The Benefits of Reducing Fraud

Daniel Becker
Federal Trade Commission

Jack Mountjoy
University of Chicago

Doug Smith
Federal Trade Commission

Erez Yoeli
Federal Trade Commission*

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Abstract

The Federal Trade Commission estimates that US consumers pay nearly $3 billion each year for fraudulent goods and services, and over 13% of surveyed consumers indicate that they have been defrauded. As large as these numbers are, they may not reflect the true economic damage from fraud if consumers' general distrust of markets with fraud prevents mutually beneficial transactions. We characterize the loss in consumer confidence in markets with one kind of fraud: when a valueless object is made to seem identical, prior to sale, to a valuable legitimate good. This kind of fraud increases the effective price of obtaining a legitimate good, and thus acts as a tax on legitimate production. Adopting this framework, we analyze a market with a single legitimate producer and a single fraudster. We establish conditions under which the market does not collapse, solve for the equilibrium levels of legitimate and fraudulent production, and evaluate the benefits of increased anti-fraud enforcement. We find that markets are more likely to collapse when the fraudster's costs are relatively low or the elasticity of demand is relatively high, show that fraud induces the legitimate producer to increase output and thus helps to mitigate market power, and establish conditions under which enforcement increases consumer surplus. These results provide insight into the optimal allocation of anti-fraud enforcement efforts.

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> Now Laban had two daughters: the name of the elder was Leah, and the name of the younger was Rachel. And Leah's eyes were weak; but Rachel was of beautiful form and fair to look upon. And Jacob loved Rachel; and he said: 'I will serve thee seven years for Rachel thy younger daughter.' And Laban said: 'It is better that I give her to thee, than that I should give her to another man; abide with me.' And Jacob served seven years for Rachel; and they seemed unto him but a few days, for the love he had to her. And Jacob said unto Laban: 'Give me my wife, for my days are filled, that I may go in unto her.' And Laban gathered together all the men of the place, and made a feast. And it came to pass in the evening, that he took Leah his daughter, and brought her to him; and he went in unto her. And Laban gave Zilpah his handmaid unto his daughter Leah for a handmaid. And it came to pass in the morning that, behold, it was Leah; and he said to Laban: 'What is this thou hast done unto me? Did not I serve with thee for Rachel? Wherefore then hast thou beguiled me?'
>
> – Genesis 29:16-25

The Federal Trade Commission estimates payments for fraud in the US at nearly $3 billion each year, with over 13% of surveyed consumers indicating that they have been taken by a fraud. International rates are comparable (Shadel 2009). As large as these numbers are, they may not reflect the true economic damage from fraud if consumers' general distrust of markets with fraud prevents mutually beneficial transactions. Unfortunately, existing economic theory is silent on the subject. We aim to address this gap in the literature, characterizing how market conditions affect the prevalence of fraud and evaluating the benefits to anti-fraud enforcement.

We examine markets with one kind of fraud: when an object is made to seem identical, prior to sale, to a valuable legitimate good. This kind of fraud is sometimes labeled counterfeiting or forgery. For now,[1] we focus on experience goods, that is, goods that, post purchase, are revealed to be of lower value than those they imitated. Examples include powdered sugar passed off as cocaine and payments taken for services that are then not provided. For these kinds of goods, we exactly characterize the loss in consumer confidence due to fraud. Fraud increases the effective price of obtaining a legitimate good, and thus acts like a tax on legitimate production.

Adopting this framework, we examine a market with one legitimate producer and one fraudster.[2] We establish conditions under which a Nash equilibrium exists and the market does not collapse. An equilibrium is more likely to exist if the cost of producing fraudulent goods is high relative to the cost of legitimate production, or if demand is relatively inelastic. When an equilibrium exists, there is always some fraudulent production. Interestingly, we find that the legitimate producer increases output in the presence of fraud. The legitimate producer does this because, by increasing output, she increases the proportion of legitimate goods in the market and thus consumer confidence. Fraud thus mitigates at least somewhat the effects of market power.

[1] An analysis of markets with fraud for goods with credence characteristics is forthcoming.
[2] An analysis of markets with multiple legitimate firms and multiple fraudsters is forthcoming.

We also suggest a framework for evaluating the effect of increased enforcement on welfare and describe the effect of increased enforcement separately for consumers, the legitimate firm, and the fraudster. We find that the quantity of legitimate production, and consequently consumer surplus, is increasing in enforcement as long as the fraudster's costs, inclusive of any costs related to avoiding enforcement, are lower than the legitimate firm's costs. Surprisingly, the legitimate producer's profits always fall with increased enforcement. Finally, we find that if payments to fraudsters are treated as transfers of wealth, total surplus may fall even when the quantity of legitimate production is increasing in enforcement.

Given the widespread prevalence of fraud, it is surprising that theories of fraud in the general economics literature are so scant. The most similar paper to ours is Leland (1979) which explores the impact of minimum quality and licensing in markets where consumers cannot distinguish quality differences across products. More recently, Armstrong and Chen (2009) explore a market in which some consumers are simultaneously inattentive to quality differences across products and ignore price signals. Other work that looks at fraud in settings different from ours includes Darby and Karny (1973), who describe fraudulent oversupply of credence goods in a competitive market, so customers cannot evaluate whether they have received a fraudulent good, and Gong, McAfee and Williams (2011) who describe macroeconomic fraud cycles over time. The rest of the literature focuses on specific frauds such as insurance, medical, accounting, or financial fraud. Our analysis is distinguished from these previous studies by its emphasis on consumers' loss of confidence from fraud and the consequent loss of welfare from reduced market participation. Our work is perhaps more similar in its spirit to the literature on adverse selection (beginning, of course, with Akerlof 1970), in particular, product quality and disclosure (see, e.g., Milgrom 2008) and insurance markets (for a review, see Einav and Finkelstein 2011).

It is less surprising that the empirical literature on fraud is scant given the difficulty in obtaining accurate data on fraudulent production. Qian (2011) surmounts this difficulty and presents evidence from the Chinese shoe industry suggesting that entry of fraudulent production hurts sales of legitimate low-end products but increases sales of legitimate high-end products through an advertising effect.

The remainder of the paper is organized as follows. Section 1 characterizes demand for fraud of the type examined in this paper. Section 2 explores the impact of fraud in markets with one legitimate producer and one fraudulent firm. Section 5 concludes.

1 The Market for Goods or Services in the Presence of Fraud

Consider a market in which sellers know the quality of the service or product they provide, but buyers do not. There are two possible quality types $\{l, f\}$, where l represents legitimate and f represents fraudulent production. Each is produced at a constant marginal cost. The legitimate producer's costs are represented by c_l. The fraudster's costs are $c_f = m_f + \alpha_f$ and include both manufacturing costs, m_f, and the costs of avoiding enforcement, α_f. This assumption encompasses some simple models of enforcement. For example, suppose that fraudulent goods are confiscated with some fixed probability, γ, which is determined by regulation and enforcement. Then, for every unit produced, the fraudster sells $1-\gamma$ units, and $c_f = \frac{1}{1-\gamma}\overline{m_f}$. Rearranging terms yields, $c_f = m_f + \alpha_f$ where $\alpha_f = \frac{\gamma}{1-\gamma} m_f$. Similarly, suppose that the fraudster is fined F if her activity is detected, and that every unit produced increases the probability of detection by ω. In this case, $c_f = \overline{c_f} + \alpha_f$, and $\alpha_f = \omega F$. However, as the second example highlights, assuming that the fraudster's costs are constant in Q_f and Q_l is an oversimplification; a more realistic model would have the cost of enforcement increasingly convexly in fraudulent output. To accommodate markets in which the probability of confiscation, detection, and otherwise evading regulation vary with Q_f and Q_l, c_f would have to be allowed to vary with Q_f and Q_l. This is beyond the scope of the current analysis.

