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Warning labels as cheap-talk: why regulators ban drugs

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Abstract

One explanation for drug bans is that regulators know more than consumers about product quality. But why not just communicate the information in their ban, perhaps via a 'would have banned' label? Because product labeling is cheap-talk, any small market failure tempts regulators to lie about quality, inducing consumers who suspect such lies to not believe everything they are told. In fact, when regulators expect market failures to result in under-consumption of a drug, and so would not ban it for informed consumers, regulators ex ante prefer to commit to not banning this drug for uninformed consumers.

Keywords: Cheap-talk; Quality; Bans; Paternalism

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1. Introduction

The US Food and Drug Administration can prohibit the sale of food and drugs that it considers unsafe or ineffective. Why is the FDA given this power, and why does it use this power so often?

Regulatory product bans and limits on quality have been explained as due to regulatory capture (Stigler, 1971; Maurizi, 1974), or as a public interested response to inefficient monopolist quality menus (Mussa and Rosen, 1978),

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inefficient signaling (Shapiro, 1986) consumer irrationality (Spence, 1977) and negative use externalities. Negative externalities are mentioned especially frequently regarding recreational drugs (Johnson et al., 1985), such as alcohol (Isaac, 1965). Smoking externalities are said to exist between people (Boyes and Marlow, 1996) and within people (Gruber, 2001).

In public forums, however, by far the most common rationale offered for banning supposed health aids is public interested concern about consumer ignorance about product quality (Leffler, 1978; Lambert and McGuire, 1990; Jensen, 1992). Regulators are presumed to know which health aids are good and which are bad, and to keep the public from the bad ones. The Florida statute requiring medical licensing, for example, begins by explaining that 'it is difficult for the public to make an informed choice when selecting a physician' (Feinstein, 1985). This regulatory rationale receives very high levels of public support (Lipset and Schneider, 1979).

The main problem with this banning rationale, however, is that while bans can benefit ignorant consumers (Leland, 1979), in theory consumers should benefit even more if regulators instead put warning labels on, or refused to certify, the products they would have banned (Higgs, 1995; Leffler, 1978; Gieringer, 1985). Some models do favor bans (Gale, 1997; Shapiro, 1986), but these models do not directly compare bans to certification of the information in the ban, as in a 'would have banned' label. Models that do directly compare favor certification (Shaked and Sutton, 1981).

Empirical studies on cigarettes, saccharin, seat belts, and alcohol have found the effects of warnings to range from mild to non-existent (U.S. Dept. of H.&H.S., 1987; Magat and Viscusi, 1992). Some attribute this to high consumer costs of dealing with labels, but effects are small even when consumers seem to have read and understood labels (Mayer et al., 1991). Furthermore, 'a case could probably be made for allowing establishment of certain stores ... that sell only products that do not meet regulatory standards' (Kelman, 1981). Something like a driver's license might even be required to ensure knowledgeable consumers. Yet political support for such options seems close to non-existent.

This paper explores a cheap-talk explanation of product bans. If regulators care only about the market consequences of regulatory warnings, then regulator drug labeling becomes a cheap-talk signaling game (Crawford and Sobel, 1982). In such a game, any small temptation for the regulator to lie, if she would be believed, can induce large losses in information transfer. Furthermore, a regulator with any other reason to regulate choices, i.e. who expects informed consumers to over- or under-consume the product, is tempted to lie about quality to uninformed consumers. Perhaps regulators just *cannot* communicate the information implicit in a product ban.

This paper describes a simple game-theoretic model of such a cheap-talk explanation of drug bans. In the model, a market chooses the quantity purchased of some drug, and that quantity depends on consumers beliefs about the one-

dimensional quality of that drug. Those consumers may be *informed*, and know as much about quality as the regulator does, or may be *uninformed*, and know substantially less.

Also in the model is a regulator, who is empowered to require one of several warning labels on the drug, and may also be empowered to ban the drug. Due to market failures or regulatory capture, this regulator expects even informed consumers to either *over-consume* or *under-consume* the drug. We obtain the following results:

- With informed consumers, regulators only ban when they expect over-consumption, and ban only a small fraction of drugs when the over-consumption amount is small.
- With uninformed consumers, regulators ban both when they expect over-consumption *and* when they expect under-consumption, and they can ban a large fraction of drugs even when the expected over- or under-consumption amount is small.
- Averaging over possible quality levels, a regulator who expects under-consumption is better off when she *cannot* ban the drug, because consumers will then believe more severe warnings. Anyone whose informed ideal point lies between the regulator's ideal point and what the unconstrained market would produce is also better off. Such agents would prefer a prior commitment to not ban.

Thus a regulator concerned only about consumer ignorance would never ban drugs, and a regulator concerned only about mild use externalities, for example, would ban only a small fraction of drugs, and then only for negative externalities. But regulators concerned about both of these problems will typically ban a large fraction of drugs, for both positive and negative externalities.

