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Violence in Illicit Markets: Unintended Consequences and the Search for Paradoxical Effects of Enforcement

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Abstract

The textbook competitive model of drug markets predicts that greater law enforcement leads to higher black market prices, but also to the unintended consequences of greater revenue and violence. These predictions are not in accord with the paradoxical outcomes evinced by recent history in some drug markets, where enforcement rose even as prices fell. We show that predictions of the textbook model are not unequivocal, and that when bandwagon effects among scofflaws are introduced, the simple predictions are more likely to be reversed. We next show that even simple models of noncompetitive black markets can elicit paradoxical outcomes. Therefore, we argue that instead of searching for assumptions that lead to paradoxical outcomes, which is the direction the literature has taken, it is better for policy analysis to choose appropriate assumptions for the textbook model. We finish with performing such an analysis for the case of banning menthol cigarettes. Under the most plausible assumptions enforcement will indeed spur violence, although the legal availability of electronic cigarettes may mitigate or reverse this conclusion.

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I.   Introduction

The problem of violence in black markets for prohibited goods has vexed

policymakers in the United States at least since Prohibition. While violence may be

endemic in markets for any illegal or smuggled good, illicit drugs provide a prime example

of the relationships between banning sale of a good and violence. Illicit drug markets are

prone to violence because the high value of the illegal goods, coupled with the lack of

recourse to the legal system to settle conflicts, creates instabilities, uncertainties, and

distrust in the market (Miron and Zwiebel, 1995; Andreas and Wallman, 2009). This is

exacerbated by illicit-market participants' pre-existing experiences with violence;

participants tend to be recruited from communities with above-average rates of violence

(Moeller and Hesse, 2013).[1]

If violence stems from trafficking in illicit drugs, then it may seem that enforcement

of laws against trafficking should reduce violent crime. However, both practical experience

and economic theory show that enforcement against illegal activity in drug markets may

have the unintended consequence of exacerbating violence. Systematic reviews of the

empirical literature show that nearly all studies find evidence of an adverse impact of drug

law enforcement on levels of violence (Werb et al., 2011; Hawken, Kulick, and Prieger,

2013). The theoretical literature offers a number of explanations for why stricter

enforcement targeting illicit drug markets might increase violence. To begin with,

increased enforcement disrupts the market. Destabilizing established hierarchies renews

competition, and violence can follow as participants jostle for exclusive territory ("turf")

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[1] As Reuter (1991) points out, "a business involving large sums of cash and valuable commodities, staffed by young, poorly educated males, operating outside the law, is one in which violence is likely to be an important method for settling the numerous disputes that inevitably arise."

and market share (Rasmussen and Benson, 1994; Costa Storti and De Grauwe, 2008; Papachristos, 2009) and try to deter entry (Levitt and Venkatesh, 2000). Furthermore, stricter enforcement increases the risk of detection and punishment, which in turn increases the risk premium and therefore profitability of sales (Kuziemko and Levitt, 2004). Revenue becomes worth fighting for: Increasing the share of total cost attributed to enforcement risk can increase the incentive for violence, because violence may deter enforcement agencies and potential informants (Caulkins, Kleiman, and Kulick, 2010; Kleiman, 2011). A third economic argument postulates that prohibition and enforcement lower the marginal cost of violence, since evading apprehension for violent crime is complementary to evading arrest for trafficking in the illicit good (Miron and Zweibel, 1995).

This article explores the economic link between enforcement and violence in illicit markets. We begin with the "textbook analysis":[2] enforcement, which is typically directed primarily at suppliers, raises opportunity costs by increasing risks for suppliers (Reuter and Kleiman, 1986) and shifts the supply curve up, and therefore raises prices. When demand is inelastic, as it typically is estimated to be for goods like illicit drugs and tobacco, revenue rises with the market price (Becker, Murphy, and Grossman, 2006). Given the reasons mentioned above that violence might increase with illicit revenue, greater enforcement therefore can have the unintended consequence of increasing violence. The textbook analysis relies on straightforward arguments based on supply and demand, and the predictions are clear enough that many authors assume or assert that enforcement in black markets leads to more violence (e.g., Reuter and MacCoun, 1995). The textbook

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[2] So named by Caulkins, Reuter, and Taylor (2006), for example.

model of a competitive drug market lies at the heart of much applied policy research

(Rydell and Everingham, 1994; Caulkins et al., 1997; Moore et al., 2005; Becker, Murphy,

and Grossman, 2006).

While higher revenue and violence are *unintended* consequences of enforcement,

the experience of the 1980s and the first half of the 1990s showed that there can be

paradoxical outcomes as well. That period was a time of greatly increased enforcement

effort in the "War on Drugs" but also a time when the street prices of cocaine and heroin

fell dramatically.[3] That so much enforcement effort, which mostly targeted the supply

chain, was coincident with sharply falling prices is therefore a puzzle. The divorce between

the theoretical predictions from the standard economic analysis and the reality on the

streets sparked a vigorous effort among researchers to build models of black markets that

exhibit paradoxical outcomes. Some research in this vein suggests or develops models in

which additional enforcement causes prices to fall or quantities consumed to rise (e.g., Lee,

1993; Skott and Gepsen, 2002; Poret, 2003; Caulkins and Reuter, 2006; Jacobsson and

Naranjo, 2009). Others look specifically at violence, and construct economic models in

which more enforcement reduces violence through non-price channels (Caulkins, Reuter,

and Taylor, 2006). The latter finding is (perhaps paradoxically, to non-economists) also

paradoxical, given that the textbook economic analysis predicts that additional

enforcement increases violence.

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[3] Cocaine prices for small users fell from about $450 per pure gram in 1981 to below $200 by 1994 (ONDCP, 2001). Prices largely remained low until 2007, when they began to rise again (UNODC, 2014). Changes in the street price of heroin were less dramatic. Heroin prices slid more slowly than cocaine prices during the 1980's but continued to fall through the subsequent decade. From 1981 to 1998, annual federal expenditures aimed at reducing the use of illegal drugs through the criminal justice system, interdiction, and intelligence increased almost seven-fold (TRAC, 2000).

Therefore, on the one hand, the textbook analysis offers simple predictions about how enforcement affects prices, revenues, and violence, while on the other hand, the "paradoxical outcomes" literature seeks models that internally generate opposite conclusions. In the textbook model, targeting supply for enforcement leads to a higher price and revenue, and therefore violence; there are no other issues complicating the simple analysis. When the standard competitive model is replaced with models embodying different assumptions, which include downward-sloping supply curves (Caulkins and Reuter, 2006), imperfectly competitive vertically differentiated supply chains (Poret, 2003), demand-side switching costs (Skott and Gepsen, 2002), market power over product demand characterized by contest success functions (Jacobssen and Naranjo, 2009), and enforcement that induces larger quantities per purchase (Lee, 1993), paradoxical outcomes instead are the result.