In order to keep the analysis more general, we make no assumption about the magnitude of c_f relative to c_l.

1.1 Demand

We represent consumers' demand for the legitimate good by the function $P(Q_l)$ and assume that this function has the following properties:

- Demand is differentiable and strictly downward sloping, $P'(Q_l) < 0$.
- There is some price at which consumers demand positive quantity in the absence of fraud, $c_l < P(0)$. This assumption implies that the market would exist in the absence of fraud.
- There is some price such that for any price greater than it, consumers do not purchase any legitimate goods, $P(0) < \infty$. This rules out demand curves where price can increase without limit, such as constant elasticity demand.
- There is a finite demand $\overline{Q}$ for the good at prize zero such that $\hat{Q}_l \geq \overline{Q}$ implies $P(\hat{Q}_l) = 0$, and costless disposal of the product.
- We further assume that the monopolist's profit function π^M (that is, the legitimate firm's profit function if there were no fraud) satisfies $(\pi^M)'' < 0$.

To extend these preferences to the case when a consumer may purchase both legitimate and fraudulent products, we assume that consumers may repeatedly purchase any chosen quantity, learn what fraction of their newly purchased goods are fraudulent, and decide whether to return to the market to purchase more.

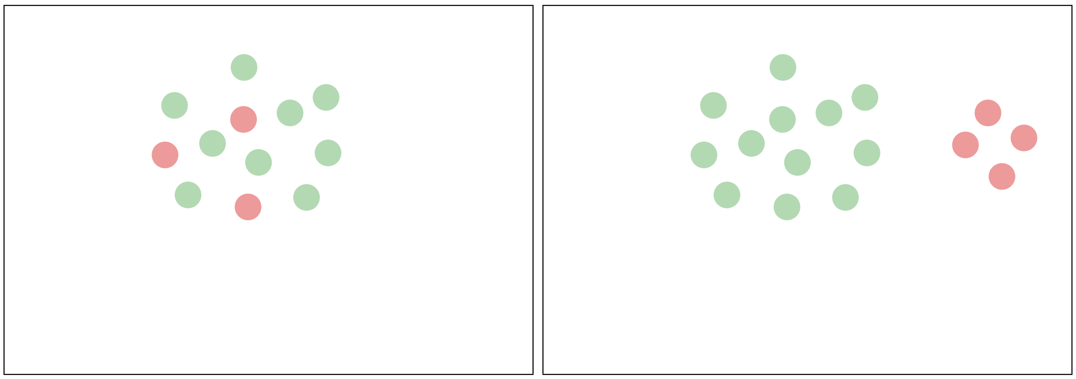
Then, we make three further assumptions about consumers' preferences:

- Utility is separable in legitimate and fraudulent goods. Consequently, demand for legitimate goods is independent of consumption of fraudulent goods.[3]
- Consumers are risk neutral over purchases. That is, goods in this market are sufficiently inexpensive relative to income so that the purchase of fraudulent goods does not impact the marginal utility of income. Together with the previous assumption, this implies that consumers' marginal utility depends only on the number of legitimate goods they have consumed.

[3] Similarly, we hope to relax this assumption in a follow-up that explores the harm from fraud due to "business stealing".

- Finally, we assume that the fraudulent good is valueless to consumers. This assumption is not necessary, but it greatly simplifies the math throughout the analysis (and corresponds to many real-world instances of fraud).

Figure 1: The Impact of Fraud on Individual Consumers



(a) Consumers go to market with the goal of obtaining legitimate (green) goods, but recognizing they will purchase some fraudulent (red) goods.

(b) Since fraudulent goods are valueless and are simply discarded, they increase the effective price of obtaining the legitimate goods consumers actually want.

In the presence of fraudulent goods, consumers end up purchasing some goods that are legitimate and some that are fraudulent, and therefore buy more goods than they end up consuming. This makes purchasing legitimate goods costlier (see figure 1). There will be two "prices" that are relevant to the analysis:

- **Transaction price, p_t.** This is the amount of money that the consumer pays the producer of a good (either legitimate or fraudulent) when purchasing said good, and the amount that the producer receives. We assume that the fraudulent firm sets a price equal to the legitimate firm's price. This can be motivated by the assumption that if the fraudulent firm set a different price it would be identified by consumers as fraudulent. The legitimate firm will determine transaction price by considering the other relevant price:

- **Effective price, p_e.** If the fraudulent firm produces the quantity Q_f, then the probability that a good the consumer buys is legitimate is $\frac{Q_l}{Q_l+Q_f}$. In expectation, then, the consumer needs to buy $\frac{Q_l+Q_f}{Q_l}$ units of goods to on average get one unit of legitimate good. Therefore the expected expenditure to purchase one unit of legitimate good is

$$p_e = \frac{Q_l + Q_f}{Q_l} p_t \tag{1}$$

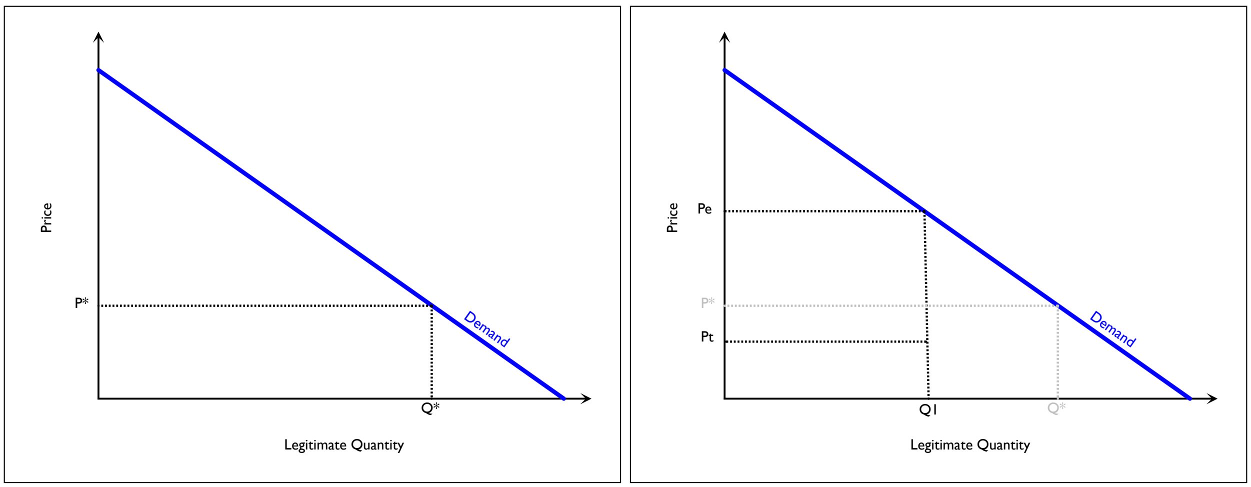
  It is straightforward to see that when $Q_f = 0$, $p_e = p_t$. When $Q_f > 0$, however, then $p_e > p_t$.