We might thus help explain the ubiquity of drug bans, mild responses to labels, and low political support for labels as substitutes, as all due in part to the *combination* of consumer ignorance and a small portion of any of the other reasons offered for regulating quality, such as use externalities. And we can view many such bans as political commitment failures, a common form of political failure. In our model, if a regulator would not want to ban some type of drug when consumers and regulators had the same information about quality, that regulator would want to commit to not banning such drugs even when she had superior information.

For example, consider a drug produced by a monopolist, or a drug with a positive use externality produced by a competitive market. In either case, a regulator concerned only about total economic welfare expects under-consumption by fully informed consumers. What if consumers are ignorant of this drug's (one-dimensional) quality, while regulators are informed? Then if consumers believed anything the regulator said, the regulator would want to lie and announce

a higher-than-true quality estimate. This quality over-estimate would increase demand and compensate for the reduced consumption caused by the monopoly pricing or positive externality.

If consumers anticipate such lies, however, then a regulator-labeling cheap-talk equilibrium consists of a set of quality intervals. A regulator who knows the true drug quality can then only tell consumers which interval this quality falls in, and cannot credibly communicate finer distinctions. Furthermore, the number of quality intervals shrinks as the temptation to lie increases.

If the regulator cannot ban the drug, and announces that the quality is in the lowest quality interval, consumers purchases will reflect an average over this quality interval. And if the true quality happens to be near its lowest possible value, this regulator can regret not being able to ban the drug. If, however, the regulator can ban the drug, in addition to announcing a quality interval, then the signaling game is changed. Any drug in the lowest quality interval is banned, and the boundaries of all quality intervals move. In equilibrium, not banning a drug is taken by consumers as an *endorsement* of drug quality. This encourages a regulator who can ban to ban often.

A regulator who on average expects under-consumption, however, should ex ante lament her ability to ban drugs. After all, when consumers are told that quality is in some interval, and are then free to choose, consumption is based on an average of quality in that interval. But for the quality interval of banned products, consumption is below this average level. Thus bans reduce average consumption.

We will now show how the market drug quantity can be thought of as being chosen by a 'market agent,' describe when a regulator will ban drugs for informed consumers, when a regulator who cannot ban will warn ignorant consumers, compare these behaviors to those of a regulator who can warn or ban ignorant consumers, and finally illustrate these results with some simple examples.

2. What markets maximize

Consider the situation where producers sell a quantity q of a certain drug to consumers who may be uncertain about the quality a of that drug. The total cost of production is $C(q)$, and consumers directly gain an aggregate value $V(q,a)$ from consumption. Consumers also indirectly obtain value from the consumption of others, via an aggregate consumption externality $E(q,a)$ (which transaction costs preclude being internalized).

The marginal cost of production is $MC(q) = C_q(q)$. If consumers knew the quality a, this drug could be sold for a price given by the inverse demand $MV(q,a) = V_q(q,a)$. If consumers were instead uncertain about drug quality, but shared common beliefs G about that quality, then the drug could be sold for a price given by the expectation $\overline{MV}(q) = \mathrm{E}_G[MV(q,a)]$.

Let us consider three possible forms of industrial organization: a single

monopolist, a competitive market, and N identical firms engaged in quantity competition. If allowed by the regulator to sell his drug, a monopolist will choose drug quantity q to maximize profit

$$\overline{\pi}_{\mathrm{M}}(q) = q\overline{MV}(q) - C(q).$$

In contrast, a competitive market chooses quantity q to maximize expected direct welfare

$$\overline{\pi}_{\mathrm{C}}(q) = \overline{V}(q) - C(q),$$

where $\overline{V}(q) = \mathrm{E}_G[V(q,a)]$, and in general $\overline{f(y)} = \mathrm{E}_G[f(y,a)]$.

Finally, when N identical firms engage in quantity competition, each firm i will choose firm quantity q_i to maximize firm profit

$$\overline{\pi}_i(q_i) = q_i\overline{MV}(q) - \hat{C}(q_i),$$

where $q = \Sigma_i\ q_i$ and $\hat{C}$ is the common firm cost function. The first order conditions (FOCs) for choosing q_i to maximize $\overline{\pi}_i$ are

$$0 = \overline{MV}(q) + q_i\overline{MV}_q(q) - M\hat{C}(q_i).$$

Assuming a symmetric equilibria where $q_i = q/N$, and letting $C(q) = \Sigma_i\ \hat{C}(q_i)$ so that $MC(q) = M\hat{C}(q_i)$, these FOC on $\overline{\pi}_i$ imply

$$0 = N\overline{MV}(q) + q\overline{MV}_q(q) - NMC(q).$$

But this equation is the FOC for choosing q to maximize

$$\overline{\pi}(q) = \left(1 - \frac{1}{N}\right)\overline{\pi}_{\mathrm{C}}(q) + \frac{1}{N}\overline{\pi}_{\mathrm{M}}(q).$$

Furthermore, the second order condition (SOC) for $\max_q \overline{\pi}(q)$ implies the SOCs for $\max_{q_i} \overline{\pi}_i$.

