types a is completely determined by the parameters λ, $\bar{a}$, and ϕ. These parameters imply that the variance of a equals $\phi(1-\phi)(1-\lambda)^2\bar{a}^2$. One can view this number as the amount of ex ante uncertainty the firm faces.

To operationalize the amount of uncertainty the IG faces we consider the following class of c.d.f.'s $(F_k)_{k \geq 1}$:

$$F_k(z) = k\binom{2k-1}{k}\int_0^z t^{k-1}(1-t)^{k-1}\,\mathrm{d}t, \quad z \in [0,1], \quad k \geq 1. \tag{4.7}$$

This is the c.d.f. of the Beta(k,k)-distribution.[15] It has mean $\frac{1}{2}$ and variance $\frac{1}{4(2k+1)}$. Note that the variance of the Beta(k,k)-distribution decreases monotonically from $\frac{1}{12}$ ($k = 1$, the uniform distribution) to 0 ($k \to \infty$, the degenerate distribution with $\Pr(c = \frac{1}{2}) = 1$). This feature allows us to vary the amount of uncertainty the IG faces by simply varying k: a smaller k means more uncertainty. In other words, $\frac{1}{k}$ measures the amount of uncertainty the IG faces. We denote the density function of the Beta(k,k)-distribution by f_k.

The following results regarding the amount of uncertainty each player faces and the outcomes of the game can be obtained:

Proposition 4.3 *In equilibrium $m^* = m^*(\bar{a}, \lambda, \phi, k)$, the ex ante probability that an impasse occurs, $\rho^* = \phi(1 - F_k(\frac{\bar{a}}{2}))$, decreases in the saliency of the issue $\bar{a}$ as perceived by the high type IG, does not vary with the distance λ between the high type and low type IG, increases in the probability ϕ that the IG is a high type, and decreases in the amount of uncertainty $\frac{1}{k}$ the IG faces.*

The amount of money burnt, m^*, increases in the saliency of the issue $\bar{a}$ as perceived by the high type IG and does not vary with the probability ϕ that the IG is a high type. Furthermore:

[15] See for instance Mood et al. (1974), pp. 115-116, for a concise discussion of this class of distributions.

- *There exists a* $\bar{\lambda} = \bar{\lambda}(\bar{a}, k) \in (0, 1)$ *such that* m^* *increases in the distance* λ *between the high type and low type IG if* $\lambda < \bar{\lambda}$, *whereas* m^* *decreases in* λ *if* $\lambda > \bar{\lambda}$,
- *If* $\bar{a} \leq \frac{1}{2} - \frac{1}{2}\sqrt{\frac{1}{2k+1}}$, *then* $m^*(\bar{a}, \lambda, \phi, k+1) - m^*(\bar{a}, \lambda, \phi, k) < 0$. *On the other hand, if* $\bar{a} > \frac{1}{2} - \frac{1}{2}\sqrt{\frac{1}{2k+1}}$, *then* $m^*(\bar{a}, \lambda, \phi, k+1) - m^*(\bar{a}, \lambda, \phi, k) \leq 0$ *as long as* $\lambda \leq \hat{\lambda}$ *and* $m^*(\bar{a}, \lambda, \phi, k+1) - m^*(\bar{a}, \lambda, \phi, k) > 0$ *if* $\lambda > \hat{\lambda}$ *for some* $\hat{\lambda} = \hat{\lambda}(\bar{a}, k) \in (0, 1)$.

Proof. See the appendix. ■

The comparative statics results with respect to the probability that an impasse occurs have an intuitive appeal. As the saliency of the issue as perceived by the high type ($\bar{a}$) increases, the firm faces a larger campaign should it ignore the IG's request for change. The firm is therefore more inclined to switch to the clean technology and the probability that the firm does not switch after inferring that the IG is a high type $(1 - F_k(\frac{\bar{a}}{2}))$ consequently decreases. Since by definition impasses have nothing to do with low types, ρ^* does not depend on λ. By the same token, impasses are more likely to occur if the IG is more often a high type. As the amount of uncertainty the IG faces increases (k decreases), the probability that c is less than $\frac{\bar{a}}{2}$ and thus the probability that the firm meets the IG's demands increases. In other words, the probability that an impasse occurs decreases.[16] So, an increase in uncertainty can coincide with an increase in the probability that c is in the 'right' interval. In fact, this always occurs if c is Beta(k,k)-distributed, leading to the surprising conclusion that impasses happen less often if the amount of uncertainty the IG faces is larger.

Next, we turn to the comparative statics with respect to the amount of money burnt. If $\bar{a}$ increases, then both IG types lose more should the firm not switch to the new technology. This implies that the low type's incentives to mimic the high type increase. The fact that m^* does not depend on ϕ is a standard feature of equilibria of signalling games. To discourage the low type from such mimickry, the high type is forced to burn more money. A close look at m^* reveals that the amount of money burnt is governed by two effects: the impact money burning has on the probability that the firm switches (the first part of (4.5), i.e. $F_k(\frac{\bar{a}}{2}) - F_k(\frac{\lambda\bar{a}}{2})$) and the impact it has on the low type's payoff should this type be able to convince the firm to switch (the second part of (4.5), i.e. $\lambda\bar{a}(1 - \frac{\lambda\bar{a}}{4})$). As λ increases the first effect becomes less

[16] This last result hinges admittedly on the focus on the Beta(k,k)-distributions. These distributions are such that their mean ($\frac{1}{2}$) is located to the right of $\frac{\bar{a}}{2}$. If the mean of the distribution from which c is drawn would be located to the left of $\frac{\bar{a}}{2}$, then the same reasoning would yield a different conclusion: ρ^* *increases* in the amount of uncertainty.

important: an increase in λ implies that the probability $F_k(\frac{\bar{a}}{2}) - F_k(\frac{\lambda\bar{a}}{2})$ decreases. If this mechanism were the sole driving force behind m^* as a function of λ, then the amount of money burnt would decrease in the distance λ. However, an increase in λ also means that the low type loses more should the firm not switch, thereby increasing the low type's incentives to mimic the high type and thus forcing the latter to burn more. If λ is relatively small the 'payoff effect' dominates the 'probability effect'. The opposite is true if λ is relatively large. This explains the nonmonotonicity of $\frac{\mathrm{d}m^*}{\mathrm{d}\lambda}$.