We re-examine both the textbook model and the "paradoxical outcomes" literature. We also discuss an application to menthol cigarettes, which face an imminent ban in the European Union and possible bans in the United States and Canada. We proceed in five steps, beginning with an examination of a model of a competitive illicit drug market. We first show that the textbook model is in reality more nuanced than is often presented. Whenever enforcement creates risks for buyers as well as sellers, inelastic demand is a necessary but no longer a sufficient condition for revenue and violence to rise with enforcement. When the demand curve itself moves, there is a countervailing demand-shifting effect that can reduce revenue even when demand is inelastic. Second, we derive a paradoxical outcome of our own: when there are bandwagon effects in abiding by the law, even though each scofflaw creates a negative externality for society by discouraging others

from following the law, violence is less likely to rise with enforcement. Third, we show that non-standard assumptions about the primitives of the market are not required for models of illicit markets to exhibit paradoxical outcomes. In fact, the search for paradoxical outcomes is over almost before it begins; even the simplest noncompetitive models, monopolistic competition and Cournot oligopoly, lead to the literature's "desired" paradoxical outcome that revenue and violence can fall with enforcement. Fourth, we therefore argue that instead of searching for assumptions that lead endogenously to desired modeling outcomes, it is most helpful for analysis of public policy to choose appropriate assumptions for the basic model. We finish with performing such an analysis for the current policy issue of banning menthol cigarettes. Under the most plausible assumptions enforcement will indeed spur violence, although the legal availability of electronic cigarettes may mitigate or reverse this conclusion

We proceed in the next section by examining the textbook model of an illicit market with two additional features, demand-side enforcement (which is sometimes omitted from the textbook analysis) and bandwagon effects among scofflaws. In section II we show how the demand-shifting effect may reverse the typical textbook conclusions, and also show that bandwagon effects make such reversal more likely. In section III we turn to a brief examination of three of the simplest models possible for illicit markets: the textbook competitive market (the model from section II without the bandwagon effects), a monopolistically competitive market, and a Cournot oligopoly. No more than these three models is necessary to generate the full range of outcomes from supply-side enforcement: it increases revenue and violence in the competitive market, has no impact in the monopolistically competitive market when all enforcement is against suppliers, and

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decreases revenue and violence in the oligopolistic market. In section IV, we return to competitive model and apply it to a potential prohibition on menthol cigarettes, showing that plausible choices for the parameters of the model imply that violence indeed increases with enforcement.

II. A Competitive Illicit Market with Bandwagon Effects

We present a relatively simple model of a black market characterized by enforcement action against trafficking in the good, violence driven by revenue in the market, and bandwagon effects among scofflaws. Like Becker, Murphy, and Grossman (2006) and Reuter and Kleiman (1986), we assume the illicit market is competitive. The model here is an extension of that examined in Prieger and Kulick (2014).

A. The Model

Consider a competitive market for an illicit drug. Enforcement against trafficking in the good is a continuous variable, $e \geq 0$. For analytical convenience, enforcement e is not differentiated according to the target (producer, importer, dealer, or user) and so represents total effort or money expended on law enforcement against trafficking. We do not, however, assume that enforcement targets only one side of the market or that it affects both sides equally, as will be made clear below. Instead, any difference in the amount of enforcement directed at the supply and demand sides is subsumed into the functions describing how total enforcement raises costs for suppliers and consumers. Section A in the appendix formalizes this.

1. Supply

Each homogeneous seller has a cost function $c(q_i)$ with derivative $c'(q_i) \geq 0$ that represents the physical costs of procuring, processing, and distributing the good. Enforcement against the illicit market raises the effective cost of doing business by a multiple $\varphi(e) \geq 1$. These additional costs include the monetization of the perceived risks of arrest, sanction, fine, and incarceration, as well as any supply-disruptive activity following from enforcement, such as product seizure, as discussed in Reuter and Kleiman (1986). The costs are created only by enforcement: we assume that $\varphi(0) = 1$ and $d\varphi/de \geq 0$. We typically expect that φ rises with enforcement; the case $d\varphi/de = 0$ pertains when enforcement is directed exclusively toward buyers.

Marginal production costs for each firm i are therefore $\varphi c'(q_i)$, and the firm's supply curve is $q_{S_i}(p_S) = k^{-1}(p/\varphi)$, where $k(q) = c'(q)$.[4] Here, $p_S = p/\varphi$ is the net price sellers receive after accounting for enforcement risk, and price p is the monetary price exchanging hands in the market. Summing the firms' supply curves yields the market supply curve, $q_S(p_S) = \sum_i q_{S_i}(p_S)$. Denote the supply elasticity with $\eta_S = q_S'(p_S) \, p_S/q_S(p_S)$. Defining $\psi = \varphi^{-1}$, the quantity supplied under enforcement is thus:

$$Q_S(p, e) = q_S(\psi(e)p) \tag{1}$$

The properties of φ imply that $\psi(e) > 0$, $\psi(0) = 1$ and $d\psi/de \leq 0$.

The impact of enforcement on the supply curve is illustrated in Figure 1. With no enforcement, the supply curve is S_0. Enforcement raises costs by multiple φ to new supply

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[4] By identifying the supply curve with the inverse marginal cost curve, we ignore the breakeven profit constraint. Either there are no fixed costs or the price is always above the level below which no firm wishes to produce.

curve S$_1$. Thus the quantity supplied at a price such as p'' falls from $q_S(p'')$ to $q_S(\psi p'')$, as marked in the figure.

2.   Demand

In the absence of a ban, the market quantity demanded for the good is q_D, a downward-sloping function of the market price. When the good is banned, there are two changes to demand. First, we assume that a fraction $\ell \in [0,1]$ of consumers are law-abiding, in the sense that, regardless of the street price of the banned good, they would *never* purchase any in an illicit market. These consumers either switch to legal substitutes or cease consuming altogether. We assume that the demand of these consumers is completely typical, so that after a ban the market demand curve for the illicit good is only $(1 - \ell)$ what it was before the ban.

Unlike Becker, Murphy, and Grossman (2006), who assume that all enforcement is on the supply side, we also consider demand-side impacts. As on the supply side, on the demand side we must also distinguish between the market price p and the inclusive price consumers must pay, p_D. If enforcement affects buyers, then the perceived inclusive expenditure on the product is higher than the transacted market price p by a multiple $\rho(e)$. This "risk tax" on buyers acts like an expenditure tax of rate $\rho - 1$. We assume the risk tax satisfies $\rho(0) = 1$ and $d\rho/de \geq 0$. We typically expect that ρ rises with enforcement; the case $d\rho/de = 0$ pertains only when enforcement is directed exclusively toward sellers. Thus ℓ reflects moral, religious, or social reasons for reduction in market demand, while ρ incorporates the direct impact of economic disincentives to consume, such as the expected legal consequences, to reduce demand.

Demand elasticity is $\eta_D = -q_D'(p_D)\,p_D/q_D(p_D) > 0$, and, in keeping with much of the literature on addictive substances, demand is presumed to be inelastic: $0 \leq \eta_D < 1$. We justify this assumption for our application to cigarette markets below in section IV. The quantity demanded at black market monetary price p, accounting for buyers' risk from enforcement and the loss of the law abiders from the market, is:

$$Q_D(p, e) = (1 - \ell)q_D(\rho(e)p) \tag{2}$$

There are bandwagon effects among scofflaws: the more the illegal good is consumed in the market, the lower the fraction of consumers who abide by the law.[5] The bandwagon effects may come from social considerations ("if everyone is breaking the law, why shouldn't I?") or the rational calculation that for any given amount of enforcement, the expected cost to the violator of detection and punishment of illegal activity must fall (Kleiman's (1993) "enforcement swamping" effect). We take fraction ℓ to be a downward sloping function of Q_D, with $\lim_{Q_D \to \infty} \ell \geq 0$. Thus equation (2) only implicitly defines Q_D, since it enters the right side through $\ell(Q_D)$.

The impact of enforcement on the demand curve is illustrated in Figure 1. With no enforcement, the demand curve is D_0. If ℓ were identically zero, then enforcement raises costs by multiple ρ, shifting the demand curve in to D_1. When ℓ is nonzero as assumed above, then the demand curve shifts again to the left by amount ℓq_D, to D_2. The amount of the shift at any given price depends on ℓ, which increases at quantity demanded increases. Thus, $\ell' < \ell''$ as drawn on the graph.