We can thus summarize all three of our cases in one profit expression. We can say that when not constrained by regulators, the 'market' chooses q to maximize the expectation, using consumer beliefs G about a, of profit

$$\begin{aligned}\pi(q,a) &= \left(1 - \frac{1}{N}\right)\pi_{\mathrm{C}}(q,a) + \frac{1}{N}\pi_{\mathrm{M}}(q,a)\\ &= \left(1 - \frac{1}{N}\right)V(q,a) + \frac{1}{N}qMV(q,a) - C(q),\end{aligned}$$

where for monopoly $N = 1$, for perfect competition $N = \infty$, and N is intermediate in the case of identical quantity-competing firms. That is, we can consider market choices to be those that would be made by a 'market agent' with preferences $\pi(q,a)$.

3. Regulation of quality

Consider a regulator who is informed about the drug quality a, and who prefers that quantity q maximize regulator welfare

$$W(q,a) = V(q,a) - C(q) + E(q,a) + B(q,a).$$

The first three terms describe standard economic welfare, while the forth and last term $B(q,a)$ describes other considerations entering into regulator welfare.

This regulator may be empowered either to ban this drug or to warn consumers about its quality, but has no other regulatory powers over drug quantity, pricing, or profits. (This is intended as a model of an agency like the FDA). If the regulator issues one of several warnings w prior to consumer choice, consumers can then base their expectations $G(w)$ on this warning. If the regulator bans the drug, this induces $q = x \in [\underline{q},\overline{q}]$ for sure. The obvious case is $x = 0$, but we may also want to consider a small $\overline{x} > 0$ resulting from legal exceptions or imperfect law enforcement.

Before considering our general case, let us consider two special cases. First, consider the case where consumers know quality a as well as the regulator. In this case warnings are irrelevant, and the regulator would ban the drug if a satisfies

$$W(x,a) > W(q^*(a),a), \qquad \text{where } \; q^*(a) = \text{argmax}_q \pi(q,a).$$

If $B(q,a)$ were zero, so that regulators maximized economic welfare, then it would clearly be economically efficient to give regulators the power to ban the drug. The regulator would then only actually ban the drug when allowing drug consumption lowered economic welfare, such as in the case of a low quality drug with large negative use externalities.

Second, consider the case where the regulator has no power to ban the product, and so can only warn consumers about product quality. If the only costs to regulators from communicating a warning w to consumers are embodied in the market choice of quantity q, then a regulator warning consumers is involved in a one-dimensional cheap-talk signaling game. Such a game was the subject of one of the first published papers on cheap-talk, by Crawford and Sobel (1982) (hereafter, C&S).

We can adapt the C&S results to our case if we make appropriate assumptions. Let us therefore assume that regulator welfare $W(q,a)$ and market 'welfare' $\pi(q,a)$ are twice continuously differentiable. Defining marginal welfare as $MW = W_q$ and $M\pi = \pi_q$, assume *concavity*, $MW_q < 0$ and $M\pi_q < 0$, and *sorting* (or single-crossing), $MW_a > 0$ and $M\pi_a > 0$. These imply strictly increasing and unique ideal points $q^*(a)$ and $\tilde{q}(a) = \text{argmax}_q W(q,a)$. We can without loss of generality assume $M\pi(a,a) = 0$, which implies $q^*(a) = a$. Furthermore, assume that quality a is drawn from a differentiable c.d.f $F(a)$ with support $[\underline{a},\overline{a}]$, which is a subset of the

possible quantity choices $[\underline{q},\bar{q}]$. Finally, assume that $\bar{q}(a) \neq q^*(a)$ for all a, which is implied by $MW \neq M\pi$.

These C&S assumptions can be satisfied in our drug market if we make the following assumptions. Let C, E, B be twice, and V be thrice, continuously differentiable. Let us require $MC_q \geq 0$, i.e. increasing marginal costs, and $MV_q < 0$, i.e. downward-sloping demand. Also assume $MC_q - 2MV_q > qMV_{qq}$, so that these effects outweigh any demand convexity. Defining $MB = B_q$ and $ME = E_q$, let us also assume that $MB_q + ME_q \leq 0$, so that there is a net downward-sloping 'demand' for the externality and non-economic-welfare benefits the regulator sees. These assumptions assure the concavity of W and π.

To ensure that W and π satisfy sorting, assume that MV_a is positive and larger than both $-qMV_{qa}$ and $-MB_a - ME_a$. That is, higher quality induces higher demand, and this effect outweighs any increases in the demand slope or decreases in the externality demand due to higher quality. Also, since

$$MW - M\pi = \frac{1}{N}(V - qMV) + ME + MB,$$

and since $V - qMV$ is positive, then $MW \neq M\pi$ is satisfied if $ME + MB$ is non-negative or not sufficiently negative. The fact that regulators commonly encourage and subsidize health care suggests that they consider $ME + MB$ to typically be non-negative for drugs intended to be health-improving. Thus we typically expect $MW > M\pi$ in such cases. To ensure that $[\underline{a},\bar{a}] \subset [\underline{q},\bar{q}]$, let $\underline{q} = 0$, let $\bar{q}$ be imposed by a consumer budget constraint, and assume that for each distinct quality level a above the lowest possible, at least one customer is desperate enough to rationally consume some amount $q > 0$ of this drug.