Note that the change in the amount of money burnt as k changes is proportional to the change in $F_k(\frac{\bar{a}}{2}) - F_k(\frac{\lambda\bar{a}}{2})$. If $\bar{a}$ and λ are relatively small, then an increase in k pushes probability mass out of the interval $[\lambda\bar{a}, \bar{a}]$ towards the mean of the distribution, which is located to the right of this interval. In this case an increase in k thus leads to a decrease in the probability $F_k(\frac{\bar{a}}{2}) - F_k(\frac{\lambda\bar{a}}{2})$ and consequently a decrease in the amount burnt. If, however, $\bar{a}$ is sufficiently large, then an increase in k leads to an increase in the probability density in the point $\bar{a}$, i.e. $f_{k+1}(\bar{a}) > f_k(\bar{a})$. If in addition λ is sufficiently close to 1, then also $f_{k+1}(\lambda\bar{a}) > f_k(\lambda\bar{a})$. It follows that $F_k(\frac{\bar{a}}{2}) - F_k(\frac{\lambda\bar{a}}{2})$ increases in k and therefore that the high type burns more money as k increases (i.e. the amount of uncertainty the IG faces decreases) if both $\bar{a}$ and λ are sufficiently large. If $\bar{a}$ is relatively large, but the distance between the low type and the high type is considerable (λ sufficiently small), then we are back to the first possibility: $F_k(\frac{\bar{a}}{2}) - F_k(\frac{\lambda\bar{a}}{2})$ decreases as k increases. Observe that the IG's gain associated with money burning is proportional to the probability $F_k(\frac{\bar{a}}{2}) - F_k(\frac{\lambda\bar{a}}{2})$ that it affects the firm's third stage behaviour. The above explanation can thus be summarized as follows: the high type burns more money as k changes if this change in k leads to a larger probability that money burning is pivotal in the firm's equilibrium choice of technology.

4.4 Welfare

In order to assess the welfare implications of uncertainty we compare the payoffs of all agents (consumers, the firm, and the IG) in equilibrium m^* (for arbitrary c.d.f. F) with their payoffs in the equilibrium of the following complete information benchmark. In the benchmark game a and c become common knowledge right after these are drawn by Nature. Moreover, at the same time all consumers become aware of the damaging aspects of the firm's production practices. Clearly, if all players are perfectly informed, then the IG has nothing to do: both money burning and campaigning are redundant. The benchmark game therefore consists of only three stages. After Nature has drawn a and c, the firm decides whether it switches to the new technology in the second stage. In the last stage the firm sets a price, sells its product, and payoffs are realized. We now derive the unique equilibrium of this game.

Note that in the last stage demand equals $q = 1 - p$ (this is equation (4.1) evaluated at $\gamma = 1$) if the firm continues to use the old technology. So, if the firm does not switch ($\delta = 0$), then it charges $\tilde{p}(0) = \frac{1}{2}$ and it makes a profit of $\tilde{\pi}(0) = \frac{1}{4}$. If the firm does switch to the clean technology ($\delta = 1$), then it charges $\tilde{p}(1) = 1$ and its net profit reads $\tilde{\pi}(1) = 1 - c$. Comparing the two profit expressions yields the firm's optimal strategy which leads to:

Proposition 4.4 *In the equilibrium of the complete information benchmark game the firm employs the following strategy:*

- *Second stage switching rule:* $\tilde{\delta}(c) = \mathbf{1}_{\{c \leq \frac{3}{4}\}}$,
- *Third stage pricing rule:* $\tilde{p}(\delta) = \frac{1}{2} + \frac{1}{2}\delta$.

The firm's equilibrium behaviour is simple: switch to the new technology if such a switch is not too costly. Contrary to the equilibrium of the game with incomplete information, the firm faces an everywhere downward-sloping demand curve if it does not switch. The equilibrium price $\tilde{p}(0)$ is therefore less than 1.

We now move on to the welfare comparison. The relevant ex ante expected payoffs, i.e. the payoffs players expect to receive at the start of the game (before any types are drawn by Nature), are collected in the next lemma:

Lemma 4.2 *In equilibrium m^* of the incomplete information game the ex ante expected payoffs are as follows:*

- *Ex ante expected consumers' surplus:* $E(CS^*) = 0$,
- *Ex ante expected profit:*

$$E(\pi^*) = 1 - (1-\phi)\Big(\int_0^{\frac{\lambda\bar{a}}{2}} t \, \mathrm{d}F(t) + \int_{\frac{\lambda\bar{a}}{2}}^1 \tfrac{\lambda\bar{a}}{2} \, \mathrm{d}F(t)\Big) - \phi\Big(\int_0^{\frac{\bar{a}}{2}} t \, \mathrm{d}F(t) + \int_{\frac{\bar{a}}{2}}^1 \tfrac{\bar{a}}{2} \, \mathrm{d}F(t)\Big),$$

- *Ex ante expected payoff of the IG:*

$$E(V^*) = -(1-\phi)\lambda\bar{a}(1 - \tfrac{\lambda\bar{a}}{4}) \int_{\frac{\lambda\bar{a}}{2}}^1 \mathrm{d}F(t) - \phi\bar{a}(1 - \tfrac{\bar{a}}{4}) \int_{\frac{\bar{a}}{2}}^1 \mathrm{d}F(t) - \phi m^*.$$

In the equilibrium of the complete information benchmark game the ex ante expected payoffs are as follows:

- *Ex ante expected consumers' surplus:* $E(\tilde{CS}) = \frac{1}{8}\big(1 - F(\frac{3}{4})\big)$,
- *Ex ante expected profit:* $E(\tilde{\pi}) = 1 - \Big(\int_0^{\frac{3}{4}} t\,\mathrm{d}F(t) + \int_{\frac{3}{4}}^{1} \frac{3}{4}\,\mathrm{d}F(t)\Big)$,
- *Ex ante expected payoff of the IG:* $E(\tilde{V}) = -\frac{1}{2}\big((1-\phi)\lambda\bar{a} + \phi\bar{a}\big)\big(1 - F(\frac{3}{4})\big)$.