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[5] The terms *bandwagon*, *herding*, and demand *externalities* or *spillovers* are all used (sometimes interchangeably, sometimes not) in the literature for cases in which one consumer's behavior directly affects the decisions of other consumers. Becker, Murphy, and Grossman (2006) also endogenize demand for drugs in their model, but in a different way, by assuming that expenditures on persuading consumers to "just say no" reduces demand for the drugs.

3.   Violence

Since the insights of Goldstein (1985), it is common in models of illicit drug markets to assume that violence rises with illicit revenue R earned in the market. We thus assume that violence can be measured with a function V that is strictly increasing in R. We set aside any direct beneficial effect of enforcement effort on violence ($\partial V / \partial e = 0$), since we model specific enforcement against trafficking and not general law enforcement against violent crime.

B.   The Impact of Enforcement on Violence

Now we examine how prices, revenue, and violence change as enforcement activity increases.

1.   Impact on Market Price

Define excess demand as

$$G(p, e) = Q_D(p, e) - Q_S(p, e) \tag{3}$$

Then applying the implicit function theorem to the equilibrium condition $G(p, e) = 0$ gives an expression for how the equilibrium price changes with enforcement:

$$\frac{dp}{de} = -\frac{\partial G / \partial e}{\partial G / \partial p} = p \left(\underbrace{-\omega_S \, \psi' / \psi}_{\substack{\text{supply-side} \\ \text{effect}}} + \underbrace{\left[-\frac{\omega_D \, \rho' / \rho}{1 + \ell'(Q_D) q_D} \right]}_{\text{demand-side effect}} \right) \tag{4}$$

where $\omega_D = \eta_D / (\eta_D + \eta_S)$, $\omega_S = 1 - \omega_D$, and the elasticities are understood to be evaluated at the effective prices ρp and ψp (see appendix for proof). As labeled, enforcement creates supply-side and demand-side effects.

The supply side effect

The supply side effect is positive since ψ is decreasing in e, assuming the supply curve does not slope down. Enforcement raises costs on the supply side and shifts the supply curve up, increasing the equilibrium price. This is the (only) outcome of the textbook model with supply-side enforcement only. The decrease in quantity and the increase in price from the supply side effect in isolation is shown in Figure 1 with the movement from point A to point B on the graph.

The demand side effect

The demand side effect in expression (4) is negative. We distinguish two cases. Case 1 applies when there are no bandwagon effects. Without contagion among scofflaws, $\ell' = 0$ and so the demand-side effect is clearly negative. This corresponds to the simple textbook case of enforcement shifting the demand curve down, so that the equilibrium price falls in response to demand-side enforcement. In Figure 1, this corresponds to moving from point B to point C on the graph.

Case 2 is for when the bandwagon effect is present. However, we exclude the possibility that $|\ell'(Q_D)q_D| \geq 1$, which would imply that the bandwagon effects are so strong that demand function Q_D slopes up in price.[6] In this case, the demand-side effect in expression (4) remains negative. However, since the denominator of the demand-side effect is smaller than in case 1, the bandwagon effect amplifies the demand-side effect. The decrease in demand causes the quantity consumed to fall. When scofflaws respond to total demand, some of them will "fall off the bandwagon," ℓ rises, and total demand Q_D falls even

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[6] If $\ell' q_D$ is ever lower than -1, it can only be for a finite range of market quantity. Fraction ℓ is bounded on both sides, and so its derivative cannot be large except in a local region. In particular, ℓ' must approach zero as Q_D becomes large enough. Thus, we expect case 2 to be the usual case when there are bandwagon effects.

further. The greater fall in quantity from the bandwagon effect is depicted in Figure 1.

Starting from point B, the risk tax alone moves equilibrium from point B to point C, and

then the bandwagon effect moves equilibrium further to point D.

The total effect on price

The sign of dp/de is determined by the relative magnitudes of the demand- and supply-

side effects on price. The appendix shows that the sign of the expression in (4) is positive,

so that

$$\frac{dp}{de} > 0 \quad \Leftrightarrow \quad \frac{\eta_D \epsilon_\rho}{1 + \ell' q_D} < -\eta_S \epsilon_\psi \tag{5}$$

where ϵ_f is the elasticity of function f with respect to enforcement. Both sides of the

inequality on the right side of (5) are positive. The left side captures the demand-side price

sensitivity to changes in enforcement, while the right side reflects the supply side. Whether

the market price will increase with marginal increases in enforcement depends on the

relative magnitudes involved. Thus, when enforcement has demand-side effects in addition

to those on the supply side, enforcement can lead to higher or lower prices. The price

effect of increased enforcement is ambiguous in general. If demand is elastic enough,

consumers are highly sensitive to enforcement risk, or bandwagon effects are strong

enough, the demand-side effects can cause the market price to fall. The opposite case is

depicted in Figure 1, where moving from the initial, no-enforcement equilibrium at point A

to the equilibrium with enforcement at point D increases the price.

2.   Impact on Revenue

If the demand curve does not shift, and demand is inelastic as assumed, then the

direction of the price change alone determines how revenue and violence change.

However, when the demand curve shifts downward in response to enforcement, there is a

countervailing effect on revenue. Equilibrium revenue can be written as $R = \hat{p}Q_D(\hat{p}, e)$,

where $\hat{p}$ is the equilibrium price given enforcement level e. The total impact on violence of

a marginal change in enforcement level is

$$\frac{dV}{de} = \frac{dV}{dR}\frac{dR}{de} = \frac{dV}{dR}\left[\frac{d\hat{p}}{de}Q + \hat{p}\left(\frac{\partial Q_D}{\partial p}\frac{d\hat{p}}{de} + \frac{\partial Q_D}{\partial e}\right)\right]$$

$$= \frac{dV}{dR}\left[\underbrace{\left(Q + \hat{p}\frac{\partial Q_D}{\partial p}\right)\frac{d\hat{p}}{de}}_{\text{price effect}} + \underbrace{\hat{p}\frac{\partial Q_D}{\partial e}}_{\substack{\text{demand-shifting}\\\text{effect}}}\right] \tag{6}$$

We have $dV/dR > 0$ by assumption. The first term in the brackets in the final expression

in equation (6) is the price effect. When enforcement rises, the price changes in accord

with equation (5), which has a marginal impact on revenue. The term in parentheses in the

price effect is the usual marginal revenue term for an increase in price. For the assumed

inelastic demand, where $\eta_D < 1$, this term is always positive:

$$Q + \hat{p}\frac{\partial Q_D}{\partial p} = Q(1 - \eta_D) > 0 \tag{7}$$

Thus, with only supply-side enforcement, revenues changes in the same direction as price.

This is usually assumed in the textbook analysis of illicit markets and violence.[7]

     However, the second term in equation (6), the direct impact of enforcement on the

demand curve (the "demand-shifting" effect, or DSE), is negative whenever enforcement

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[7] See, e.g., Caulkins, Reuter, and Taylor (2006): "A standard argument in the analysis of drug markets is that when enforcement drives up the price of the drug, it also increases the revenues flowing to drug dealers if demand is inelastic."

has any effect on consumers (so that $\epsilon_\rho > 0$). From implicit differentiation of equation (2), we can derive:

$$DSE = \hat{p}\,\frac{\partial Q_D}{\partial e} = -\frac{\eta_D R \epsilon_\rho}{e[1 + \ell'(Q_D)q_D]} < 0 \qquad (8)$$

where it is again assumed that bandwagon effects are mild enough that the expression in square brackets is positive (see the appendix for derivation). This term is the offsetting effect on revenue of the demand curve shifting down in response to enforcement risk. Thus, even when the sign on the price change is clear from inequality (4), the total effect on revenue and violence is ambiguous. If the DSE is great enough, revenue falls in response to a price increase even with inelastic demand.