In what follows it will be convenient to work with p_e. This is because the relevant price for the demand function $P(Q_l)$ is actually the effective price, which is the price consumers pay, in expectation, for a single legitimate unit of the good (see figure 2). Wherever the relevant price is the transaction price, we use the following substitution derived from equation (1):

$$p_t(Q_l, Q_f) = \frac{Q_l}{Q_l + Q_f} P(Q_l) \tag{2}$$

For the rest of the paper we will substitute $P(Q_l)$ for p_e and use equation (2) to substitute for p_t.

FIGURE 2: THE IMPACT OF FRAUD ON DEMAND



(a) The market in the absence of fraud

(b) Fraud increases the effective price to consumers, p_e, but producers only get the transaction price, p_t

2 One Legitimate Producer and One Fraudulent Firm

Consider a market with demand as described in Section 1, a single legitimate producer, and a single fraudulent firm. We make the Cournot assumption: after choosing Q_l (and observing Q_f), the legitimate firm chooses price to sell its entire output Q_l at the maximum price, i.e., $p_e = P(Q_l)$.

2.1 Best Replies

2.1.1 Fraudulent firm's best reply

Proposition 1. *The fraudulent firm's best reply function $Q_f(Q_l)$ is equal to:*

$$Q_f(Q_l) \quad = \quad Q_l \left(\sqrt{\frac{P(Q_l)}{c_f}} - 1 \right) \tag{3}$$

where $P(Q_l) \geq c_f$, and 0 otherwise.

Proof. The fraudster maximizes profits, $\pi_f = Q_f(\frac{Q_l}{Q_l+Q_f} P(Q_l) - c_f)$ where we have used equation (2) to substitute for the transaction price. The first order condition is then:

$$\begin{aligned}\frac{\partial \pi_f}{\partial Q_f} &= \left(\frac{Q_l}{Q_l+Q_f}P(Q_l)-c_f\right)-\frac{1}{(Q_l+Q_f)^2}\cdot Q_l\cdot Q_f\cdot P(Q_l)\\ &= 0\end{aligned}$$

which implies:

$$Q_l \cdot P(Q_l)(Q_l+Q_f^*)-c_f(Q_l+Q_f^*)^2-Q_f^*\cdot Q_l\cdot P(Q_l)=0. \tag{4}$$

Distributing leads to:

$$Q_l^2\cdot P(Q_l)+Q_f^*\cdot Q_l\cdot P(Q_l)-c_f(Q_l+Q_f^*)^2-Q_f^*\cdot Q_l\cdot P(Q_l)=0 \tag{5}$$

and with some cancelling of terms we get:

$$c_f\cdot(Q_f^*)^2+2c_fQ_f^*\cdot Q_l+(c_f+P(Q_l))\cdot Q_l^2=0 \tag{6}$$

Applying the quotient rule and discarding the negative root yields the result. □

2.1.2 Legitimate firm's best reply

We will now explore the legitimate firm's problem. First it will be helpful to describe the legitimate firm's problem when there is no fraudulent firm. In that case the firm's profit is:

$$\pi_l^M(Q_l)=Q_l\left(P(Q_l)-c_l\right) \tag{7}$$

and the first order condition is

$$\frac{d\pi_l^M}{dQ_l}=P(Q_l)+P'(Q_l)Q_l-c_l. \tag{8}$$

In contrast, the legitimate firm's profit function, in the presence of fraud, is

$$\pi_l=Q_l\left(\frac{Q_l}{Q_l+Q_f}P(Q_l)-c_l\right). \tag{9}$$

The following proposition shows that the first order conditions of the two problems are related.

Proposition 2. *For a fixed Q_f, the first order condition for the legitimate firm in the presence of fraud is equal to:*

$$\frac{d\pi_l}{dQ_l}=\frac{Q_l}{Q_l+Q_f}\frac{d\pi_l^M}{dQ_l}+\frac{Q_f}{Q_l+Q_f}\left(\frac{Q_l}{Q_l+Q_f}P(Q_l)-c_l\right) \tag{10}$$

That is, it is the weighted average of the no-fraud first order condition and a term that is positive if and only if $p_t(Q_l,Q_f)>c_l$, where the weights depend on Q_l.

Proof.

$$\pi_l(Q_l)=\frac{Q_l}{Q_l+Q_f}P(Q_l)Q_l-c_lQ_l \tag{11}$$

First order condition using equation (11):[4]

$$\frac{d\pi_l}{dQ_l} = \left(\frac{1}{Q_l + Q_f} - \frac{Q_l}{(Q_l + Q_f)^2}\right) P(Q_l)Q_l + \frac{Q_l}{Q_l + Q_f} P'(Q_l)Q_l + \frac{Q_l}{Q_l + Q_f} P(Q_l) - c_l \tag{12}$$

We will simplify this expression, but first it is useful to consider that each term of this first order condition has a straightforward interpretation:

The **first term** captures the effect that raising Q_l has on narrowing the gap between p_t and $P(Q_l)$: the first fraction in the parentheses is the effect of increasing the numerator (which increases the transaction price the firm is able to charge) while the second term is the effect of increasing the denominator (which conversely decreases the transaction price relative to $P(Q_l)$).

The **second term** captures the effect on the revenue from units already being sold when the monopolist lowers price to sell more Q_l. Note that if $Q_f > 0$ then this effect is smaller than it would be if the monopolist were operating without the presence of fraud, by a factor of $\frac{Q_l}{Q_l + Q_f}$. This reflects that changes in the effective price lead to a change in the transaction price that is smaller by that factor.

The **third term** captures the effect of the additional revenue from more Q_l sold. As with the second term, this is smaller than the no-fraud case by a factor of $\frac{Q_l}{Q_l + Q_f}$, reflecting the difference between the transaction price and the effective price.

The **fourth term** is just the marginal cost of producing additional Q_l.

Now we can transform this expression in the following useful way. First, the expression in the parantheses can be simplified to get:

$$\frac{d\pi_l}{dQ_l} = \frac{Q_f}{(Q_l + Q_f)^2} P(Q_l)Q_l + \frac{Q_l}{Q_l + Q_f} P'(Q_l)Q_l + \frac{Q_l}{Q_l + Q_f} P(Q_l) - c_l \tag{13}$$

and the first term can then be rearranged as follows:

$$\frac{d\pi_l}{dQ_l} = \frac{Q_f}{Q_l + Q_f} \cdot \frac{Q_l}{Q_l + Q_f} P(Q_l) + \frac{Q_l}{Q_l + Q_f} P'(Q_l)Q_l + \frac{Q_l}{Q_l + Q_f} P(Q_l) - c_l \tag{14}$$

Using the fact that all the terms except the last are multiplied by $\frac{Q_l}{Q_l + Q_f}$, we divide through by that ratio:

$$\frac{Q_l + Q_f}{Q_l} \frac{d\pi_l}{dQ_l} = \frac{Q_f}{Q_l + Q_f} P(Q_l) + P'(Q_l)Q_l + P(Q_l) - \frac{Q_l + Q_f}{Q_l} c_l \tag{15}$$

$$= P'(Q_l)Q_l + P(Q_l) - c_l + \frac{Q_f}{Q_l + Q_f} P(Q_l) - \frac{Q_f}{Q_l} c_l \tag{16}$$

$$= \frac{d\pi_l^M}{dQ_l} + \frac{Q_f}{Q_l} \left(\frac{Q_l}{Q_l + Q_f} P(Q_l) - c_l\right) \tag{17}$$

Multiplying both sides by the same ratio, $\frac{Q_l}{Q_l + Q_f}$, and simplifying gives equation (10) and completes the proof. □

[4] Note that repeated use of the chain rule implies that $(f \cdot g \cdot h)' = f' \cdot g \cdot h + g' \cdot f \cdot h + h' \cdot f \cdot g$.