Proof. See the appendix. ∎

One sees that some consumers are able to appropriate some surplus in the complete information benchmark. The equilibrium price is less than 1 in that scenario, implying that consumers with a small θ pay less than their willingness-to-pay of $1-\theta$. Since the IG cannot influence consumer behaviour in the benchmark setting, the expected profit of the firm does not depend on ϕ, $\bar{a}$, or λ in that setting. In equilibrium m^* though, expressions that do depend on these parameters are subtracted from the profit the firm would obtain should the old technology be perceived by all to be clean (this profit equals 1). Since the IG does not exert efforts in the complete information benchmark, the IG's expected payoff in that scenario only features the disutility associated with the externality the firm is causing. Efforts, both those related to informing consumers and those to burning money, do affect the IG's expected payoff in equilibrium m^*.

Comparing the payoffs under the two scenarios yields the following insights:

Proposition 4.5 *The firm benefits from the lack of information ($E(\pi^*) > E(\tilde{\pi})$), whereas both the consumers and the IG prefer the complete information setting ($E(CS^*) < E(\tilde{CS})$ and $E(V^*) < E(\tilde{V})$).*[17]

Proof. See the appendix. ∎

In the complete information scenario the firm sets a price of $\frac{1}{2}$. Consumers with a θ below $\frac{1}{2}$ therefore obtain a surplus when buying the firm's product. Since in equilibrium m^* the IG informs less than half the consumer population, the firm simply ignores the informed consumers and sets the price equal to 1, the willingness-to-pay of uninformed consumers. This strategy leads to zero consumer surplus. Consumers thus prefer the complete information benchmark. Suppose the firm continues to use the old technology. Then because in the complete information setting the firm

[17] To be precise, all consumers *weakly* prefer the complete information setting and some consumers (those with $\theta < \frac{1}{2}$), *strictly* prefer that setting.

charges a lower price and sells its product to less consumers compared to equilibrium m^*, the firm's profit is lower in the benchmark setting. This result is rather intuitive: as long as some consumers are unaware of the damage the firm is causing, the firm can set a price of 1 thereby extracting all surplus of uninformed consumers. The firm consequently switches more often in the benchmark setting, leading to a larger probability that the cost c is incurred. Lastly, the IG does not play an active role in the benchmark setting: supplying information to consumers is redundant in a setting with complete information. One could say that the costly task the IG has set for itself has already been performed in the benchmark setting. This obviously leads to a higher payoff for the IG in the latter setting.

We have not yet compared total welfare in equilibrium m^* with that in the equilibrium of the complete information benchmark. It turns out that these two quantities cannot be unambiguously ordered. Suppose for example that F is the uniform distribution and that $\bar{a} = \frac{3}{4}$. As λ approaches 0, $E(CS^* + \pi^* + V^*)$ goes to $\frac{512-351\phi}{512}$, whereas $E(\tilde{CS} + \tilde{\pi} + \tilde{V})$ converges to $\frac{18-3\phi}{32}$. It follows that total welfare in equilibrium m^* exceeds total welfare in the benchmark equilibrium if ϕ is sufficiently small. Conversely, if ϕ is very large, then total welfare is higher in the benchmark equilibrium. The reason is that the outcomes and payoffs of equilibrium m^* converge to the outcomes and payoffs of a situation in which no externality is present as both λ and ϕ approach 0. In fact, if $\lambda = 0$ and $\phi = 0$, then the IG is de facto absent (the IG is then with probability 1 a low type with zero saliency) and no consumer ever learns about the damage the firm is causing. A consumer's willingness-to-pay is then 1. By contrast, in the benchmark situation all consumers already know about the damage at the start of the game and a consumer's willingness-to-pay is less than 1, namely $1 - \theta$.

The last observation illustrates an important point: we have modelled the impact on consumers of the damage caused by the firm in such a way that consumers are only affected by the damage if they are informed about it. One could say that the consumers' ignorance regarding the externality is their bliss: they only experience the disutility θ if the IG informs them about the damage. The way the damage's impact on consumers' utility is modelled resembles the way Gabaix and Laibson (2006) model the interaction between *shrouded attributes* and *myopic* consumers. In their model myopic consumers do not consider any future expenses associated with a given product when purchasing that product as long as the seller shrouds these future expenses. An example of such future expenses is the price of a hotel breakfast which is not included in the rent of a room. The fact that you have to pay something extra to get breakfast does not cross the mind of myopic consumers making an online reservation if this information is not explicitly mentioned on the hotel's website. These consumers are unpleasantly surprised when they order breakfast. In contrast to the consumers in Gabaix and Laibson (2006), our consumers never learn about the downside of their purchases.[18]

As an alternative, one can assume that consumers who are not informed by the IG do learn about the firm's damaging practices ex post. This reduces an uninformed consumer's utility by θ. It could be that consumers learn about the externality because it is revealed through consumption. In that case the externality is no longer a credence attribute of the good, but an *experience* attribute.[19] We take this information to be an 'eyeopener', i.e. consumers who are not informed by the IG could not even imagine that something was wrong at the moment they bought the product. In other words, consumers are still myopic in the Gabaix and Laibson (2006)-sense. Note that consumers' myopia ensures that equilibrium m^* is also the unique equilibrium surviving the Intuitive Criterion with this alternative information structure.