Note that the presence of bandwagon effects in demand can lead to a paradoxical result. At first blush, bandwagon effects among scofflaws would appear to work against policymakers wishing to reduce consumption of the illicit good. Each scofflaw creates a negative externality for society (assuming consumption is indeed socially harmful) by discouraging others from following the law. However, the existence of the bandwagon effect makes the DSE larger and therefore makes it easier for prices to fall. Revenue and violence are therefore less likely to rise with enforcement when there are bandwagon effects.

III.   Three Simple Models Yielding All Possible Outcomes

In this section, we compare the impact of enforcement on violence with three models of competition. The results show that non-standard assumptions tailored to the unique characteristics of particular drug markets are not required to generate the full

range of outcomes regarding enforcement and violence. For simplicity, and to make clear that the conclusions are not driven by any non-standard assumptions, here we assume all consumers are scofflaws. If buyers care only about the direct economic incentives provided by consumption and risk, there is no bandwagon effect, and $\ell = \ell' = 0$.

A. The Competitive Model without Bandwagon Effects

Setting aside the bandwagon effect, the condition for the effect of enforcement on market price from (5) is:

$$\frac{dp}{de} > 0 \iff \eta_D \epsilon_\rho < -\eta_S \epsilon_\psi \tag{9}$$

Rearranging terms, this condition for a positive price change can be expressed as:

$$\frac{\eta_D}{\eta_S} < -\frac{\epsilon_\psi}{\epsilon_\rho} \tag{10}$$

Recalling that $\epsilon_\psi < 0$, it is thus sufficient for the market price to rise with more enforcement that 1) demand be less elastic than supply, and 2) enforcement have more impact on the supply side than on the demand side, as measured by the impacts on risk-adjusted prices given by the elasticity ratios on the right side. The appendix shows that the latter condition holds when the proportion of enforcement directed at the demand side is small.

The condition for the total effect of enforcement on revenue (the part inside the square brackets in equation (6)), expressed as a revenue elasticity, can be written as:

$$\frac{dR}{de}\frac{e}{R} = -\omega_D(1 + \eta_S)\epsilon_\rho - \omega_S(1 - \eta_D)\epsilon_\psi \tag{11}$$

(see the appendix), where ω_D and ω_S are as defined above after equation (4). The first term is negative and the second term is positive if demand is inelastic. This expression is positive if and only if

$$\eta_D \epsilon_\rho < -\eta_S \epsilon_\psi \left(\frac{1 - \eta_D}{1 + \eta_S} \right) \tag{12}$$

Comparing this condition with inequality (10), we see that the condition for revenue and therefore violence to rise with enforcement is stricter than the condition for price to rise.[8] This is because the demand shifting effect in the revenue impact is always negative. Examination of condition (12) shows that inelastic demand is a necessary but not sufficient condition for violence to rise with enforcement. We therefore consider various market situations.

1. Case 1: No direct enforcement on consumers

If enforcement is focused entirely on suppliers and consumers are left alone, then $\epsilon_\rho = 0$, conditions (10) and (12) are satisfied. Prices and violence both rise with enforcement effort. This is the textbook analysis, depicted in Figure 1 with the movement from point A to point B.

2. Case 2: The long run in a constant-cost industry

In the long run in a competitive constant-cost industry the supply curve is horizontal. With infinite η_S, inequality (10) is satisfied and greater enforcement of a ban leads to higher prices. The limit of condition (12) as supply becomes infinitely elastic is

$$\frac{\eta_D}{1 - \eta_D} < -\frac{\epsilon_\psi}{\epsilon_\rho} \tag{13}$$

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[8] Conditions (10) and (12) differ only in the additional term on the right side in parentheses in condition (12). If demand is inelastic and supply slopes up, the ratio composing the extra term is less than one.

which is easier to satisfy the more inelastic is demand or the higher the supplier-side

enforcement elasticity is relative to the consumer-side enforcement elasticity. As section A

in the appendix shows, the ratio on the right side will be large when there is little demand-

side enforcement.

3.   Case 3: Completely inelastic demand

If all consumers with any sensitivity to price (at least in the relevant range of market

prices) have left the market, then the demand curve is vertical. In the drug literature, it is

sometimes assumed for simplicity that the hardest-core addicts have completely inelastic

demand.[9] Then since $\eta_D = 0$, inequality (12) is satisfied and violence rises with

enforcement.

B.   Monopolistic Competition

If consumers in the black market do not in fact treat goods sold by different sellers

as identical, then a model with market power on the part of sellers becomes appropriate.

Perhaps the simplest such model is the monopolistic competition model of Dixit and Stiglitz

(1977). There is a continuum of sellers of measure n, with the quantity sold by seller ι

denoted $q(\iota)$. The representative consumer likes variety, and views any two of the goods as

equally substitutable. A taste for variety may seem to be an odd assumption for black-

market drugs, in which many users cultivate exclusive relationships with dealers.

However, given that sellers in drug markets often have geographical monopolies (their

"turf") and that buyers are geographically distributed, in the aggregate a taste for variety

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[9] However, in reality such addicts often spend nearly all their disposable income on drugs, as much as they
can afford, instead of having a bliss point in consumption. Refer also to Rasmussen and Benson (1994) for
discussion on the assumption of perfectly inelastic demand for addictive drugs.

for the fictional representative consumer is appropriate. In the most basic form of the

monopolistic competition model,[10] the utility of the representative consumer is

$$U = q_0^{1-\mu} \left[\left(\int_0^n q(\iota)^r d\iota \right)^{\frac{1}{r}} \right]^\mu \tag{14}$$

where q_0 is the outside good representing all purchases made outside the black market.

Here, r measures the substitutability between the goods of the black market sellers and

parameter μ is between zero and one. As in the perfect competition model, the monetary

price of each good, $p(\iota)$, is marked up to include enforcement risk (if any) so that the

consumer treats the price as being $\rho(e)p(\iota)$.

While it is possible to solve for the profit-maximizing quantities offered for sale by

each firm, the equilibrium price, and the resulting equilibrium revenue, the simple form of

preferences in equation (14) makes the calculations unnecessary. Given the Cobb-Douglas

form of preferences for the outside good and the composite black market good defined by

the expression within the square brackets of equation (14), it follows that parameter μ is

the share of the consumer's income I spent on black market goods. Since the risk tax from

demand-side enforcement raises the effective price for the consumer to ρp, total

expenditure (including the psychic "payment") of μI yields total (monetary) revenue in the

black market of only $\mu I / \rho$.[11] Therefore the impact of enforcement on violence is:

$$\frac{dV}{de} = \frac{dV}{dR}\frac{dR}{de} = \frac{dV}{dR}\left(-\frac{\mu I}{\rho^2}\rho'(e)\right) = -\frac{dV}{dR}\left(\frac{\mu I}{e\rho}\epsilon_\rho\right) \le 0 \tag{15}$$

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[10] Although this form for the utility function is often called "Dixit-Stiglitz preferences," Neary (2004) points out that Dixit and Stiglitz (1977) never analyzed such a simple form of utility, and so "Dixit-Stiglitz lite" is a better label.

[11] We assume that the compensation required by the consumer for bearing the black market risk is consumed through additional expenditure on the outside good, without explicitly incorporating this assumption into the utility function.