Note that when $Q_f = 0$ the first order condition collapses to the monopolist without fraud's first order condition. Now we can determine some results for the case when the fraudulent firm produces positive output. The following remark and lemma help us determine what Q_l at which the first order condition equals zero is the best reply.

Remark 1. *For $Q_f > 0$, $\frac{d\pi_l}{dQ_l}|_{Q_l=0} = -c_l$ and $\lim_{Q_l \to \infty} \frac{d\pi_l}{dQ_l} = -c_l$.*

Proof. Straightforward calculation and use of the assumptions on $P(Q)$. □

Lemma 1. *For a given $Q_f > 0$, the number of values of Q_l at which the first order condition crosses 0 is an even number, potentially zero. For exactly half those values the second order condition is negative, i.e., the firm's profit at that value of Q_l is a local maximum.*

Proof. Remark 1 establishes that the first order condition is negative for both $Q_l = 0$ and $Q_l = \infty$. By inspection, the first order condition is continuous (given that $P(Q_l)$ is continuous). It is immediate that a continuous function that starts below zero and ends below zero must cross zero an even number of times. When the first derivative crosses from negative to positive, the second derivative must be positive, and so the profit at the crossing point is a local minimum. When the first derivative crosses from positive to negative, the second derivative must be negative and so the profit at that crossing point is a local maximum. □

It is possible that the first order condition reaches zero but then does not cross from positive to negative, or vice-versa. It is straightforward but tedious to show that such a point cannot be a local maximum, and so we omit that part of the proof.

Now we define $Q_l(Q_f)$ in the following way: $Q_l(Q_f)$ is the maximizer of $\pi_l(Q_l, Q_f)$. If there is more than one Q_l that maximizes that expression, $Q_l(Q_f)$ is defined as the maximum of those values, unless those values include 0, in which case $Q_l(Q_f)$ is equal to zero. Lemma 1 ensures that $Q_l(Q_f)$ is well defined, as the best reply must be one of the local maxima.

Proposition 3. *If $Q_l(Q_f) > 0$, then the transaction price at $Q_l(Q_f)$ is greater than c_l, i.e.,*

$$\frac{Q_l(Q_f)}{Q_l(Q_f) + Q_f} P\left(Q_l(Q_f)\right) - c_l > 0 \tag{18}$$

and furthermore

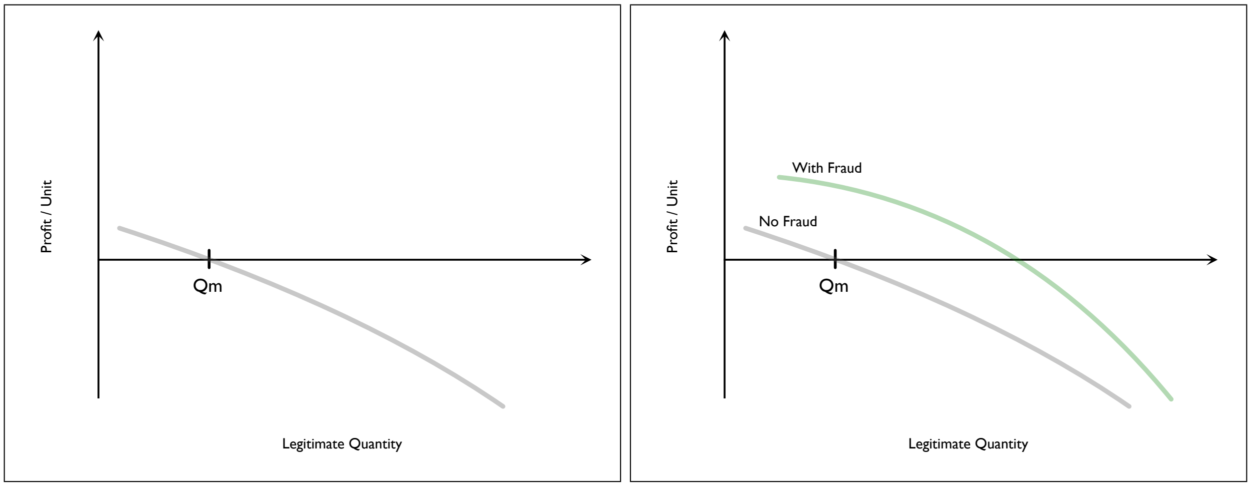
$$Q_l(Q_f) > Q^M. \tag{19}$$

Proof. Note that $Q_l(Q_f) > 0$ implies that $\pi_l(Q_l(Q_f), Q_f) > 0$. This implies that $\frac{Q_l}{Q_l+Q_f} P(Q_l(Q_f)) - c_l > 0$. Therefore the second term in the first order condition is positive. Because the first order condition must be 0 at $Q_l(Q_f)$, that implies that the first term is negative. The first term can only be negative if $\frac{d\pi_l^M}{dQ_l}|_{Q_l=Q_l(Q_f)} < 0$. But that implies that $Q_l(Q_f) > Q^M$. □

The intuition for proposition 3 is presented in figure 3.

The following lemma and proposition determine conditions under which the legitimate firm's best reply is a positive quantity.

Figure 3: The Legitimate Firm Increases Output in Response to Fraud



(a) The legitimate firm's FOC in the absence of fraud (in grey).

(b) The legitimate firm's FOC in the presence of fraud (in green). If the legitimate firm is making positive profits, the legitimate firm's FOC must be positive at the monopoly quantity (see equation 17) and intersect the x-axis to the right of where it would have intersected in the absence of fraud. This means the legitimate firm increases output in response to fraud.

Lemma 2.

$$\frac{Q_l}{Q_l + Q_f} P(Q_l) - c_l > 0 \tag{20}$$

if and only if

$$\pi_l^M(Q_l) - Q_f \cdot c_l > 0. \tag{21}$$

Proof. Observe that equation (20) holds if and only if

$$Q_l \cdot P(Q_l) - c_l(Q_l + Q_f) = (P(Q_l) - c_l) Q_l - Q_f \cdot c_l > 0 \tag{22}$$

Substituting for $\pi_l^M(Q_l)$ gives equation (21). □

Proposition 4. $Q_l(Q_f) > 0$ *if and only if*

$$\pi_l^M(Q^M) > Q_f \cdot c_l. \tag{23}$$

Proof. Recall that by definition, Q^M maximizes $\pi_l^M(Q_l)$. Combined by with lemma 2, this implies that if equation (23) does not hold, then for all Q_l the per unit profit is (weakly) negative, so $Q_l = 0$ is a best reply to Q_f. Then by construction $Q_l(Q_f) = 0$.

Conversely, if equation (23) does hold, then

$$\frac{Q^M}{Q^M + Q_f} P(Q^M) - c_l > 0 \tag{24}$$

which implies the per-unit profit is positive at Q^M. Therefore $Q_l = 0$ cannot be a best reply to Q_f, so by construction $Q_l(Q_f) > 0$. $\square$

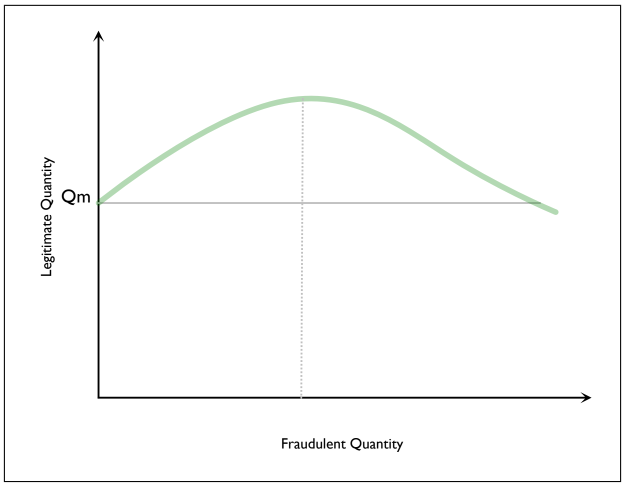
The following proposition determines a condition under which an increase in the quantity of fraudulent good leads to an increase in the legitimate firm's profit maximizing quantity.