If consumers learn about the externality ex post, then ex ante expected (that is, as expected by a nonmyopic outside observer at the start of the game before any types are drawn) consumers' surplus is reduced by[20]

$$(1-\phi)(1-\tfrac{\lambda\bar{a}}{2})\tfrac{1}{2}+\phi(1-\tfrac{\bar{a}}{2})\tfrac{1}{2}. \tag{4.8}$$

Total welfare is thus lower if consumers do learn about the externality ex post. In fact:

Proposition 4.6 *Suppose all consumers do learn about the externality ex post and that c is Beta(k,k)-distributed, $k \geq 1$.[21] Then total welfare, being the sum of ex ante expected consumers' surplus, profit, and the IG's payoff, is lower in equilibrium m^* than in the equilibrium of the complete information benchmark game.*

Proof. See the appendix. ■

[18] This discussion of consumer myopia hints at a second possible benchmark that might be of interest. In our benchmark each agent is fully informed. This does not only remove informational asymmetries, but it also removes the distinction between myopic and nonmyopic consumers. A benchmark in which the IG and the firm are omniscient, but in which consumers are unaware of the damage ex ante leaves this distinction intact. More details available from the author upon request.

[19] Alternatively, consumers could learn about the externality via a third party, for instance a regulator.

[20] To see this, note that with probability $1-\phi$ a fraction $1-\frac{\lambda\bar{a}}{2}$ of the consumers buys the product. These consumers experience a disutility of $\frac{1}{2}$ on average. With probability ϕ only a fraction $1-\frac{\bar{a}}{2}$ buys the product.

[21] The proposition holds for any distribution which is symmetric around $\frac{1}{2}$. We confine attention to the Beta(k,k)-distributions to keep the discussion in line with that of the previous section.

The difference between the situation of Proposition 4.5 and the situation of Proposition 4.6 is that in the latter case (ex ante expected) consumers' surplus in equilibrium m^* is much lower, because (4.8) is taken into account. In fact, the informational rents accruing to the firm ($E(\pi^* - \tilde{\pi})$) do not suffice to offset the aggravated disutility experienced by consumers (and the IG) caused by the lack of information. Returning to the numerical example mentioned above, if we subtract (4.8) evaluated at $\bar{a} = \frac{3}{4}$ and $\lambda = 0$ from consumers' surplus, then total welfare in equilibrium m^* is *less* than total welfare in the complete information setting irrespective of the value of ϕ.

Let us now turn attention to the impact the IG has on welfare. The above insights highlight the role the IG plays in equilibrium m^* with the alternative information structure: it alleviates (at the expense of the firm) the loss in consumers' surplus stemming from the externality the firm is causing by informing consumers before the market opens. Yet, the IG's actions only have significant impact on market outcomes if the IG 'cares a lot' ($\bar{a}$, λ, ϕ large) and is consequently willing to exert considerable efforts in order to 'persuade' the firm to alter its behaviour.[22] If the IG does not care a lot ($\bar{a}$, λ, ϕ small), then the IG's impact on the market is insignificant and most consumers suffer from the damage the firm is causing should they learn about this externality after having purchased the firm's product. This observation is formalized as follows:

Proposition 4.7 *Suppose all consumers do learn about the externality ex post. Then in equilibrium m^* ex ante expected consumers' surplus increases in $\bar{a}$, λ, and ϕ. Ex ante expected profit decreases in $\bar{a}$, λ, and ϕ. If c is Beta(k,k)-distributed, $k \geq 1$, then the sum of these two surplusses decreases in $\bar{a}$, λ, and ϕ.[23] Total welfare is consequently maximal if the IG is absent, i.e. if $\bar{a} = 0$ or $\lambda = \phi = 0$.*

Proof. See the appendix. ■

The reason that total surplus of the market participants (and thus total welfare) is maximal in the absence of the IG stems from the fact that the IG blocks socially desirable trades should the firm not adopt the clean technology. Note that even if consumers learn ex post about the damage and see their utility being reduced by θ, then still the associated trades are ex post socially desirable: $1 - \theta \geq 0$ for all θ. Yet, the incentive compatability constraint is ex post violated for almost all buying consumers: $-\theta < 0$ if $\theta > 0$.

[22] The reduction in consumers' surplus (4.8) decreases in $\bar{a}$, λ, as well as ϕ.

[23] Again, only symmetry of the distribution around $\frac{1}{2}$ is required.

4.5 Concluding Remarks

We have developed a simple framework that allows us to study strategic activism by an interest group aimed at a monopolistic firm. The IG seeks to mitigate the extent of some externality, for instance pollution, the firm is causing. Importantly, both the IG and the firm are imperfectly informed about each other's payoff function. The IG does not know how costly it is for the firm to adopt some less damaging technology, whereas the firm does not know how salient the IG perceives the externality to be. The IG initiates a campaign during which it informs consumers about the firm's malpractice should the firm not meet the IG's request to adopt the less damaging technology. Without the IG's campaign consumers remain ignorant about the firm's behaviour. To avoid such a costly campaign, the IG can signal to the firm that it cares a lot by burning money, e.g. it offers the firm's management an ostentatiously expensive report regarding the firm's production practices.