That is, violence falls when enforcement increases, as long as consumers are sensitive in any way to enforcement. If there is no demand-side enforcement, then violence does not change at all when enforcement ramps up. Supply-side enforcement plays no role in these results, for while raising cost on the supply side changes price, quantities, and profits in equilibrium (as well as the number of suppliers if entry is free), prices and total quantity purchased are offset in such a manner that revenue remains unaffected by the supply side. Under the assumption that all enforcement is on the supply side, therefore, the standard monopolistic competition model implies that enforcement has no effect on violence, regardless of the elasticity of demand.[12]

C.   Cournot Oligopoly

Some authors use the Cournot oligopoly model of quantity setting to model imperfect competition in black markets (e.g., Chiu, Mansley, and Morgan, 1998; Poret, 2003, 2009; Jacobsson and Naranjo, 2009). In contrast to the monopolistic competition model, consumers view the goods sold by different sellers as perfectly substitutable. On the supply side, sellers exercise market power and raise their profits by limiting the quantities they put on the market. The restricted quantities drive the price up, raising profits for all sellers. As opposed to the model of monopolistic competition, in which sellers choose a price for their goods and the quantity sold is determined by demand, a Cournot seller chooses an amount of product to put on the market and the price (common to all goods) is determined from inverse market demand for the total quantity produced. The notion of supply elasticity is meaningless in a market in which firms exercise market

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[12] Note, however, that the market power exercised by the firms ensures that prices are set so that demand for each good is in the elastic region.

power, because firms do not have a supply function. Therefore the Nash equilibrium of the quantity-setting game must be found in order to derive a condition analogous to condition (12) for violence to rise with enforcement.

Inverse market demand, from equation (2), is

$$P(Q, e) = f(Q)/\rho(e) \qquad (16)$$

where $Q = \sum q_i$ and $f = q_D^{-1}$. To guarantee the existence of a Nash equilibrium, we assume that the Novshek (1985) conditions are satisfied.[13] In the symmetric Cournot model with undifferentiated demand, the profit function for each of n firms is

$$\pi_i(q_i, e) = q_i P(Q, e) - \varphi(e) c(q_i) \qquad (17)$$

where as in the competitive model, φ is the cost multiple from enforcement risk and c is the firm's cost function. Then the condition for the profit maximizing choice of quantity, q_i^c, is

$$\frac{P(Q, e) - \varphi c'(q_i^c)}{P(Q, e)} = \frac{s_i}{\rho \eta_D} = \frac{1}{n \rho \eta_D} \qquad (18)$$

where s_i is the seller's market share, q_i^c/Q. This is the familiar Cournot markup condition (derived in the appendix), modified only by the introduction of enforcement risk. The second equality follows from the symmetry of the Nash equilibrium. Equation (18) implicitly defines the market quantity $Q^c = \sum q_i^c$ in equilibrium, from which the market price and revenue can be derived.

Now examine how revenue varies with enforcement. Since equilibrium market revenue is $R(Q^c(e)) = P(Q^c(e), e)Q^c(e)$, we have

$$\frac{dR}{de} = \frac{dR}{dQ^c}\frac{dQ^c}{de} = \frac{dR}{dQ^c}\left(\sum_{i=1}^{n}\frac{dq_i^c}{de}\right) \qquad (19)$$

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[13] We refer to the assumptions for Theorem 3 of Novshek (1985). The most important of these is that marginal revenue is non-increasing in the aggregate output of other firms in the region of aggregate output where the market price is positive.

The first term is marginal revenue, which must be positive for the Cournot model; firms restrict quantity until demand is in the elastic range. An expression for dq_i^c/de is derived in the appendix. Putting the pieces together, under standard assumptions about the concavity of the profit function it can be shown that the condition for revenue to fall with enforcement is

$$\frac{dR}{de} < 0 \quad \Leftrightarrow \quad -\frac{\rho'(e)}{\rho(e)} MR_i < \varphi'(e)c'(q_i^c) \tag{20}$$

where MR_i is marginal revenue for firm i. However, since $\rho' > 0$, $MR_i > 0$, $\varphi' > 0$, and $c' > 0$, this condition is always satisfied. Thus revenue, and therefore violence, always falls in the Cournot model when enforcement increases. This result does not depend on the elasticity of supply or demand,[14] and holds whether all enforcement is on the demand side (in which case the right side of the inequality in expression (20) is zero), all enforcement is on the supply side (in which case the left side of the inequality in expression (20) is zero), or enforcement is mixed.

IV.   Discussion and Application to Tobacco Control

The examination of the simple models for competitive, monopolistically competitive, and oligopolistic markets in the previous section reveals that these three models cover all possible outcomes for the impact of enforcement on violence in illicit markets. For example, consider the case in which all enforcement is on the supply side. The first model predicts unequivocally that revenue and violence increase with enforcement, the second yields the irrelevance result that there is no impact at all, and the

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[14] Keeping in mind, however, that the Cournot model only has a solution if an elastic region of demand can be found.

third predicts unequivocally that revenue and violence decrease with enforcement. Therefore one need not include non-standard assumptions about the workings of illicit drug markets to find any outcome, paradoxical or not.[15]

Plausible reasons for the great decline of prices in major illicit drug markets in the last 35 years appear to be readily at hand without recourse to models of non-competitive markets or other departures from standard assumptions. It is likely that improvements in crop yields have driven down the supply curve in illicit drug markets. Given the illicit nature of the markets, hard data on production and supply-side costs are unavailable. However, some evidence suggests that the yields of illicit crops have increased dramatically. For example, Mejía and Posada (2008) report that a UN study found that there was a 40% increase in the yields of coca (the raw ingredient for cocaine) per hectare in the early 2000's. In addition to the direct impact on the cost curves for cocaine, another benefit of increased productivity for producers of illicit crops is that supply can be grown on smaller plots of land, making aerial discovery and eradication by law enforcement more difficult. The reduced risks of eradication further lower the cost curves. Such exogenous changes in supply could easily negate or overwhelm the direct impact of enforcement on the supply curve.

Furthermore, the presence of exogenous supply shifters does not change the basic message from the analysis of the competitive market above: more enforcement still leads to more violence, *ceteris paribus*. That fact that in reality other things were *not* held constant does not falsify the model or reduce its utility for policy analysis. The competitive

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[15] This is not to say that examination of models closely tailored to the idiosyncrasies of particular drug markets, as suggested by Caulkins and Reuter (2006), is not fruitful for the better understanding of such markets.

model has two advantages for purposes of presenting policy analysis to policymakers.

Given the widespread familiarity of the Marshallian cross among even non-economists, the

reasoning behind the results can be readily understood by most policymakers. This is the

main reason that the textbook model is applied so often in policy research (Rydell and

Everingham, 1994; Caulkins et al., 1997; Moore et al., 2005; Becker, Murphy, and Grossman,

2006). Furthermore, the prediction of the model that greater enforcement leads to more

violence is in accord with nearly all of the empirical literature, as discussed in the

introduction. We now consider the competitive model's predictions regarding violence

resulting from enforcement of a ban on menthol cigarettes.

Menthol cigarettes are facing possible prohibition by the FDA in the United States

(Tavernise, 2013), an imminent ban in the European Union (Dalton and Esterl, 2013), and a

current ban in Brazil.[16] Menthol cigarettes constitute about one-third of the overall US

cigarette market (O'Connor et al., 2012) and account for approximately $25 billion in

annual retail sales (Esterl, 2011). If menthol is banned in cigarettes, consumers will either

quit tobacco altogether, switch to non-menthol cigarettes, switch to other mentholated

tobacco products,[17] or continue consumption illegally on the black market. O'Connor et al.

(2012) report that 25 percent of menthol smokers said they would "find a way to buy a

menthol brand," indicating their willingness to purchase menthol cigarettes on the black

market. Given the likely underreporting of illegal intentions, this estimate is probably

understated, possibly to a large degree. Tobacco-company representatives and industry-

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[16] Other non-tobacco flavorings are prohibited in the United States under the Family Smoking Prevention and Tobacco Control Act (FSPTCA) of 2009, but the law specifically exempted menthol. The EU ban on menthol cigarettes will be fully in effect by 2020. Brazil's ban of menthol cigarettes was enacted into law in 2012 and took effect in 2013.