C&S showed that their assumptions imply that each equilibrium of this cheap-talk signaling game consists of a finite partition of the interval $[\underline{a},\bar{a}]$ into interval parts $[a_i,a_{i+1}]$. (For an n part partition, $a_0 = \underline{a}$ and $a_n = \bar{a}$.) For all $a \in [a_i,a_{i+1}]$, the regulator gives essentially the same distinct warning w, which induces the same market response q_i. These q_i and a_i satisfy, for $i = 1$ to $n-1$,

$$W(q_{i-1},a_i) = W(q_i,a_i),$$

and for $i = 0$ to $n-1$ satisfy

$$q_i = \bar{q}(a_i,a_{i+1}) = \operatorname{argmax}_q \int_{a_i}^{a_{i+1}} \pi(q,a)\,\mathrm{d}F(a),$$

which can be written as

$$I(q_i,a_i) = I(q_i,a_{i+1}),$$

if we define a pseudo-welfare

$$I(q,a) = \int_q^a \pi(q,a')\,\mathrm{d}F(a').$$

C&S showed that such an equilibrium exists for every integer $n \in [1,\bar{n}]$, for some $\bar{n} \geq 1$.

In order to draw normative conclusions, C&S found it convenient to also assume that, when perturbed, interval boundaries a_i and market responses q_i all move in the same direction. Specifically, they made a *monotonicity* assumption equivalent to $\mathrm{d}a_i/\mathrm{d}\underline{a} > 0$ for all $i \in [1,n-1]$. This implies $\mathrm{d}q_i/\mathrm{d}\underline{a} > 0$ for all $i \in [0,n-1]$, and also implies a unique equilibrium for each size n. C&S showed that a sufficient condition for monotonicity is (something slightly weaker than) $\pi_q + \pi_a \leq 0$ and $W_q + W_a \geq 0$. An alternative sufficient condition is also available. (Proofs are in Appendix A).

Lemma 1. *Monotonicity is implied by I having steeper isoquants than W in* (q,a) *space, i.e. by*

$$\frac{I_q}{I_a} \leq \frac{W_q}{W_a}.$$

C&S showed that both the regulator and the market (considered as an agent) ex ante prefer equilibria with more distinct warnings, i.e. with higher n, and that more warnings become possible as the difference $MW - M\pi$ is reduced. Thus while the regulator would prefer to commit to telling consumers its quality signal a, without such a commitment the regulator is tempted to exaggerate drug quality (when $MW > M\pi$), in order to correct for a perceived market underconsumption. Since consumers anticipate this temptation, the regulator's inability to commit to truth-telling reduces, and sometimes eliminates, the information that she can communicate in equilibrium.

4. Combining bans and warnings

Let us continue to consider consumers who are not fully informed about drug quality a, but now let regulators be able to either ban the drug or warn consumers about its quality. Let us make the same standard C&S assumptions as above, and then compare the equilibria of our new warn-or-ban game to the equilibria of our previous warn-only game.

If the drug quantity x that is induced by banning the drug is too low or too high, the regulator will never want to ban the drug. In this case, the warn-or-ban equilibria are the same as the warn-only equilibria. If instead the regulator sometimes chooses the ban outcome x, the only change from the warn-only

equilibrium equations is that for some k, the equation $I(q_k,a_k) = I(q_k,a_{k+1})$ is replaced by the equation $q_k = x$.

As this new set of equations has the same relevant properties, C&S's proofs of the existence and finiteness of equilibria apply here as well. The only difference is that $n = 1$ is now possible only if the regulator either always or never prefers to ban. The monotonicity conditions apply here without modification.

C&S's proof of uniqueness of equilibria also applies here, except that non-uniqueness is introduced here by the fact that there is no longer any dependence in the equilibrium equations between a_k and a_{k+1}. A seven part ($n = 7$) equilibrium, for example, might have three parts on one side of x and four parts on the other, or these numbers might be reversed. We will here preserve strict uniqueness by assuming that $x = q_0$, so that the ban quantity is the lowest equilibrium quantity.

To compare the welfare between the warn-only and warn-or-ban games, we will also want to assume that the ban quantity x is at least as large as $\underline{a}$, the lowest amount that a fully informed market might choose, and that x is no greater than $\hat{q}_0$, which denotes the lowest quantity the market might choose in an equilibrium of the warn-only game. That is, $x \in [\underline{a},\hat{q}_0]$. No less is consumed under a ban than when consumers are certain that the quality is the lowest possible. And no more is consumed under a ban than when the regulator issues the severest warning available, but consumers are free to choose for themselves.

To compare welfare, we also want to focus on the case where $MW > M\pi$, i.e. where the regulator wants more of the drug consumed than a fully-informed market would choose. And we will want to consider agents whose preferences are intermediate between regulator and market preferences. That is, if $U(q,a)$ are the preferences of an agent, where $MU = U_q$, then this agent is *mixed* if MU satisfies the constraints we have imposed on both MW and $M\pi$, and if $MU = \theta MW + (1 - \theta)M\pi$ for some function $\theta(q,a) \in [0,1]$. We can show that any mixed agent prefers an equilibria of the warn-only game to a same-size equilibria of the warn-or-ban game.