We find that the fact that both the IG and the firm are imperfectly informed not only causes purely dissipative signalling, but also that it can lead to impasses. An impasse occurs if the firm ignores the IG's request despite the fact that the IG has signalled to care a lot. Surprisingly, the probability that an impasse occurs need not increase with the amount of uncertainty the IG faces. Our welfare analysis reveals that whether or not consumers learn about the externality ex post (i.e. after purchasing the product) is crucial. This informational assumption does not affect the outcomes of the game, but it does affect total welfare. Total welfare is unambiguously higher in a complete information benchmark if consumers do learn about the externality ex post. Yet, ignorance can be bliss: if consumers can only learn about the externality via an IG campaign, then total welfare can be higher in the incomplete information setting.

Our analysis is admittedly limited. The current framework precludes competition. It would be interesting to investigate a situation with multiple firms. We conjecture that with multiple firms only a subset of the firms adopt the less damaging technology, for this creates vertical product differentiation between adopters and non-adopters. This differentiation can be beneficial for both adopters and non-adopters. Secondly, we have considered a one-shot game, eschewing any dynamics. Adding dynamics to the model presumably results in new insights and might allow one to quantify the duration of impasses. We leave these issues for future research.

4.A Appendix

Proof of Proposition 4.3

The comparative statics of ρ^* with respect to $\bar{a}$, λ, and ϕ are obvious. To prove that ρ^* decreases in $\frac{1}{k}$ it suffices to show that $F_k(\frac{\bar{a}}{2}) > F_{k+1}(\frac{\bar{a}}{2})$ for every $k \geq 1$. Since the density function of the Beta(k,k)-distribution is symmetric around $\frac{1}{2}$, we know that $F_k(\frac{1}{2}) = F_{k+1}(\frac{1}{2}) = \frac{1}{2}$. The inequality $F_k(\frac{\bar{a}}{2}) > F_{k+1}(\frac{\bar{a}}{2})$ therefore follows if $\frac{F_{k+1}(t)}{F_k(t)}$ is strictly increasing in t, $t \in (0, \frac{1}{2})$. Note that for $t \in (0, \frac{1}{2})$:

$$\begin{aligned}\frac{\mathrm{d}}{\mathrm{d}t}\Big[\frac{F_{k+1}(t)}{F_k(t)}\Big] &= \frac{t^k(1-t)^k \int_0^t x^{k-1}(1-x)^{k-1}\,\mathrm{d}x - t^{k-1}(1-t)^{k-1}\int_0^t x^k(1-x)^k\,\mathrm{d}x}{c_k^{-1}\big(F_k(t)\big)^2} \\ &= \frac{t^{k-1}(1-t)^{k-1} \times \Big(\int_0^t t(1-t)x^{k-1}(1-x)^{k-1}\,\mathrm{d}x - \int_0^t x^k(1-x)^k\,\mathrm{d}x\Big)}{c_k^{-1}\big(F_k(t)\big)^2} \\ &> 0,\end{aligned}$$

where $c_k := k(k+1)\binom{2k+1}{k+1}\binom{2k-1}{k}$ and the inequality follows from the fact that $x(1-x)$ is strictly increasing on $(0, \frac{1}{2})$.

We now consider the comparative statics of m^*, ignoring the trivial relation between m^* and ϕ. The derivative of m^* with respect to $\bar{a}$ reads:

$$\frac{\mathrm{d}m^*}{\mathrm{d}\bar{a}} = \tfrac{1}{2}\big(f_k(\tfrac{\bar{a}}{2}) - \lambda f_k(\tfrac{\lambda\bar{a}}{2})\big) \times \lambda\bar{a}(1 - \tfrac{\lambda\bar{a}}{4}) + \big(F_k(\tfrac{\bar{a}}{2}) - F_k(\tfrac{\lambda\bar{a}}{2})\big) \times \lambda(1 - \tfrac{\lambda\bar{a}}{2}).$$

This function is increasing in t for $t \in (0, \frac{1}{2})$:

$$\frac{\mathrm{d}f_k(t)}{\mathrm{d}t} = k(k-1)\binom{2k-1}{k}t^{k-2}(1-t)^{k-2}(1-2t) > 0, \quad t \in (0, \tfrac{1}{2}). \tag{4.9}$$

This observation implies that $\big(f_k(\frac{\bar{a}}{2}) - \lambda f_k(\frac{\lambda\bar{a}}{2})\big) > 0$, proving that m^* increases in $\bar{a}$.

Differentiating m^* with respect to λ results in:

$$\frac{\mathrm{d}m^*}{\mathrm{d}\lambda} = \big(F_k(\tfrac{\bar{a}}{2}) - F_k(\tfrac{\lambda\bar{a}}{2})\big) \times \bar{a}(1 - \tfrac{\lambda\bar{a}}{2}) - \tfrac{\bar{a}}{2} f_k(\tfrac{\lambda\bar{a}}{2}) \times \lambda\bar{a}(1 - \tfrac{\lambda\bar{a}}{4}).$$

It can easily be verified that this derivative is positive when evaluated at $\lambda = 0$, whereas it is negative when evaluated at $\lambda = 1$. Furthermore:

$$\frac{\mathrm{d}^2m^*}{\mathrm{d}\lambda^2} = -\tfrac{\bar{a}^2}{2}\big(F_k(\tfrac{\bar{a}}{2}) - F_k(\tfrac{\lambda\bar{a}}{2})\big) - \bar{a}^2(1 - \tfrac{\lambda\bar{a}}{2})f_k(\tfrac{\lambda\bar{a}}{2}) - \bar{a}^2\tfrac{\lambda\bar{a}}{2}(1 - \tfrac{\lambda\bar{a}}{4}) \times \frac{\mathrm{d}f_k(t)}{\mathrm{d}t}\Big|_{t=\frac{\lambda\bar{a}}{2}} < 0,$$

where the inequality is a consequence of (4.9). It follows by continuity of m^* that there exists a $\bar{\lambda} = \bar{\lambda}(\bar{a}, k)$ such that $\frac{\mathrm{d}m^*}{\mathrm{d}\lambda} > 0$ if $\lambda < \bar{\lambda}$ and $\frac{\mathrm{d}m^*}{\mathrm{d}\lambda} < 0$ if $\lambda > \bar{\lambda}$.