Proposition 5. *The best reply $Q_l(Q_f)$ is increasing in Q_f if*

$$\left(\frac{Q_l(Q_f)}{Q_l(Q_f) + Q_f}\right)^2 P(Q_l(Q_f)) - c_l > 0. \tag{25}$$

Note that this expression is strictly less than the transaction price minus marginal cost at $(Q_l(Q_f), Q_f)$, so it can be negative even where a firm is making positive profits.

Figure 4: Legitimate Firm's Best Response to Fraud



The legitimate firm increases output in response to fraud (see proposition 3), increasing output more for intermediate amounts of fraud (see proposition 5).

Proof. Equation (17) shows the following result:

$$\frac{d\pi_l}{dQ_l} = 0 \tag{26}$$

if and only if

$$\frac{d\pi_l^M}{dQ_l} + \frac{Q_f}{Q_l}\left(\frac{Q_l}{Q_l + Q_f}P(Q_l) - c_l\right) = 0. \tag{27}$$

Equation (27) can be rewritten as

$$\frac{d\pi_l^M}{dQ_l} + \frac{Q_f}{Q_l + Q_f}P(Q_l) - \frac{Q_f}{Q_l}c_l = 0. \tag{28}$$

Taking the partial derivative with respect to Q_f of equation (28), we get the following result:

$$\frac{\partial}{\partial Q_f}\left(\frac{d\pi_l^M}{dQ_l} + \frac{Q_f}{Q_l+Q_f}P(Q_l) - \frac{Q_f}{Q_l}c_l\right) \tag{29}$$

$$= \frac{Q_l}{(Q_l+Q_f)^2}P(Q_l) - \frac{c_l}{Q_l} = \frac{1}{Q_l}\left(\left(\frac{Q_l}{Q_l+Q_f}\right)^2 P(Q_l) - c_l\right) \tag{30}$$

$$> 0 \quad \Leftrightarrow \quad \left(\frac{Q_l}{Q_l+Q_f}\right)^2 P(Q_l) - c_l > 0. \tag{31}$$

Taking the partial derivative of equation (28) with respect to Q_l, we get

$$\frac{\partial}{\partial Q_l}\left(\frac{d\pi_l^M}{dQ_l} + \frac{Q_f}{Q_l+Q_f}P(Q_l) - \frac{Q_f}{Q_l}c_l\right) \tag{32}$$

$$= \frac{d^2\pi_l^M}{dQ_l^2} - \frac{Q_f}{(Q_l+Q_f)^2}P(Q_l) + \frac{Q_f}{Q_l+Q_f}P'(Q_l) + \frac{Q_f}{Q_l^2}c_l \tag{33}$$

$$= \frac{d^2\pi_l^M}{dQ_l^2} + \frac{Q_f}{Q_l+Q_f}P'(Q_l) + \frac{-Q_f}{Q_l^2}\left(\left(\frac{Q_l}{Q_l+Q_f}\right)^2 P(Q_l) - c_l\right) \tag{34}$$

The first term in equation (34) is negative by the assumption on the monopolist's profit function, while the second term is negative by the assumption that demand is downward sloping. The third term is negative if equation (25) holds. Therefore the partial derivative is negative if equation (25) holds.

Combining these two partial derivatives, and taking the total derivative of equation (27) with respect to Q_l and Q_f proves the result. □

It is clear from the calculations in proposition 2.2 that Q_f may in fact be decreasing when the condition in the proposition does not hold.

2.2 Equilibrium

We can find the equilibrium by combining the two best replies:

Proposition 6. *When $c_f \leq P(Q^M)$, there exists a pure strategy equilibrium (Q_l^*, Q_f^*) if and only if*

$$\frac{P(Q^M)}{c_l} > \frac{c_l}{c_f}. \tag{35}$$

When an equilibrium exists, it satisfies

$$Q_f^* > 0 \tag{36}$$

and

$$Q_l^* > Q^M. \tag{37}$$

Proof. In any pure strategy equilibrium it must be that $Q_l^* > 0$, which also implies that $Q_f^* > 0$. We first use the fact that equation (3), the fraudulent firm's best reply, implies the following useful result(s):

$$\frac{Q_l^*}{Q_l^*+Q_f^*} = \frac{Q_l^*}{Q_l^* \cdot \left(1+\left(\frac{P(Q_l^*)}{c_f}\right)^{\frac{1}{2}}-1\right)} = \left(\frac{c_f}{P(Q_l^*)}\right)^{\frac{1}{2}} \tag{38}$$

and therefore

$$\frac{Q_f^*}{Q_l^*+Q_f^*} = 1-\left(\frac{c_f}{P(Q_l^*)}\right)^{\frac{1}{2}}. \tag{39}$$

Substituting these expressions into equation (10), the legitimate firm's first order condition, and setting it equal to zero, yields:

$$\left.\frac{d\pi_l}{dQ_l}\right|_{Q_l=Q_l^*,Q_f=Q_f^*} = \left(\frac{c_f}{P(Q_l^*)}\right)^{\frac{1}{2}}\frac{d\pi_l^M}{dQ_l} + \left(1-\left(\frac{c_f}{P(Q_l^*)}\right)^{\frac{1}{2}}\right)\left(\left(\frac{c_f}{P(Q_l^*)}\right)^{\frac{1}{2}}P(Q_l^*)-c_l\right) \tag{40}$$

$$= \left(\frac{c_f}{P(Q_l^*)}\right)^{\frac{1}{2}}\frac{d\pi_l^M}{dQ_l^*} + \left(1-\left(\frac{c_f}{P(Q_l^*)}\right)^{\frac{1}{2}}\right)\left(P(Q_l^*)^{\frac{1}{2}}\cdot c_f^{\frac{1}{2}}-c_l\right) = 0 \tag{41}$$

If: Note that then the first order condition is positive at Q^M. It is easy to show that there is then a $Q_l^* > Q^M$ such that the first order condition is zero, which is then an equilibrium.