Lemma 2. *When $MW > M\pi$ and $x \leq \hat{q}_0$, any mixed agent ex ante prefers an n part equilibrium of the warning-only game to an n part equilibrium of the warn-or-ban game. The preference is strict if the equilibria are distinct.*

We can also show that one cannot get equilibria with more parts by allowing bans.

Lemma 3. *When $MW > M\pi$ and $x \geq \underline{a}$, for every n part equilibrium of the warn-or-ban game, there exists an n part equilibrium of the warn-only game.*

Together Lemmas 2 and 3 together say that the regulator, the market agent, or any agent with intermediate preferences prefers equilibria of the warn-only game to those of the warn-or-ban game.

Theorem 1. *When $MW > M\pi$ and $x \in [\underline{a}, \hat{q}_0]$, for any equilibrium of the warn-or-ban game, there exists an equilibrium of the warn-only game which any mixed agent ex ante prefers. This preference is strict if the equilibria are distinct.*

Note that an immediate corollary is that the regulator ex ante prefers the warn-only game.

One of the standard C&S assumptions we have made is that $\underline{q} \leq \underline{a}$, which implies that there is a distinct best market action $q^*(a)$ for any quality a. This is equivalent to saying that quality cannot be negative; there is only one fully-known quality level where none of the drug would be purchased. Note, however, that we can trivially extend the result of Theorem 1 to the case where, while holding all else fixed, we vary $\underline{q}$ up into the range $[\underline{a}, \hat{q}_0]$. After all, none of the equilibrium equations are effected when we do this. Also, if we continue to raise $\overline{q}$, then we will get $\hat{q}_0 = \overline{q}$, so if $x = \overline{q}$ as well then the warn-only and warn-or-ban equilibria will be identical, and so the result of Theorem 1 will still hold.

5. A simple example

The above results can be illustrated in a simple example. Let us assume a linear inverse demand curve, $MV = A - q$, where the intercept A is a measure of drug quality. Let us also assume constant marginal values for the cost, use externality and non-economic benefit, so that $MC = c$, $ME = e$, and $MB = b$. These imply

$$M\pi = A - c - \left(1 + \frac{1}{N}\right)q = \left(1 + \frac{1}{N}\right)(a - q)$$

$$MW = A - c + e + b - q = \left(1 + \frac{1}{N}\right)a + e + b - q,$$

where on the right hand side we have replaced drug quality A with the market quantity $a = q^* = (A - c)N/(N + 1)$ that maximizes π.

For consumers who are informed about drug quality a, the regulator will ban a drug only if

$$a \leq \frac{N}{N + 2}(x - 2(e + b)).$$

Thus no drugs of any quality level will be banned if $e + b \geq x/2$.

To allow us to more easily consider consumers who are not fully informed about drug quality, let us assume $x = 0$, $N = \infty$, $e + b \neq 0$, $[\underline{A}, \overline{A}] = [c, c + 1]$, so that $[\underline{a}, \overline{a}] = [\underline{q}, \overline{q}] = [0,1]$, and $F(a) = a$. Thus quality and its resulting fully informed consumption are distributed uniformly from zero to one, and a ban induces zero consumption. With these assumptions, our example now satisfies all the relevant C&S assumptions, and in addition has a constant 'bias' $\beta = \tilde{q} - q^* =$

Table 1
Numerical equilibria examples

	Bias β	$\bar{n}$	Boundaries a_i for $n = \bar{n}$	E[π]	E[W]
No ban	−0.05	3	0, 0.53, 0.87, 1	−15.9	−18.4
No ban	−0.005	10	0, 0.19, 0.36, 0.51, 0.64, 0.75, 0.84, 0.91, 0.96, 0.99, 1	−1.66	−1.68
No ban	0.005	10	0, 0.01, 0.04, 0.09, 0.16, 0.25, 0.36, 0.49, 0.64, 0.81, 1	−1.66	−1.68
No ban	0.05	3	0, 0.13, 0.47, 1	−15.9	−18.4
Ban	−0.05	4	0, 0.31, 0.74, 0.97, 1	−17.9	−15.5
Ban	−0.005	10	0, 0.1, 0.28, 0.44, 0.58, 0.7, 0.8, 0.88, 0.94, 0.98, 1	−1.68	−1.66
Ban	0.005	10	0, 0.005, 0.04, 0.09, 0.16, 0.25, 0.36, 0.49, 0.64, 0.81, 1	−1.68	−1.70
Ban	0.05	3	0, 0.08, 0.44, 1	−18.7	−21.5

$e + b$, which says how much the regulator would lie about drug quality, if consumers would believe such a lie.

Table 1 gives numerical values for some specific equilibria. (For $|\beta| = 0.5$, all $\bar{n} = 1$). Note that drugs are banned far more often for uninformed consumers than for informed ones. Given a positive bias drugs are never banned for informed consumers but are often banned for uninformed consumers. For example, for a negative bias of $\beta = -0.005$ only one in 100 drugs is banned for informed consumers, while one in ten drugs is banned for uninformed consumers.