Note that the sign of $m^*(\bar{a},\lambda,\phi,k+1)-m^*(\bar{a},\lambda,\phi,k)$ is the same as the sign of

$$\begin{aligned}&\big(F_{k+1}(\tfrac{\bar{a}}{2})-F_{k+1}(\tfrac{\lambda\bar{a}}{2})\big)-\big(F_k(\tfrac{\bar{a}}{2})-F_k(\tfrac{\lambda\bar{a}}{2})\big)=\\&k\binom{2k-1}{k}\times\Big[(4+\tfrac{2}{k})\int_{\frac{\lambda\bar{a}}{2}}^{\frac{\bar{a}}{2}}t^k(1-t)^k\,\mathrm{d}t-\int_{\frac{\lambda\bar{a}}{2}}^{\frac{\bar{a}}{2}}t^{k-1}(1-t)^{k-1}\,\mathrm{d}t\Big],\end{aligned}$$

where we have used the fact that $(k+1)\binom{2k+1}{k+1}=(4+\frac{2}{k})\times k\binom{2k-1}{k}$. Define:

$$\psi(z,\tau):=(4+\tfrac{2}{k})\int_{\tau z}^{z}t^k(1-t)^k\,\mathrm{d}t-\int_{\tau z}^{z}t^{k-1}(1-t)^{k-1}\,\mathrm{d}t,\quad(z,\tau)\in[0,\tfrac{1}{2}]\times[0,1].$$

We have already established that $F_k(t)>F_{k+1}(t)$ as long as $t<\frac{1}{2}$, implying that $\psi(z,0)<0$ if $z\in(0,\frac{1}{2})$. Clearly, $\psi(z,1)=0$ for all $z\in[0,\frac{1}{2}]$. We can thus conclude that $\psi(z,\tau)<0$ for $z\in(0,\frac{1}{2})$ if[24]

$$\frac{\mathrm{d}\psi(z,\tau)}{\mathrm{d}\tau}=\tau^{k-1}z^k(1-\tau z)^{k-1}\times\big[1-(4+\tfrac{2}{k})\tau z(1-\tau z)\big]\geq 0.$$

The term between square brackets is positive if and only if $\tau z<\frac{1}{2}-\frac{1}{2}\sqrt{\frac{1}{2k+1}}$, an inequality which holds *a forteriori* if $\tau<1$ and $z\leq\frac{1}{2}-\frac{1}{2}\sqrt{\frac{1}{2k+1}}$. This observation proves that $m^*(\bar{a},\lambda,\phi,k+1)-m^*(\bar{a},\lambda,\phi,k)<0$ if $\bar{a}\leq\frac{1}{2}-\frac{1}{2}\sqrt{\frac{1}{2k+1}}$. Now fix a $z\in(\frac{1}{2}-\frac{1}{2}\sqrt{\frac{1}{2k+1}},\frac{1}{2})$. We have just shown that $\frac{\mathrm{d}\psi(z,\tau)}{\mathrm{d}\tau}<0$ if $\tau>\frac{1}{2z}-\frac{1}{2z}\sqrt{\frac{1}{2k+1}}$, where the last number is strictly less than 1. Since $\psi(z,0)<0$, $\psi(z,1)=0$ and ψ is continuous , it follows that $\psi(z,\tau)\leq 0$ if $\tau\leq\hat{\lambda}$ and $\psi(z,\tau)>0$ if $\tau>\hat{\lambda}$ for some $\hat{\lambda}\in(0,1)$, proving the last claim. ■

Proof of Lemma 4.2

Consider equilibrium m^*. The claim that consumers never obtain a surplus is obvious. To determine the other two expressions we have to calculate the equilibrium payoffs in the six possible 'states of the world': a is either $\lambda\bar{a}$ or $\bar{a}$ and c is either low ($c\leq\frac{\lambda\bar{a}}{2}$), takes on an intermediate value ($c\in(\frac{\lambda\bar{a}}{2},\frac{\bar{a}}{2}]$), or it is high ($c>\frac{\bar{a}}{2}$). These payoffs are as follows:[25]

- $a=\lambda\bar{a}$, $c\leq\frac{\lambda\bar{a}}{2}$: $\pi^*=1-c$, $V^*=0$,
- $a=\lambda\bar{a}$, $c\in(\frac{\lambda\bar{a}}{2},\frac{\bar{a}}{2}]$: $\pi^*=1-\frac{\lambda\bar{a}}{2}$, $V^*=-\lambda\bar{a}(1-\frac{\lambda\bar{a}}{4})$,
- $a=\lambda\bar{a}$, $c>\frac{\bar{a}}{2}$: $\pi^*=1-\frac{\lambda\bar{a}}{2}$, $V^*=-\lambda\bar{a}(1-\frac{\lambda\bar{a}}{4})$,

[24] The weak inequality suffices because ψ never remains constant on a set with positive Lebesgue measure.

[25] The profit expressions $1-\frac{\lambda\bar{a}}{2}$ and $1-\frac{\bar{a}}{2}$ follow from (4.3).

- $a = \bar{a}$, $c \leq \frac{\lambda\bar{a}}{2}$: $\pi^* = 1 - c$, $V^* = -m^*$,
- $a = \bar{a}$, $c \in (\frac{\lambda\bar{a}}{2}, \frac{\bar{a}}{2}]$: $\pi^* = 1 - c$, $V^* = -m^*$,
- $a = \bar{a}$, $c > \frac{\bar{a}}{2}$: $\pi^* = 1 - \frac{\bar{a}}{2}$, $V^* = -\bar{a}(1 - \frac{\bar{a}}{4}) - m^*$.