[17] These products may include menthol small cigars, which resemble cigarettes in most respects and which would not necessarily be banned along with menthol cigarettes (the FSPTCA, e.g., did not ban flavorings in small cigars), and menthol-flavored electronic cigarettes. We discuss the latter in the text below.

supported studies argue that severe negative impacts on public health, criminal activity, and tax revenues will ensue should a menthol ban pass, while anti-tobacco proponents contend that benefits to public health outweigh the possible social harms.[18] In the remainder of this article we comment on the likely link between enforcement against trafficking in illicit menthol cigarettes and violence.

To apply an economic model to cigarettes, four aspects of the market and model require consideration: competition, the nature of enforcement, the elasticities involved, and the possibility of large exogenous shifts in supply. Modeling the market as competitive appears to be appropriate, for several reasons. Moeller and Hesse (2013) assert that low levels of enforcement tend to result in monopolistic markets, dominated by a few well-organized suppliers. The crackdown on tobacco smuggling in the United States, however, has had the opposite effect of shifting supply toward smaller enterprises.[19] Furthermore, Reuter (1983) argues that concentration is unusual in illegal drug markets because pressure from law enforcement stimulates competition among suppliers. Finally, any noncompetitive model requires that demand be in its elastic region, which does not appear to apply to illicit drug markets[20] or (as will be noted below) the cigarette markets we consider here. The assumption that demand for any single supplier's product is elastic is defensible, and indeed is a feature in all three models considered here.[21] However, the requirement that market demand in aggregate be elastic—as in the Cournot model—

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[18] Refer to Hawken, Kulick, and Prieger (2013) for citations.

[19] Luk Joossens, a World Health Organization expert on tobacco smuggling, states that "the big companies know that to some extent the golden period of smuggling is gone. You have…a lot of small companies that are involved" (quoted in Guevara, 2008).

[20] Becker, Murphy, and Grossman (2006) note that estimated income elasticities for cocaine, marijuana, and heroin are generally well below one, tending toward 0.5. See their study for citations.

[21] In a competitive market, demand for any one firm's good is perfectly elastic by assumption. In the models of monopolistic competition and Cournot oligopoly, profit maximization requires the demand facing each firm to be in its elastic region.

appears to be untenable. For all these reasons, we adopt the competitive model for our

policy analysis.

We may expect that enforcement against trafficking in menthol cigarettes would

follow the pattern set by current practice aimed at smuggled tobacco products, which is to

target suppliers. As with other illicit drug markets, nearly all enforcement effort is

expended to disrupt supply in the market for illegal cigarettes. While possession of illegal

cigarettes is also a crime for buyers, law-enforcement agencies such as the Bureau of

Alcohol, Tobacco, Firearms and Explosives (ATF) typically focus their investigations on

suppliers to reduce the incidence of organized crime (USDOJ OIG, 2009). Furthermore,

Miron and Zweibel (1995) argue that the supply-side effects of enforcement in illicit drug

markets are likely to be much larger than the demand-side effects.

Demand for smoking cigarettes is generally measured to be inelastic. Chaloupka

and Warner (2000) summarize the literature (after excluding a few outlying studies) as

finding results in the relatively narrow band of demand elasticities between −0.3 and −0.5.

More recent work by Chiou and Muehlegger (2008) also finds demand elasticities in the

same inelastic range (−0.29 to −0.56). For menthol cigarettes in particular, Tauras et al.

(2010) conclude that "menthol and non-menthol cigarettes are not close substitutes" (p.

121), based on an econometric estimate of the switching elasticity between the two.[22]

Given that illegal menthol cigarettes would not be subject to the high taxes levied on legal

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[22] They calculate their estimated switching elasticity of −0.24 conditional on being a smoker. While Tauras et al. (2010) do not estimate the other relevant parts of the inclusive demand elasticity—the extensive margin of the smoking-participation decision and the intensive margin of how many menthol cigarettes to smoke— there is no reason to believe that the inclusive elasticity is greater than one. Most of the studies cited by Chaloupka and Warner (2000) that find elasticity in the range −0.3 to −0.5 include both the extensive and intensive margins. Since the elasticities from each part of the demand process are additive (see Chiou and Muehlegger (2008) for a proof), even adding the switching elasticity of −0.24 (Tauras et al., 2010) keeps the elasticity range well within the inelastic region.

cigarettes, the illegal product may not be much more expensive—or may even be cheaper—than the legal substitute. A small price increase (if any) and lack of close substitutes[23] thus suggest that a ban on menthol cigarettes may not decrease demand for them much.[24] We revisit the assumption regarding a lack of good substitutes below when discussing electronic cigarettes.

What about bandwagon effects in illicit consumption? There is a large but also largely unconvincing literature across the social sciences purporting to find peer effects in illicit drug use, smoking, drinking, and criminal behavior, typically among youths or college students. However, until recently most studies did not adequately control for the severe self-selection problems inherent in such research.[25] Duncan et al. (2005) draw on the natural experiment provided by random assignment of roommates in college dormitories to conclude that peer effects exist for binge drinking but not for marijuana use. Sacerdote (2014) summarizes the best-designed recent studies on peer effects as suggesting that peer effects on social outcomes such as crime and drinking are larger than on educational achievement, but nevertheless cautions that not enough is yet known about peer effects to shape policy around them. Almost nothing is known about peer or bandwagon effects among adults. For these reasons, we set aside the bandwagon effect for our analysis and instead use the simpler competitive model from section III, although as more research

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[23] Home mentholization of regular cigarettes with oils or sprays is another substitute for purchasing menthol cigarettes. However, we were unable to find any data on its prevalence.

[24] At least one other study looking specifically at demand for menthol cigarettes also comes to the conclusion that demand is relatively insensitive to price. In a non-peer reviewed, econometric study funded by a tobacco company, Compass Lexecon (2011) finds that a 10 percent increase in the risk-inclusive effective price of illegal menthol cigarettes would be associated with a 1 percent decline in overall smoking, and that a 50 percent increase in the price would reduce smoking by only 3.5 percent.

[25] Since one chooses one's peers, unobserved factors may make an individual both more likely to engage in illicit activity and to enjoy the company of others who do likewise. Thus, a large part of apparent "peer effects" may in fact be spurious.

becomes available on herding behavior and peer effects in illegal activity this may be a fruitful area of research to revisit.

Inequality (10) shows that if, as argued above, enforcement has more impact on the supply side, then if demand is less elastic than supply the market price must rise with enforcement. We have argued above that demand is relatively inelastic. Supply is likely to be more elastic in cigarette markets, particularly in the long run, although estimates of supply elasticities are rarer than for demand. There are no great diseconomies of scale in the tobacco-products industry, and the supply of unprocessed tobacco leaves is elastic.[26] Sumner and Wohlgenant (1985) found in a rigorous study of supply and demand conditions for cigarettes in the United States that "the derived supply curve for cigarettes is nearly horizontal" (p. 241), even when the domestic supply of raw tobacco is inelastic due to agricultural quotas. Given the easy conversion from producing menthol to non-menthol cigarettes, it is quite likely that the supply function for menthol cigarettes is similarly highly elastic, or at the very least elastic relative to demand.