Table 2 gives formulas for the a_i for both the warn-only and the warn-or-ban game. The q_i are given by $q_i = (a_i + a_{i+1})/2$, except that $q_0 = 0$ in the warn-or-ban game. In the warn-only game the maximum part number $\bar{n}$ satisfies $1 \geq 2|\beta|\bar{n}(\bar{n} - 1)$. The same expression applies to $\bar{n}(0)$ for the warn-or-ban game when $\beta > 0$, but when $\beta < 0$ the condition is instead $1 \geq 2|\beta|(\bar{n}(0) - 1)^2$. Thus with a negative bias allowing bans can increase the number of equilibrium parts.

This feature means that in some cases where $\beta < 0$, allowing bans can improve

Table 2
Example equilibria formula

No ban $\beta > 0$	$a_1 = \dfrac{1 - 2\beta n(n-1)}{n}$	$a_i = ia_1 + 2\beta i(i-1)$
Ban $\beta > 0$	$a_1 = \dfrac{1 - 2\beta n(n-1)}{2n - 1}$	$a_i = (2i - 1)a_1 + 2\beta i(i-1)$
No ban $\beta < 0$	$1 - a_{n-1} = \dfrac{1 + 2\beta n(n-1)}{n}$	$1 - a_{n-i} = (n-i)(1 - a_{n-1}) -$
Ban $\beta < 0$	$1 - a_{n-1} = \dfrac{1 + 2\beta(n-1)^2}{n - 1/2}$	$2\beta(n-i)(n-i+1)$

both E[W] and E[π]. This happens, for example, for $\beta \in [-0.24, -0.18]$ when we change to $F'(a) = 1/2(1-a)^{-1/2}$. Here the warn-or-ban game has a two part equilibrium, while the warn-only game only has a one part equilibrium. This example provides a counter-example showing that we cannot extend the result of Theorem 1 to the case where $MW < M\pi$.

6. Conclusion

We have considered a model of a drug regulator who is empowered to ban or to warn, but not to tax or otherwise regulate, and who is concerned about both consumer ignorance and some other mild problem, such as use externalities. We found that without consumer ignorance a regulator will ban few drugs, and without some other concern no drugs will be banned. A regulator with both concerns, however, will ban many drugs.

This model is offered to help explain the behavior of organizations like the FDA, which in effect bans most available drugs, and to help explain the observed mild effects of substituting warnings for bans. The model suggests that, given equilibrium expectations in a world where drugs can be banned, the public will not typically benefit from substituting a warning for a ban on any one drug.

We also showed, however, that regulators who ex ante expect drug under-consumption should lament their ability to ban drugs, since bans on average reduce equilibrium consumption. This regret is shared by the 'market agent,' and by any agent with intermediate preferences. This suggests that the public might support a general prohibition on health-drug bans, if they could come to understand how expectations would change in a new equilibrium. Similar conclusions may hold regarding other bans on health aids, such as health professional licensing.

Such a no-ban equilibrium arguably applies to US print media, due to a constitutional prohibition on media bans. This prohibition may be in the public interest if, setting aside quality issues, print media tend to be under-consumed. This welfare superiority of the no-ban equilibrium may also apply to other arguably under consumed products, such as education or investments. If people tend to under-save, for example, the SEC may regret its ability to prohibit specific investments.

This paper's results also apply to 'paternalistic' relations between doctors and patients, teachers and students, and of course parents and children (New, 1999; Burrows, 1993). So parents may regret their ability to limit their child's risky activities, such as dating, driving, reading, employment, or sports, if they expect too little activity from a risk-informed child. Finally, by simply reversing the sign of the quantity variable in the model, this paper's results can apply to products and activities which are required, rather than prohibited.

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Appendix A

Proof of Lemma 1

(See Fig. 1). Let us denote equation $W(q_{i-1},a_i) = W(q_i,a_i)$ as $\mathscr{E}_i^W(q_{i-1},a_i,q_i)$, and equation $I(q_i,a_i) = I(q_i,a_{i+1})$ as $\mathscr{E}_i^\pi(a_i,q_i,a_{i+1})$. This proof will apply to both