Only if: In the discussion of the properties of $Q_l(Q_f)$ we established that if $Q_l^* = Q_l(Q_f^*) > 0$ then $Q_l^* > Q^M$ and the second term must be positive. Therefore it must be the case that

$$P(Q_l^*)^{\frac{1}{2}}\cdot c_f^{\frac{1}{2}}-c_l > 0 \tag{42}$$

and $Q_l^* > Q^M$ implies that $P(Q_l^*) < P(Q^M)$, which implies that

$$P(Q_l^M)^{\frac{1}{2}}\cdot c_f^{\frac{1}{2}}-c_l > 0. \tag{43}$$

Rearranging terms and squaring both sides yields equation (35). □

Proposition 6 implies the following informative condition:

Remark 2. *A pure strategy equilibrium exists if and only if*

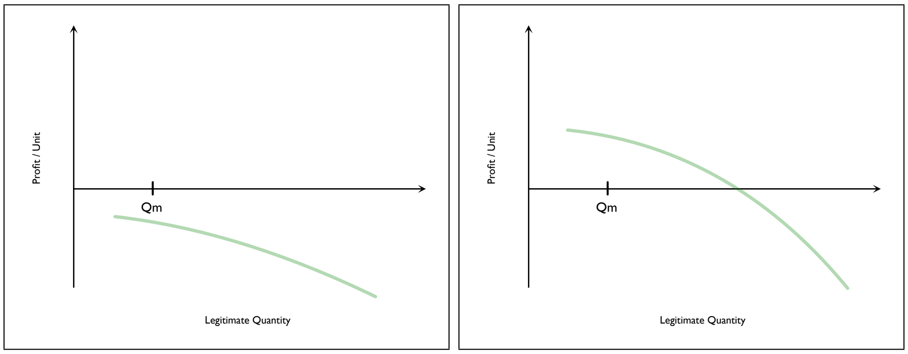
$$\frac{c_f}{c_l} \quad > \quad \left(1+\frac{1}{\epsilon^M}\right) \tag{44}$$

where ϵ^M is the elasticity of demand at the monopoly price and quantity.

Proof. In the absence of fraud, the monopolist prices where $P(Q^M) = \frac{\epsilon^M}{\epsilon^M+1}c_l$. Substituting this for $P(Q^M)$ in equation 35, rearranging terms, and squaring both sides yields the condition in equation 44. □

Equation (44) has an intuitive interpretation. According to this condition, one reason there might not be an equilibrium is if the fraudster's costs are too low relative to the legitimate firm's. Then the fraudster's production is not sufficiently constrained and she floods the market with fraudulent goods. Another reason

Figure 5: When is Equilibrium Supported?



(a) If per-unit profits are not sufficiently high, the legitimate firm's FOC will always lie below the x-axis, and it will not produce.

(b) As long as per-unit profits are sufficiently high, the legitimate firm's FOC will be positive, and the legitimate firm will produce until the point where its FOC crosses the x-axis.

an equilibrium may not exist is if demand is too elastic. Then consumers balk at the increased effective price in the presennce of even a little fraud, and demand in the market collapses.

Propositions 7 and 8 describe how equilibrium quantities of fraudulent and legitimate goods change as a function of c_f:

Proposition 7. *Q_l^* is increasing in c_f if $c_f < c_l$, and decreasing in c_f if $c_f > c_l$ (see figure 6).*

Proof. Consider equation 41. Multiplying through by $\left(\frac{P(Q_l^*)}{c_f}\right)^{\frac{1}{2}}$ and simplifying yields:

$$\frac{d\pi_l^M}{dQ_l} + \left(\left(\frac{P(Q_l^*)}{c_f}\right)^{\frac{1}{2}} - 1\right)\left(P(Q_l^*)^{\frac{1}{2}} \cdot c_f^{\frac{1}{2}} - c_l\right) = 0 \tag{45}$$

which, distributing the terms in the second expression and putting the terms involving c_f on the right side, is equal to

$$\frac{\frac{d\pi_l^M}{dQ_l}}{P(Q_l^*)^{\frac{1}{2}}} + P(Q_l^*)^{\frac{1}{2}} + \frac{c_l}{P(Q_l^*)^{\frac{1}{2}}} = \left(\frac{c_l}{c_f^{\frac{1}{2}}} + c_f^{\frac{1}{2}}\right). \tag{46}$$

The following calculation shows that whether the right side is increasing or decreasing depends only on the sign of $c_f - c_l$:

$$\frac{\partial}{\partial c_f}\left(\frac{c_l}{\sqrt{c_f}} + \sqrt{c_f}\right) \quad = \quad -\frac{1}{2}c_f^{-\frac{3}{2}}\left(c_l - c_f\right) \tag{47}$$

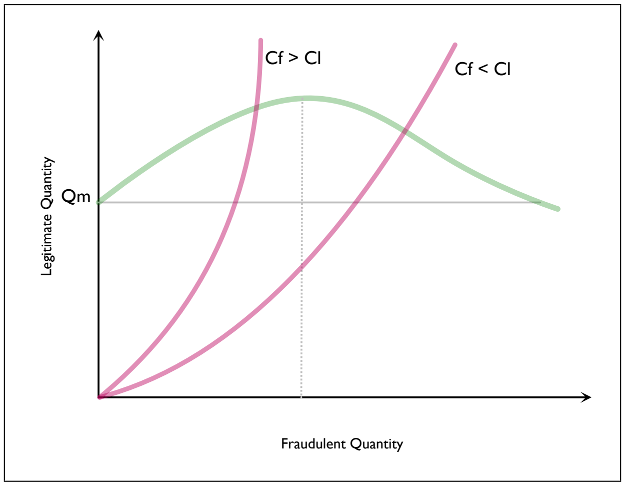
Equation (47) shows that the right side of equation (46) is decreasing in c_f if $c_l > c_f$ (which we assume if there is no regulatory enforcement) and increasing in c_f if $c_l < c_f$ (which may occur with regulation).

The left side of equation (46) depends only on Q_l^*. The monopolist's first order condition is negative and decreasing in Q_l by assumption, as is $P(Q_l^*)$, so the first term is decreasing in Q_l^*. To show the sum of the other two terms is also decreasing in Q_l^* requires the following simple calculation:

$$\frac{\partial}{\partial Q_l^*}\left(P(Q_l^*)^{\frac{1}{2}} + \frac{c_l}{P(Q_l^*)^{\frac{1}{2}}}\right) = \frac{P'(Q_l^*)}{2P(Q_l^*)^{\frac{1}{2}}}\left(1 - \frac{c_l}{P(Q_l^*)}\right) < 0. \tag{48}$$

As equation (46) must hold in equilibirum, combining the observations about the left and right side proves the result. □

Figure 6: How does legitimate quantity respond to stricter enforcement?



The legitimate firm's response to stricter enforcement depends on the intersection of its best response curve with the fraudster's. In response to increased enforcement, the fraudster's best response will shift to the left. The legitimate firm will increase output if the intersection of the best responses is to the right of its best response's peak, i.e., if there is a lot of fraud, and decrease it if the intersection is to the left of its best response's peak, i.e., when there is relatively little fraud.

Proposition 8. *Q_f^* is decreasing in c_f.*

Proof. The direct effect of an increase in c_f on the best reply function of the fraudulent firm is a strict decrease in the optimal quantity of fraudulent output. However, the best reply is increasing in Q_l^*. To prove the proposition we must show that the increase in c_f does not lead to an increase in Q_l^* sufficient to make the overall effect on Q_f^* positive. To do so, we first show an upper bound on how much Q_l^* can increase when c_f increases. We then show that increase in Q_l^* is too small to offset the direct effect of the increase in c_f on fraudulent output.