Under these conditions—competitive markets, enforcement aimed mostly at the supply side, and more elastic supply than demand—the analysis in section III.A shows that violence increases with enforcement. Under these conditions, the demand-shifting effect is small enough so that revenue and price both rise when enforcement increases. Thus, we conclude that the social calculus regarding a ban on menthol cigarette should include the likelihood that enforcement will create violence in the market, and that higher levels of

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[26] Fulginiti and Perrin (1993) estimate the supply elasticity of tobacco without production quotas (which ended in 2004 in the United States) to be about 7.0. Furthermore, the supply elasticity for tobacco may be expected to be "large, particularly in the long run, since tobacco uses a small proportion of the arable land in the world as well as in any country and the net return from growing tobacco is several times that from growing the next best alternative crops in many countries" (FAO, 2003, p.99).

enforcement will engender greater amounts of violence. As with cocaine and heroin,

exogenous supply shifters may confound this analysis. However, radical exogenous cost

reductions appear to be unlikely in the markets for illicit tobacco, since the crop is grown

legally in the United States with well established, modern methods of farming, and would

continue to be so after a ban on menthol cigarettes. Crop yields of tobacco in the US grew

an average of only 0.5% per annum from 1980 to 2012.[27]

One important policy decision may change the conclusions of the analysis above.

The growing market for the presently unregulated electronic cigarettes ("e-cigarettes")

poses interesting policy questions, and the FDA is currently deciding whether to regulate e-

cigarettes.[28] E-cigarettes, which are currently unregulated, can also be mentholated. If

menthol e-cigarettes were not subject to the same usage restrictions as combustible

cigarettes, the elasticity of demand for banned menthol cigarettes would likely rise in the

presence of the substitute, because e-cigarettes create a user experience quite similar to

that of combustible menthol cigarettes. This might have two consequences. Without a

highly inelastic demand for the banned good, prices and revenues might not rise (or might

not rise as much) in the illicit market, removing or attenuating the deleterious effect of

enforcement on violence. Furthermore, e-cigarettes can likely reduce the harm of smoking

or provide an "exit ramp" from smoking altogether for some smokers. Research on the

health effects of e-cigarettes is ongoing, but the available evidence suggests that they are

not as harmful to the smoker's health as combustible cigarettes (Cahn and Siegel, 2011;

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[27] The figure is from authors' analysis of data from the Food and Agriculture Organization of the United
Nations, from faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567.
[28] See NPRM in proceeding FDA-2014-N-0189 (79 FR 23141), April 25, 2014. The FDA does, however,
regulate e-cigarettes when marketed for therapeutic purposes.

Hajek et al., 2014).[29] The relationship between an individual's use of electronic and combustible cigarettes is also nascent, but some studies indicates that e-cigarettes may aid in cessation of smoking (Hajek et al., 2014; Biener and Hargrave, forthcoming).[30] However, if the FDA were to regulate e-cigarettes or ban menthol e-cigarettes in addition to a ban on combustible menthol cigarettes, this potentially beneficial exit ramp will be closed.

The unintended consequence of enforcement leading to violence does not, by itself, mean that menthol cigarettes (or any other drug) should not be banned. A complete cost-benefit analysis of a ban is beyond the scope of this paper. Furthermore, if the good is banned, our conclusion does not imply that the optimal level of enforcement is zero. Optimal enforcement under simple assumptions has been considered by Becker, Murphy, and Grossman (2006) and Poret (2009). However, Caulkins and Reuter (2010) and Feichtinger and Tragler (2001) contend that there are multiple equilibria to which the regulation/enforcement system may settle, due to path dependency. Thus, the question of optimal enforcement may be much more complex than previous analyses have indicated.

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[29] The principal harms from cigarette smoking come from combustion products, which are absent in e-cigarettes. The direct harms from e-cigarettes should depend on the toxicity of the inhaled vapor. No research today of which we are aware definitively measures the health risks from vapor in e-cigarettes, other than finding that toxicity is much lower than for combustible cigarettes, because "the thresholds for human toxicity of potential toxicants in e-cigarette vapor are not known" (Grana, Benowitz, and Glantz, 2014). More research is needed on this subject.

[30] For a more ambivalent view of earlier literature on e-cigarettes as an aid to cessation, see Bullen (2014).

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Appendix

A.   Enforcement Targeting

In the model, any differential between the impact of enforcement on suppliers and demanders is subsumed into the functions ρ and ψ, so that we can think of the ratio $\epsilon_\psi / \epsilon_\rho$

(as from inequality (13)) as being large when most of the enforcement is on the supply side. The justification for this is provided here.

Assume that fraction α of total enforcement e is directed toward the demand side, and define $e_D = \alpha e$ to be the amount of demand-side enforcement. Let $\tilde{\rho}(e_D)$ be the "risk tax" on buyers as a function of demand-side enforcement. Then the risk tax function in the text is $\rho(e) = \tilde{\rho}(\alpha e)$, and clearly the elasticity of $\tilde{\rho}$ with respect to e_D equals ϵ_ρ. Denote the former elasticity with $\epsilon_{\tilde{\rho}}$. Assuming that the derivative of $\tilde{\rho}$ is finite at $e_D = 0$ and is continuous, $\epsilon_{\tilde{\rho}}$ can be made arbitrarily small by making α small, because $\epsilon_{\tilde{\rho}} = e_D\tilde{\rho}'(e_D)/$ $\tilde{\rho}(e_D)$ and $\tilde{\rho}(0) = 1$ by assumption. Thus, when few resources are devoted to demand-side enforcement, so that α and e_D are small, $\epsilon_{\tilde{\rho}}$ and therefore ϵ_ρ are small.

B.   Perfect Competition Model

Given the distinction between market and effective prices, two identities will be useful for the derivations to follow. When evaluated at effective price ρp, we have $\eta_D(\rho p) = -\rho p q_D'(\rho p)/Q_D$ by definition of demand elasticity η_D above. Hence,

$$pq_D' = -\eta_D q_D/\rho \tag{21}$$

where q_D and q_D' are understood to be evaluated at effective price ρp. Similarly, we also have

$$pq_S' = \eta_S q_S/\psi \tag{22}$$

where q_S and q_S' are evaluated at effective price ψp.

Derivation of the DSE, equation (8)

Define $\hat{q}_D(\rho(e))$ and $\hat{Q}_D(e)$ to be the pre- and post-ban demand functions when treated as functions of e alone, holding price fixed. Total differentiation of the equation

$\hat{Q}_D = [1 - \ell(Q_D)]\hat{q}_D(\rho(e))$, yields

$$d\hat{Q}_D = -\ell'(\hat{Q}_D)d\hat{Q}_D\hat{q}_D + [1 - \ell(\hat{Q}_D)]\hat{q}_D'(e)p\rho'(e)de$$

Rearranging terms gives

$$\frac{d\hat{Q}_D}{de} = \frac{[1 - \ell(\hat{Q}_D)]p\hat{q}_D'(e)\rho'(e)}{[1 + \ell'(\hat{Q}_D)\hat{q}_D]} \tag{23}$$

Dropping the hats on Q_D and q_D to allow p to vary again, and therefore writing the

derivative as a partial instead of a total allows derivative (23) to be written as

$$\frac{\partial Q_D}{\partial e} = \frac{-(1 - \ell)\eta_D q_D \epsilon_\rho/e}{1 + \ell'(Q_D)q_D} \tag{24}$$

where identity (21) and $\epsilon_\rho = \rho'(e)e/\rho$ are used. After substituting $\hat{Q}_D$ for $(1 - \ell)\hat{q}_D$ in the

numerator of the right side, and then substituting revenue R for pQ_D, equation (8) for the

DSE follows directly from equation (24) multiplied by p.