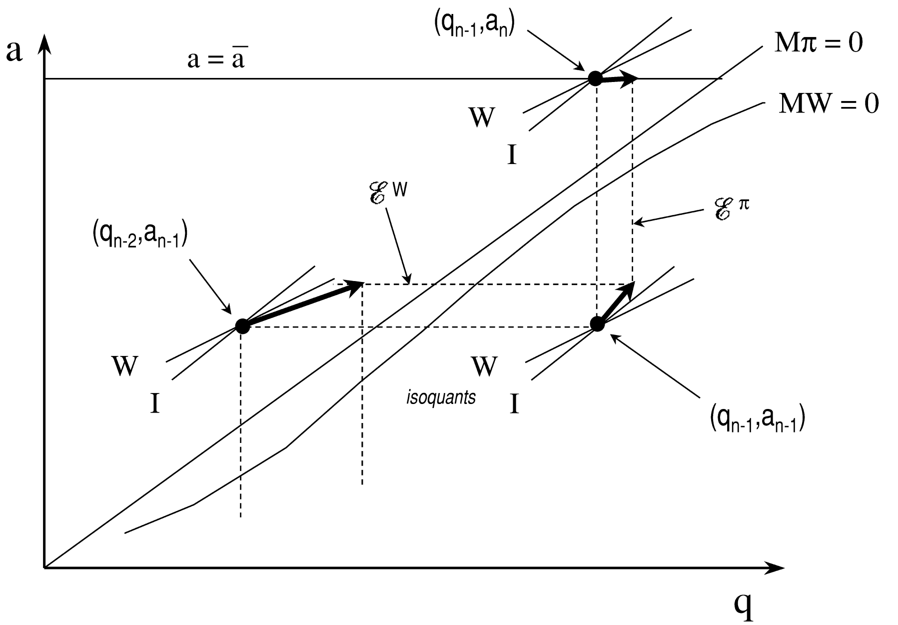

Fig. 1. Aid to monotonicity proof.

the warn-or-ban and the warn-only game. Let us consider first varying x in the warn-or-ban game.

An equilibrium can be thought of as a path through the (q,a) plane. The ban point (x,a_{k+1}) is connected by a horizontal line representing equation $\mathscr{E}^W_{k+1}$ to a point (q_{k+1},a_{k+1}). A vertical line representing equation $\mathscr{E}^\pi_{k+1}$ then connects this to a point (q_{k+1},a_{k+2}). This zig–zag pattern continues until a vertical line reaches the last point $(q_{n-1},\bar{a})$. If $x \neq q_0$, then going in the other direction from point (x,a_k), the zig–zag pattern ends at a vertical line reaching $(q_0,\underline{a})$.

As x varies, each point (q,a) will vary with some vector $(\mathrm{d}q/\mathrm{d}x, \mathrm{d}a/\mathrm{d}x)$, and the equations corresponding to each line connect the vectors on the two ends of the lines. The $\mathscr{E}^W_i$ equations say that if the vector on one side of a horizontal line cuts the W isoquants so as to move toward lower W, the other side must cut in the opposite direction, so as to also move toward lower W. Since points connected by lines are on opposite sides of the $\tilde{q}(a)$ (i.e. $MW=0$) curve, opposite movement means they both move 'inside' (toward $MW=0$), or both move 'outside' (away from $MW=0$). Similarly, the $\mathscr{E}^\pi_i$ equations say that the vector must cut the I isoquants in opposite directions from the $q=x$ (i.e. $M\pi=0$) line at the two ends of a vertical line.

The end point $(q_{n-1},\bar{a})$ must vary along the line $a=\bar{a}$, which as q_{n-1} increases must cut inside the isoquants of I. Thus at (q_{n-1},a_{n-1}) the vector must also be inside I, and is hence positive, and a steeper I vector implies inside W as well. Continuing, at (q_{n-2},a_{n-1}) the vector must cut inside W and be positive, which is now also inside I, since we are on the other side of $MW=0$. Continuing this down the zig–zag shows all vectors are $(+,+)$ to (x,a_{k+1}). The same argument applies starting from $(q_0,\underline{a})$ which varies along the line $a=\underline{a}$, making vectors are $(+,+)$ for $i<k$. The same sort of argument also applies when varying $\underline{a}$ in the warn-only game. QED.

Proof of Lemma 2

In general ex ante expected utility for any mixed agent is

$$\mathrm{E}[U] = \sum_{i=0}^{n-1} \int_{a_i}^{a_{i+1}} U(q_i,a)\,\mathrm{d}F(a).$$

To compare the expected utility of different equilibria, let us continuously vary one equilibrium into another in a way that maintains the sign of the local derivative of $\mathrm{E}[U]$. (This proof closely follows C&S's proof of their theorem three).

Let q_{-1} be the solution to $\mathscr{E}^W_0(q_{-1},\underline{a},\hat{q}_0)$. If $x<q_{-1}$, the regulator will never choose x, making the warn-only and warn-or-ban equilibria the same. As we vary x in the warn-or-ban game from q_{-1} to $\hat{q}_0$, we move through the various n part equilibria of the warn-or-ban game to one that is equivalent to an n part

equilibrium of the warn-only game. Along this path, the local derivative of E[U] with respect to x is

$$\frac{\mathrm{dE}[U]}{\mathrm{d}x} = \sum_{i=0}^{n-1} \left(\frac{\mathrm{d}q_i}{\mathrm{d}x} \int_{a_i}^{a_{i+1}} MU(q_i,a)\,\mathrm{d}F(a) - \frac{\mathrm{d}a_i}{\mathrm{d}x} \int_{q_{i-1}}^{q_i} MU(q,a_i)\,\mathrm{d}q \right).$$

Given monotonicity all the $\mathrm{d}a_i/\mathrm{d}x$ and $\mathrm{d}q_i/\mathrm{d}x$ are positive.