Lemma 3.

$$\frac{dQ_l^*}{c_f} < \frac{-1}{P'(Q_l^*)}\frac{P(Q_l^*)}{c_f}. \tag{49}$$

Proof. Clearly we can restrict attention to the case when $\frac{dQ_l^*}{c_f} > 0$. In this case, equation (45) implies that

$$\frac{d}{dc_f}\left(P(Q_l^*)^{\frac{1}{2}} \cdot c_f^{\frac{1}{2}} - c_l\right) > 0. \tag{50}$$

This then implies

$$\frac{P'(Q_l^*)}{2P(Q_l^*)^{\frac{1}{2}}} c_f^{\frac{1}{2}} \frac{dQ_l^*}{dc_f} + \frac{P(Q_l^*)^{\frac{1}{2}}}{2c_f^{\frac{1}{2}}} > 0 \tag{51}$$

which with some simplification yields equation (49). □

Now we calculate an upper bound on the total derivative. The total derivative of the the fraudster's best response function equals:

$$\frac{dQ_f^*}{dc_f} = \left[\left(\frac{P(Q_l^*)}{c_f} \right)^{\frac{1}{2}} - 1 + \frac{P'(Q_l^*)Q_l^*}{2P(Q_l^*)^{\frac{1}{2}} c_f^{\frac{1}{2}}} \right] \frac{dQ_l^*}{dc_f} - \frac{Q_l^* P(Q_l^*)^{\frac{1}{2}}}{2c_f^{\frac{3}{2}}}. \tag{52}$$

Substituting using equation (49) yields

$$\frac{dQ_f^*}{dc_f} < \left[\left(\frac{P(Q_l^*)}{c_f} \right)^{\frac{1}{2}} - 1 + \frac{P'(Q_l^*)Q_l^*}{2P(Q_l^*)^{\frac{1}{2}} c_f^{\frac{1}{2}}} \right] \frac{-1}{P'(Q_l^*)} \frac{P(Q_l^*)}{c_f} - \frac{Q_l^* P(Q_l^*)^{\frac{1}{2}}}{2c_f^{\frac{3}{2}}} \tag{53}$$

which, by distributing out the term $\frac{-P(Q_l^*)^{\frac{1}{2}}}{2P'(Q_l^*)c_f^{\frac{3}{2}}}$,

$$= \frac{-P(Q_l^*)^{\frac{1}{2}}}{2P'(Q_l^*)c_f^{\frac{3}{2}}} \left(\left[\left(\frac{P(Q_l^*)}{c_f} \right)^{\frac{1}{2}} - 1 + \frac{P'(Q_l^*)Q_l^*}{2P(Q_l^*)^{\frac{1}{2}} c_f^{\frac{1}{2}}} \right] \frac{c_f^{\frac{1}{2}} P(Q_l^*)^{\frac{1}{2}}}{P'(Q_l^*)} + \frac{P'(Q_l^*)Q_l^*}{2} \right) \tag{54}$$

which can be simplified further,

$$= \frac{-P(Q_l^*)^{\frac{1}{2}}}{2P'(Q_l^*)c_f^{\frac{3}{2}}} \left(P(Q_l^*) - P(Q_l^*)^{\frac{1}{2}} c_f^{\frac{1}{2}} + P'(Q_l^*)Q_l^* \right) \tag{55}$$

$$= \frac{-P(Q_l^*)^{\frac{1}{2}}}{2P'(Q_l^*)c_f^{\frac{3}{2}}} \left(\frac{d\pi^M}{dQ_l^*} + (c_l - P(Q_l^*)^{\frac{1}{2}} c_f^{\frac{1}{2}}) \right). \tag{56}$$

Both terms within the parentheses are negative, the first because $Q_l^* > Q^M$ and the second because it is equal to the the legitimate firm's marginal cost minus the equilibrium transaction price. Therefore $\frac{dQ_f^*}{dc_f} < 0$ and the proof is complete. □

2.3 Welfare Implications of Increasing Regulation

We wish to examine the welfare implications of increasing regulatory efforts in the market. Consistent with the discussion in Section 1, we model an increase in regulation as an increase in the costs of avoiding enforcement, α_f, and, consequently c_f.

In markets where no equilibrium exists, increasing α_f may push $\frac{c_f}{c_l}$ beyond the threshold established in equation 44 and reverse market collapse. This would yield large gains in efficiency, which we do not formally characterize. Instead, we focus on the effect of increased enforcement in markets that have not collapsed. Since policy makers may not consider fraudsters' welfare, we begin the analysis by separately examining the effect of an increase in α_f on consumer surplus and the legitimate producer's profits.

Proposition 9. *Consumer surplus is increasing in enforcement if and only if $c_f < c_l$.*

Proof. In equilibrium, consumer surplus is:

$$CS = \int_0^{Q_l^*} (P(Q_l) - P(Q_l^*))dQ_l \tag{57}$$

By inspection, consumer surplus is increasing when Q_l^* is increasing. By proposition 7, Q_l^* is increasing in c_f when $c_f < c_l$. Since $\frac{\partial c_f}{\partial \alpha_f} = 1$, Q_l^* is increasing in enforcement costs when $c_f < c_l$. □

Consumer surplus depends only on the quantity of legitimate goods and not the quantity of fraudulent goods because consumers are exactly compensated for the fraudulent goods they purchase through lower transaction prices.

Proposition 10. *The legitimate producer's profits are increasing in enforcement.*

Proof. In equilibrium, the legitimate producer's profits are:

$$\pi_l = \left(\frac{Q_l^*}{Q_l^* + Q_f^*} P(Q_l^*) - c_l \right) Q_l^* \tag{58}$$

Let $\pi_l^* = \pi\left(Q_l^*\left(Q_f^*(c_f)\right), Q_f^*(c_f)\right)$ denote the legitimate firm's profits in equilibrium. By the chain rule, $\frac{\partial \pi_l^*}{\partial \alpha_f} = \frac{\partial \pi_l^*}{\partial Q_f^*} \cdot \frac{\partial Q_f^*}{\partial c_f} \cdot \frac{\partial c_f}{\partial \alpha_f}$. We consider each term in turn.

First, by the envelope theorem:

$$\frac{\partial \pi_l^*}{\partial Q_f^*} = \left. \frac{\partial \pi\left(Q_l, Q_f^*(c_f)\right)}{\partial Q_f} \right|_{Q_l = Q_l^*\left(Q_f^*(c_f)\right)} \tag{59}$$

$$= -\frac{Q_l^{*2} P(Q_l^*)}{(Q_f^* + Q_l^*)^2} \tag{60}$$

By inspection, this is negative. Second, by proposition 8, $\frac{\partial Q_f^*}{\partial c_f} < 0$. Finally, $\frac{\partial c_f}{\partial \alpha_f} = 1$. Thus, π_l^* is increasing in enforcement. □

Changes in the legitimate producer's profits are inversely proportional to changes in the amount of fraudulent production. The legitimate producer's profits therefore increase when Q_f^* falls in response to increased enforcement.

Proposition 11. *The cost of fraudulent production is increasing in enforcement if $-\frac{\partial Q_f^*}{\partial c_f} < \frac{Q_f^*}{c_f}$.*

Proof. In equilibrium, the cost of fraudulent production is $c_f Q_f^*$. $\frac{\partial}{\partial \alpha_f}\left[c_f Q_f^*\right] = Q_f^* + c_f \cdot \frac{\partial Q_f^*}{\partial c_f} \cdot \frac{\partial c_f}{\partial \alpha_f}$. $Q_f^* + c_f \cdot \frac{\partial Q_f}{\partial c_f} \cdot \frac{\partial c_f}{\partial \alpha_f} > 0$ if and only if $-\frac{\partial Q_f^*}{\partial c_f} < \frac{Q_f^*}{c_f}$. Note that since we are considering a market that has not collapsed, by proposition 6, $Q_f^* > 0$, and by proposition 8, $\frac{\partial Q_f^*}{\partial c_f} < 0$. Finally, $\frac{\partial c_f}{\partial \alpha_f} = 1$. □

The cost of fraud increases in response to increased enforcement if the fraudster does not sufficiently reduce output to counter the increase in its costs.

Finally, we consider total surplus in proposition 12, treating payments to fraudsters as transfers of wealth.