Using these results one obtains:

$$\begin{aligned} E(\pi^*) =& (1-\phi)\int_0^{\frac{\lambda\bar{a}}{2}} (1-t)\,\mathrm{d}F(t) + (1-\phi)(1-\tfrac{\lambda\bar{a}}{2})\int_{\frac{\lambda\bar{a}}{2}}^1 \mathrm{d}F(t) + \phi\int_0^{\frac{\bar{a}}{2}} (1-t)\,\mathrm{d}F(t) \\ &+ \phi(1-\tfrac{\bar{a}}{2})\int_{\frac{\bar{a}}{2}}^1 \mathrm{d}F(t) = 1 - (1-\phi)\Big(\int_0^{\frac{\lambda\bar{a}}{2}} t\,\mathrm{d}F(t) + \int_{\frac{\lambda\bar{a}}{2}}^1 \tfrac{\lambda\bar{a}}{2}\,\mathrm{d}F(t)\Big) \\ &- \phi\Big(\int_0^{\frac{\bar{a}}{2}} t\,\mathrm{d}F(t) + \int_{\frac{\bar{a}}{2}}^1 \tfrac{\bar{a}}{2}\,\mathrm{d}F(t)\Big), \\ E(V^*) =& -(1-\phi)\lambda\bar{a}(1-\tfrac{\lambda\bar{a}}{4})\int_{\frac{\lambda\bar{a}}{2}}^1 \mathrm{d}F(t) - \phi\bar{a}(1-\tfrac{\bar{a}}{4})\int_{\frac{\bar{a}}{2}}^1 \mathrm{d}F(t) - \phi m^*. \end{aligned}$$

To assess the various ex ante expected payoffs of the benchmark equilibrium, we have to calculate the equilibrium payoffs in four different 'states of the world': a is either $\lambda\bar{a}$ or $\bar{a}$ and c is either smaller than or equal to $\frac{3}{4}$ or c is larger than $\frac{3}{4}$. These payoffs are listed below (recall that the IG's payoff reads $-(1-\delta)aq$ if it does not exert any efforts):

- $a = \lambda\bar{a}$, $c \leq \frac{3}{4}$: $\tilde{CS} = 0$, $\tilde{\pi} = 1 - c$, and $\tilde{V} = 0$,
- $a = \lambda\bar{a}$, $c > \frac{3}{4}$: $\tilde{CS} = \frac{1}{8}$, $\tilde{\pi} = \frac{1}{4}$, and $\tilde{V} = -\frac{\lambda\bar{a}}{2}$,
- $a = \bar{a}$, $c \leq \frac{3}{4}$: $\tilde{CS} = 0$, $\tilde{\pi} = 1 - c$, and $\tilde{V} = 0$,
- $a = \bar{a}$, $c > \frac{3}{4}$: $\tilde{CS} = \frac{1}{8}$, $\tilde{\pi} = \frac{1}{4}$, and $\tilde{V} = -\frac{\bar{a}}{2}$.

The ex ante expected payoffs mentioned in the lemma now follow straightforwardly. ■

Proof of Proposition 4.5

Let us first deal with the profits. Consider the map

$$H : z \mapsto \int_0^z t\,\mathrm{d}F(t) + z\int_z^1 \mathrm{d}F(t). \tag{4.10}$$

Differentiating $H(z)$ yields (f denotes the density function associated with F)

$$H'(z) = \frac{\mathrm{d}}{\mathrm{d}z}\Big[zF(z) - \int_0^z F(t)\,\mathrm{d}t\Big] + \int_z^1 \mathrm{d}F(t) - zf(z) = \int_z^1 \mathrm{d}F(t) > 0.$$

Consequently: $E(\pi^*) = 1 - (1-\phi)H(\frac{\lambda\bar{a}}{2}) - \phi H(\frac{\bar{a}}{2}) > 1 - H(\frac{3}{4}) = E(\tilde{\pi})$.

The claim pertaining to consumers' surplus is obvious. It remains to show that the IG prefers the complete information scenario. Note that $-a(1-\frac{a}{4}) < -\frac{a}{2}$ for all $a \in (0,1)$. This observation implies that

$$\begin{aligned} E(V^*) &< -(1-\phi)\lambda\bar{a}(1-\tfrac{\lambda\bar{a}}{4})\int_{\frac{\lambda\bar{a}}{2}}^{1} \mathrm{d}F(t) - \phi\bar{a}(1-\tfrac{\bar{a}}{4})\int_{\frac{\bar{a}}{2}}^{1} \mathrm{d}F(t) \\ &< -(1-\phi)\tfrac{\lambda\bar{a}}{2}\int_{\frac{\lambda\bar{a}}{2}}^{1} \mathrm{d}F(t) - \phi\tfrac{\bar{a}}{2}\int_{\frac{\bar{a}}{2}}^{1} \mathrm{d}F(t) \\ &< -(1-\phi)\tfrac{\lambda\bar{a}}{2}\int_{\frac{3}{4}}^{1} \mathrm{d}F(t) - \phi\tfrac{\bar{a}}{2}\int_{\frac{3}{4}}^{1} \mathrm{d}F(t) = E(\tilde{V}). \end{aligned}$$