For W, the second integral is exactly zero for all i, and so since $MW \geq MU$, this integral term contributes non-negatively. For π, the first integral is exactly zero for all $i \neq 0$, and for $i = 0$ is positive for any $x \in [q_{-1},\hat{q}_0]$, since x is less than the ideal point $\bar{q}(\underline{a},a_1)$ where this integral is zero. (x is clearly less at $x \leq \underline{a}$, and by continuity stays less across this range; otherwise it would be equal somewhere between, identifying another n part equilibrium the warn-only game, which contradicts monotonicity). Thus for U the first integral contributes positively.

Thus for $x \leq \hat{q}_0$, the sum is positive, and so U strictly prefers a distinct n part equilibrium of the warn-only game to an n step equilibrium of the warn-or-ban game. QED.

Proof of Lemma 3

We need to show that for $\underline{a} \leq x = q_0$ and $MW > M\pi$, the maximum equilibrium parts $\bar{n}(x)$ for the warn-or-ban game is no larger than the maximum $\bar{n}$ for the warn-only game.

Let us consider allowing the range $[\underline{a},\bar{a}]$ to vary within a larger range $[\underline{r},\bar{r}]$. A varying $F_{\underline{a},\bar{a}}$ will be obtained by conditioning on a differentiable c.d.f $G(a)$ with support $[\underline{r},\bar{r}]$, as in

$$F_{\underline{a},\bar{a}}(a) = \frac{G(a) - G(\underline{a})}{G(\bar{a}) - G(\underline{a})}.$$

Let us hold $x = \underline{a}$ true as we vary $\underline{a}$ in the warn-or-ban game. Observe that since the equations $\mathscr{E}_i^W, \mathscr{E}_i^\pi$ are in terms of continuous functions of the q_i,a_i, their solutions vary continuously as we vary $\underline{a}$, in both the warn-or-ban and warn-only cases. Thus the only thing preventing us from varying $\underline{a}$ to collapse a solution with n parts over range $[\underline{a},\bar{a}]$ all the way to $[\bar{a},\bar{a}]$ is that at some point the solutions will begin to violate one of the constraints $a_i \leq a_{i+1}$ or $q_{i-1} \leq q_i$.

If there were a sequence of solutions to $\mathscr{E}_i^W$ approaching $q_{i-1} = q_i$, then we would have $MW(q_{i-1},a_i) = 0 \geq M\pi(q_{i-1},a_i)$. $M\pi_a > 0$ and $\mathscr{E}_{i-1}^\pi$ imply that if this $M\pi(q_{i-1},a_i)$ is zero, then $a_i = a_{i-1}$, and otherwise $\mathscr{E}_{i-1}^\pi$ has no solution. Thus as $\underline{a}$ increases, $\bar{n}_{[\underline{a},\bar{a}]}(x)$ and $\bar{n}_{[\underline{a},\bar{a}]}$, the maximum part numbers in the warn-or-ban and warn-only game, respectively, can decrease only immediately after the $\underline{a}$ points which have *boundary solutions* where $a_i = a_{i+1}$ for some i.

$\mathscr{E}_i^\pi$, $M\pi_a > 0$, and $M\pi(a,a) = 0$ imply that if any two of a_i,q_i,a_{i+1} become

equal, all three are equal. Similarly, $MW \geq M\pi$, $M\pi(a,a) = 0$, and $MU_q < 0$ imply that $\mathscr{E}_i^W$ has no solution for $q_{i-1} < a_i = q_i$. Taken together these imply boundary solutions must satisfy $\underline{a} = a_0 = a_1$, in both the warn-only and warn-or-ban games, with $a_i < a_{i+1}$ for all $i > 0$. In the warn-only game $\mathscr{E}_0^{\pi}$ implies $q_0 = a_0$, while in the warn-or-ban game $x = \underline{a}$ implies the same thing. Thus both games will have a boundary solution for a given $\underline{a}$ if either does. Since for $\underline{a} = \bar{a}$ we have $\bar{n}(x) = \bar{n} = 1$, and since $\bar{n}(x), \bar{n}$ change one unit at a time, we must have $\bar{n}_{[\underline{a},\bar{a}]} = \bar{n}_{[\underline{a},\bar{a}]}(x)$ for all $\underline{a}, \bar{a}$ when $x = \underline{a}$.

Now consider ban outcomes $x \geq \underline{a}$. For any equilibrium of the warn-or-ban game with $x = q_0$, a_0 only appears in the constraint $\underline{a} = a_0 \leq a_1$. Thus given such an equilibrium, we can construct other equilibria on other ranges by simply varying $\underline{a} = a_0$ within $[\underline{r}, a_1]$. This implies that for $q_0 = x \geq \underline{a}$, $\bar{n}_{[\underline{a},\bar{a}]} \geq \bar{n}_{[\underline{a},\bar{a}]}(x)$. Thus for any equilibria of the warn-or-ban game where $x \geq \underline{a}$, there is an equilibria of the warn-only game with at least as many parts. QED.

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