Derivation of dp/de, equation (4)

Using definitions (1) and (2), excess demand from equation (3) changes with price

as:

$$\frac{\partial G}{\partial p} = (1 - \ell)q_D'(\rho p)\rho - q_S'(\psi p)\psi \tag{25}$$

Using identities (21) and (22), this can be written

$$\frac{\partial G}{\partial p} = (1 - \ell)q_D'(\rho p)\rho - q_S'(\psi p)\psi \tag{26}$$

Excess demand from equation (3) changes with enforcement as:

$$\frac{\partial G}{\partial e} = \frac{\partial Q_D}{\partial e} - \frac{\partial}{\partial e}q_S(\psi(e)p) = \frac{\partial Q_D}{\partial e} - q_S'p\psi' \tag{27}$$

Making use of equations (22) and (24), this is

$$\frac{\partial G}{\partial e} = \frac{-(1-\ell)\eta_D q_D \, \rho'/\rho}{1 + \ell' q_D} - \eta_S q_S \, \psi'/\psi \tag{28}$$

Combining equations (26) and (28) via the implicit function theorem yields:

$$\frac{dp}{de} = -\frac{\partial G/\partial e}{\partial G/\partial p} = -\frac{\dfrac{-(1-\ell)q_D \eta_D \, \rho'/\rho}{1+\ell' q_D} - q_S \eta_S \, \psi'/\psi}{-\dfrac{(1-\ell)q_D \eta_D}{p} - q_S \eta_S/p} \tag{29}$$

Using equations (1) and (2) and recognizing that $Q_D = Q_S$ in equilibrium transforms (29)

into:

$$\frac{dp}{de} = p \, \frac{\eta_D \left(\dfrac{-\rho'/\rho}{1+\ell' q_D} \right) - \eta_S \, \psi'/\psi}{\eta_D + \eta_S} \tag{30}$$

With $\omega_D = \eta_D/(\eta_D + \eta_S)$ and $\omega_S = 1 - \omega_D$, equation (30) can be written as in equation (4).

Derivation of the condition for dp/de>0, inequality (5)

The denominator of (29), $\partial G/\partial p$, is clearly negative if supply does not slope up.

Therefore the sign of (29) is the same as the sign of the numerator $\partial G/\partial e$. Using equations

(1) and (2) and recognizing that $Q_D = Q_S = Q$ in equilibrium transforms equation (28) into

$$\frac{\partial G}{\partial e} = \left(\frac{-\eta_D \, \rho'/\rho}{1+\ell' q_D} - \eta_S \, \psi'/\psi \right) Q \tag{31}$$

Converting the enforcement cost function expression to elasticities and dividing by Q, we

see that (31) has the same sign as

$$\frac{-\eta_D \epsilon_\rho/e}{1 + \ell' q_D} - \eta_S \epsilon_\psi/e$$

Dividing by e, we arrive at condition (5).

Derivation of the revenue effect without bandwagon effects, equation (11) and inequality (12)

The revenue effect of a price change, from (6), is

$$\frac{dR}{de} = \left(Q + \hat{p}\frac{\partial Q_D}{\partial p}\right)\frac{d\hat{p}}{de} + \hat{p}\frac{\partial Q_D}{\partial e} = -R(1-\eta_D)\left(\frac{\omega_D\rho'}{\rho} + \frac{\omega_S\psi'}{\psi}\right) - \eta_D R\epsilon_\rho \tag{32}$$

where equations (4), (7), and (8) are used for the latter equality. Using elasticities for all expressions involving derivatives yields:

$$\frac{dR}{de}\frac{e}{R} = -(1-\eta_D)(\omega_D\epsilon_\rho + \omega_S\epsilon_\psi) - \eta_D\epsilon_\rho \tag{33}$$

After combining the terms involving ϵ_ρ, equation (11) follows. Inequality (12) follows directly from multiplying the right side of equation (11) by $(\eta_D + \eta_S)$.

C.   Cournot Model

Derivation of FOC for profit maximization

Define $R_i(q_i, q_{-i}) = q_i f(q_i + q_{-i})/\rho$ as revenue for firm i, where $q_{-i} = \sum_{j\neq i}q_j$ and inverse demand is from equation (16). From the profit function (17), the first order condition for profit maximization given e is:

$$\frac{\partial \pi_i(q_i, e)}{\partial q_i} = \frac{\partial R_i(q_i, q_{-i})}{\partial q_i} - \varphi(e)c'(q_i) = 0 \tag{34}$$

where under the Nash assumption that other sellers' quantities are invariant to changes in q_i we have

$$\frac{\partial R_i(q_i, q_{-i})}{\partial q_i} = MR_i = w[f(Q) + q_i f'(Q)] = P + q_i f'(Q) \tag{35}$$

In the expression, for convenience $w = 1/\rho$. From the inverse function theorem and equation (21), $f'(Q) = -P/w\eta_D Q$, and so we have

$$MR_i = P\left(1 - \frac{q_i}{Q}\frac{w}{\eta_D}\right) = P\left(1 - s_i\frac{w}{\eta_D}\right) \tag{36}$$

Combining (34) and (36) yields

$$P\left(1 - s_i\frac{w}{\eta_D}\right) - \varphi(e)c'(q_i) = 0 \quad \Leftrightarrow \quad \frac{P - \varphi c'}{P} = s_i\frac{w}{\eta_D} \tag{37}$$

from which the Cournot markup condition (18) readily follows. Incidentally, the equation

on the left side of (37) also shows that MR_i must be positive.

Derivation of $dq_i{}^c/de$ and dR/de, expression (20)

To derive dq_i^c/de, first write the first order condition (34) as:

$$P(Q,e) - \varphi c' + q_i^c \frac{\partial P}{\partial Q} = 0 \tag{38}$$

Then apply the implicit function theorem to equation (38) to yield:

$$\frac{dq_i^c}{de} = \frac{\frac{\partial P}{\partial e} - \varphi'c' + q_i^c \frac{\partial^2 P}{\partial Q \partial e}}{-(n+1)\frac{\partial P}{\partial Q} + \varphi c'' - q_i^c n \frac{\partial^2 P}{\partial Q^2}} \tag{39}$$

Under standard assumptions for the existence of Cournot Nash equilibrium, discussed

below, the denominator of equation (39) is positive and the sign of dq_i^c/de is determined

by the numerator. Recall that $w = \rho^{-1}$. Then, since from (16) we have $P(Q,e) = w(e)f(Q)$, the numerator of (39) is

$$w'f - \varphi'c' + q_i^c w'f' = \frac{w'}{w}[w(f + q_i^c f')] - \varphi'c' = \frac{w'}{w}MR_i - \varphi'c' = \frac{\rho'}{\rho}MR_i - \varphi'c' \tag{40}$$

In equation (19), we know that the marginal revenue term (defined in equation (35)) is

positive and dq_i^c/de is the same for all sellers because of symmetry. Therefore, the

condition that $dR/de > 0$ is the same as the condition that equation (40) is greater than zero, hence inequality (20).

Above it was claimed that the denominator of equation (39) is positive, which is to say that

$$\left(n\frac{\partial P}{\partial Q} - \varphi c''\right) + \left(\frac{\partial P}{\partial Q} + Q^c \frac{\partial^2 P}{\partial Q^2}\right) < 0 \tag{41}$$

The first term in parentheses is negative if demand slopes down and cost is weakly convex.[31] The second term in parentheses is non-positive under assumption (3) of Novshek (1985), which he shows is equivalent to the assumption that each firm's marginal revenue is not increasing in q_{-i} (see footnote 13). Thus follows the inequality.

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[31] Assuming that the cost function is convex is stronger than required for the Novshek (1985) assumptions, but is nevertheless a common assumption in the literature.

Figure 1: The Impact of Enforcement on Equilibrium in a Competitive Market