This completes the proof. ■

Proof of Proposition 4.6

Note that with the alternative information structure and ignoring any money burning total welfare in equilibrium m^* equals

$$-\tfrac{1}{2}(1-\tfrac{a}{2}) + 1 - H(\tfrac{a}{2}) - a(1-\tfrac{a}{4})\int_{\frac{a}{2}}^{1} \mathrm{d}F(t) \tag{4.11}$$

if the IG is of type a, where H is defined in (4.10). The first part of (4.11) ($-\frac{1}{2}(1-\frac{a}{2})$) is the expected reduction in consumers' surplus, the second part ($1-H(\frac{a}{2})$) is the firm's expected profit, and the last part is the expected payoff of the IG. In the equilibrium of the complete information benchmark total welfare equals

$$\tfrac{1}{8}(1-F(\tfrac{3}{4})) + 1 - H(\tfrac{3}{4}) - \tfrac{a}{2}(1-F(\tfrac{3}{4}))$$

should the IG be of type a. Observe that ex ante expected welfare in equilibrium m^* is a convex combination of (4.11) evaluated at $a = \lambda\bar{a}$ and (4.11) evaluated at $a = \bar{a}$. Moreover, the money burning term (ϕm^*) reduces total welfare. Because of these two facts, it suffices to show that:

$$\tfrac{1}{2}(\tfrac{1}{4}-a)(1-F(\tfrac{3}{4})) - (H(\tfrac{3}{4}) - H(\tfrac{a}{2})) + \tfrac{1}{2}(1-\tfrac{a}{2}) + a(1-\tfrac{a}{4})(1-F(\tfrac{a}{2})) > 0, \quad a \in (0,1).$$

Or, equivalently that:

$$\Delta(z) := \Delta(0) - z(1-F(\tfrac{3}{4})) + H(z) - \tfrac{z}{2} + z(2-z)(1-F(z)) > 0, \quad z \in (0, \tfrac{1}{2}),$$

where $\Delta(0) := \frac{1}{8}(1-F(\frac{3}{4})) - H(\frac{3}{4}) + \frac{1}{2}$. We proceed in two steps: first we show that $\Delta(0) > 0$, then we show that $\Delta(z) - \Delta(0) > 0$ if $z \in (0, \frac{1}{2})$.

Using the definition of H one obtains:

$$\begin{aligned}\Delta(0) =& \tfrac{1}{8}(1-F(\tfrac{3}{4})) - \Big(\tfrac{3}{4}F(\tfrac{3}{4}) - \int_0^{\frac{3}{4}} F(t)\,\mathrm{d}t + \tfrac{3}{4}(1-F(\tfrac{3}{4}))\Big) + \tfrac{1}{2}\\ =& -\tfrac{1}{8} - \tfrac{1}{8}F(\tfrac{3}{4}) + \int_0^{\frac{3}{4}} F(t)\,\mathrm{d}t.\end{aligned}$$

Because $F = F_k$ for some $k \geq 1$, we know that $F(\frac{1}{2}) = \frac{1}{2}$ and that $\int_0^1 t\,\mathrm{d}F(t) = \frac{1}{2}$. The last equality implies that $\int_0^1 F(t)\,\mathrm{d}t = 1 - \int_0^1 t\,\mathrm{d}F(t) = \frac{1}{2}$. Consequently:

$$\begin{aligned}\Delta(0) =& -\tfrac{1}{8} - \tfrac{1}{8}F(\tfrac{3}{4}) + \int_0^{\frac{3}{4}} F(t)\,\mathrm{d}t = -\tfrac{1}{8} - \tfrac{1}{8}F(\tfrac{3}{4}) + \Big(\tfrac{1}{2} - \int_{\frac{3}{4}}^{1} F(t)\,\mathrm{d}t\Big)\\ >& -\tfrac{1}{8} - \tfrac{1}{8} + (\tfrac{1}{2} - \tfrac{1}{4}) = 0.\end{aligned}$$

By definition of H we have:

$$\begin{aligned}&H(z) - \tfrac{z}{2} + z(2-z)(1-F(z)) = zF(z) - \int_0^z F(t)\,\mathrm{d}t + z(1-F(z)) - \tfrac{z}{2}\\ &+ z(2-z)(1-F(z)) = -\int_0^z F(t)\,\mathrm{d}t + \tfrac{z}{2} + z(2-z)(1-F(z)).\end{aligned}$$

We can consequently write $\Delta(z) - \Delta(0)$ as follows:

$$\Delta(z) - \Delta(0) = -z(1-F(\tfrac{3}{4})) + \tfrac{z}{2} + z(2-z)(1-F(z)) - \int_0^z F(t)\,\mathrm{d}t. \tag{4.12}$$

Because $z < \frac{1}{2}$ and thus $F(z) < \frac{1}{2}$, one has:

$$\int_0^z F(t)\,\mathrm{d}t < zF(z) < z(1-F(z)).$$

Combining these inequalities with (4.12) yields

$$\Delta(z) - \Delta(0) > -z(1-F(\tfrac{3}{4})) + \tfrac{z}{2} + z(1-z)(1-F(z)) > z(1-z)(1-F(z)),$$

where we have used the fact that $1 - F(\frac{3}{4}) < \frac{1}{2}$ to establish the last inequality. ■

Proof of Proposition 4.7

The claims with respect to consumers' surplus follow straightforwardly from (4.8). From the proof of Proposition 4.5 we know that $E(\pi^*) = 1 - (1-\phi)H(\frac{\lambda\bar{a}}{2}) - \phi H(\frac{\bar{a}}{2})$, where H is an increasing function. These facts imply that $E(\pi^*)$ decreases in $\bar{a}$, λ, and ϕ. Note that $E(CS^* + \pi^*)$ is a convex combination of $K(\frac{\lambda\bar{a}}{2})$ and $K(\frac{\bar{a}}{2})$, where:

$$K : z \mapsto 1 - \tfrac{1}{2}(1-z) - H(z).$$

The last claim is now implied by the fact that $K'(z) = \frac{1}{2} - H'(z) = \frac{1}{2} - \int_z^1 \mathrm{d}F(t) < 0$, where the inequality follows from the equality $F(\frac{1}{2}) = \frac{1}{2}$.[26] ■

[26] The fact that $H'(z) = \int_z^1 \mathrm{d}F(t)$ is established in the proof of Proposition 4.5.