Proposition 12. *Let total surplus refer to the sum of consumer surplus, the legitimate firm's profits and the fraudster's profits. Total surplus is:*

$$TS = \int_0^{Q_l^*} \left(P(Q_l) - c_l\right) dQ_l - c_f Q_f^* \tag{61}$$

Proof. Total surplus is:

$$\begin{aligned} TS &= \left(\int_0^{Q_l^*} P(Q_l)dQ_l - P(Q_l^*)Q_l^*\right) + \left(\frac{Q_l^*}{Q_l^* + Q_f^*}P(Q_l^*)Q_l^* - c_l Q_l^*\right) + \left(\frac{Q_l^*}{Q_l^* + Q_f^*}P(Q_l^*)Q_f^* - c_f Q_f^*\right) \\ &= \int_0^{Q_l^*} P(Q_l)dQ_l - P(Q_l^*)Q_l^* + \frac{Q_l^*}{Q_l^* + Q_f^*}P(Q_l^*)Q_l^* - c_l Q_l^* + \frac{Q_f^*}{Q_l^* + Q_f^*}P(Q_l^*)Q_l^* - c_f Q_f^* \end{aligned}$$

Collecting terms and simplifying yields the stated result. □

Total surplus is comprised of two terms. The first term is the benefit from legitimate transactions. Some of this benefit accrues to consumers, some to the legitimate firm, and some to the fraudster. Whether the first term increases or decreases in enforcement depends only on whether the quantity of legitimate goods increases. The second term is the cost of fraudulent production. These costs are borne entirely by the fraudster. Total surplus increases in response to enforcement so long as the costs of fraudulent production do not increase sufficiently rapidly to negate the gains from legitimate transactions.

3 Many Legitimate Firms and Many Fraudsters

3.1 Best Replies

3.1.1 Fraudulent firms' best replies

3.1.2 Legitimate firms' best replies

3.2 Equilibrium

3.3 Welfare

4 Extension to Goods With Credence Characteristics

So far, we have limited our analysis to goods that consumers can identify as fraudulent immediately upon consumption. Many goods have credence characteristics which consumers cannot observe upon consumption. For example, consumers often cannot tell with certainty whether a drug contributed to reducing symptoms or combatting a disease, they cannot taste whether tomatoes certified as organic were actually raised in accordance with organic farming practices, and they are not equipped to evaluate whether an expert service such as tax advice or auto repair reduces their tax liability or the risk their car would break down. For these kinds of goods, consumers cannot establish whether they are fraudulent. Precisely because of this, markets for credence goods are especially ripe for fraud. We therefore extend our analysis to these markets.

The key difference between consumers' behavior in markets for credence goods and the markets for experience goods we analyzed above is that consumers cannot go back to market to purchase precisely their desired number of legitimate goods. Therefore, there is uncertainty over the number of legitimate goods obtained, and consumers' utility from their purchase is the expected utility over all possible combinations of legitimate and fraudulent goods. Evaluating this expected utility requires making assumptions about consumers' individual utility functions, and, in particular, their preferences over risk.

To incorporate consumers' preferences over risk, we adapt demand as follows. First, we restrict consumers to having unit demand; that is, they value the first legitimate unit of a good at v_i and the remaining units at \$0. This simplification is appropriate for many of the goods we are most interested in. For example, consumers usually need only one dose of a legitimate drug to treat an infection or disease. A second dose will not help them heal faster and may be unsafe. Similarly, consumers need their car to be maintained or their tumor removed properly the first time. If done right the first time, additional maintenance or surgery is worthless. Second, we assume consumers' valuations vary, and that the distribution of valuations is described by the *c.d.f.*, $F(v)$. Market demand for the legitimate good in the absence of fraud is thus $Q_l(p) = \psi\left(1 - F(p)\right)$, where ψ is the number of consumers, and inverse demand is $P(Q_l) = F^{-1}\left(1 - \frac{Q_l}{\psi}\right)$. We restrict $F(v)$ so that inverse demand maintains the four properties listed in Section 1.1. Third, we restrict consumers' to going to market once. Fourth, we maintain the assumption that fraudulent goods are valueless to consumers.

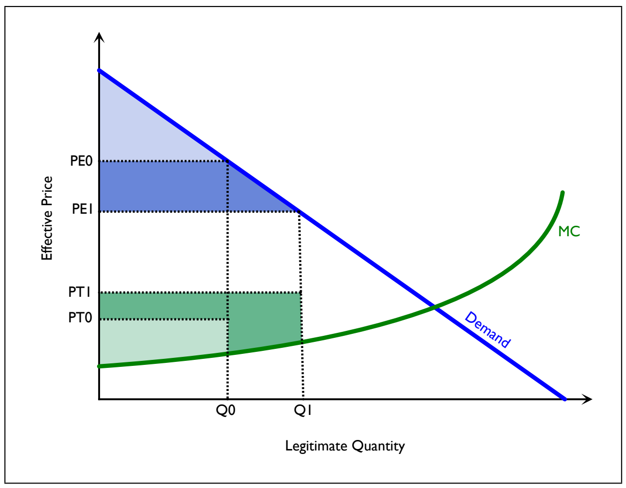
To extend these preferences to the case when a consumer may purchase both legitimate and fraudulent products, we assume consumers' expected utility from consuming the first good is $\phi\left(\frac{Q_l}{Q_l+Q_f}\right)v_i$, where ϕ represents consumers' shared preferences over risk. We restrict $\phi(0) = 0$ and $\phi(1) = 1$. $\phi = \frac{Q_l}{Q_l+Q_f}$ corresponds to risk neutral individuals, and $\phi < \frac{Q_l}{Q_l+Q_f}$ corresponds to risk averse individuals. Each consumer decides whether to go to market by comparing her expected utility to the transaction price. That is, she goes to market and buys one unit of the good if $\phi v_i > p_t$ or, after rearranging terms, if $v_i > \frac{1}{\phi}p_t$. Market demand for the good is thus $Q_l = \psi\left(1 - F\left(\frac{1}{\phi}p_t\right)\right)$.

How does this compare to situation described in Section 1.1, in which consumers can identify fraudulent goods and return to market? In that case, consumers purchase as long as $v_i = \frac{Q_l+Q_f}{Q_l}p_t$ and demand is $\psi\left(1 - F\left(\frac{Q_l+Q_f}{Q_l}p_t\right)\right)$. This is identical to demand in the credence case when individuals are risk neutral. If individuals are risk averse, $F\left(\frac{1}{\phi}p_t\right) > F\left(\frac{Q_l+Q_f}{Q_l}p_t\right)$, so $Q_l = \psi\left(1 - F\left(\frac{1}{\phi}p_t\right)\right) < \psi\left(1 - F\left(\frac{Q_l+Q_f}{Q_l}p_t\right)\right)$, and fraud reduces demand more for credence goods than those consumers can identify as fraudulent upon consumption. Thus, the deadweight loss from fraud will be greater in markets for credence goods.

5 Conclusion

We develop a simple framework for characterizing the loss of consumer confidence in markets with fraud and apply this framework to analyze a market with a single legitimate producer and a single fraudster. We establish conditions under which a Nash equilibrium exists, describe the equilibrium and how it changes in response to increased enforcement, and explore the welfare implications of these changes. By establishing conditions under which markets collapse and enforcement benefits consumers, our analysis yields useful results which, we hope, can help guide more effective enforcement when resources for fighting fraud are limited.

Figure 7: Taking the Analysis to Data



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