THE IMPACT OF WEIGHT-BASED PENALTIES ON DRUG PURITY AND CONSUMPTION: A THEORETICAL ANALYSIS

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INTRODUCTION

Reuter and Caulkins [1995] state that the appropriate goals of any drug policy are the reduction of drug consumption and the reduction of related harm. Often, federal drug enforcement does not simultaneously produce the desired goals. Lee [1993], for example, shows that increased harassment of drug users decreases dealer costs as drug users make fewer drug transactions. Under these conditions, drug prices may fall resulting in a potential increase in illicit drug consumption. As well, many other studies show that crime, clearly a related harm, often rises during episodes of increased drug enforcement spending. Benson et al. [1992] show that Florida experienced an increase in property crime during the mid-1980's as enforcement agencies diverted scarce law enforcement resources to drug enforcement and away from activities such as theft enforcement. Another study by Rasmussen et al. [1993] shows that intensified drug reduction efforts in one jurisdiction entice dealers to move to a jurisdiction with low drug enforcement. Migration results in a higher violent crime rate as migrant drug dealers struggle for turf with incumbent dealers. Miron [1999] surmises that arresting dealers generates violence as other dealers fight over freed up turf.

Harm associated with increased drug enforcement is not, however, limited to increased non-drug crime; enforcement may also lead to the consumption of higher purity (more dangerous) drugs. Similar to penalties for bootlegging during the Prohibition years, the severity of punishment for drug distribution, under federal sentencing guidelines, is based on the weight and generally ignores the purity of confiscated drugs. Thus, an increase in the certainty of punishment for drug trafficking motivates the distribution of lower weight, higher purity drugs [Rasmussen and Benson, 1994]. In support of this proposition, Warburton [1932] shows that the Prohibition years were characterized by an increase in the consumption of high potency alcohol products relative to low potency products. Similarly, Demleitner [1994] proposes that the War on Drugs resulted in a shift from marijuana consumption to cocaine consumption.

Evidence also suggests that street level quantities of a particular drug may become more pure during increased enforcement. Thornton [1991] shows that a $1 million increase in real federal drug enforcement spending results in a 0.01 percent increase in marijuana purity. The U.S. drug experience confirms (generally) this phenomenon for cocaine and heroin. While federal expenditures on drug control increased almost

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600 percent from 1982 to 2000, Table 1 shows that the purity of retail level cocaine increased from 36 percent to 61 percent while the purity of street level heroin has increased from 5 percent to 25 percent during the same time period.

TABLE 1
Cocaine and Heroin Purity and Price per Pure Gram, Federal Drug Budget Expenditures, and Emergency Room Drug Episodes [1982-2000]

Year	Cocaine Purity	Cocaine Price per Pure Gram	Heroin Purity	Heroin Price per Pure Gram	Federal Drug Enforcement Expenditures	Drug Induced Death Rates per 100,000 Population
1982	36	433	5	3,285	2,633	3.2
1983	39	399	6	3,652	2,966	3.2
1984	44	378	8	3,485	3,493	3.3
1985	40	328	8	3,146	3,945	3.6
1986	51	315	9	3,502	4,042	4.2
1987	64	292	11	3,306	6,546	4.0
1988	75	238	17	3,123	6,219	4.5
1989	78	226	19	2,597	8,482	4.3
1990	69	267	16	2,924	11,957	3.8
1991	78	227	17	3,022	12,974	4.1
1992	76	224	21	2,863	13,385	4.6
1993	74	199	25	2,635	13,504	5.1
1994	73	187	25	2,721	13,251	5.3
1995	67	196	24	2,652	14,091	5.4
1996	72	175	23	2,424	13,837	5.6
1997	65	195	28	2,373	15,040	6.0
1998	68	183	25	2,087	15,729	6.3
1999	64	184	27	1,929	17,492	7.0
2000	61	212	25	2,088	17,818	7.2

Notes: Purity and price figures are reported by the Office of National Drug Control Policy and come from the DEA's System to Retrieve Information on Drug Evidence. Drug budget expenditures are collected from various issues of EOP National Drug Control Strategy. Expenditure figures are reported in billions of real chained 2000 dollars. Drug induced deaths are from the National Vital Statistics Report, volumes 47-50, and do not include alcohol or cigarette deaths.

Rasmussen and Benson [1994] worry that increased purity may increase the quantity of pure drugs consumed. Indeed, both Warburton [1932] and Demlietner [1994] note increased alcohol and drug related overdoses during Prohibition and the War on Drugs, respectively. In other words, while the weight of drugs consumed may decrease, increased purity may result in increased pure drug consumption, equal to the weight times the purity of drugs consumed. The recent U.S. drug environment roughly confirms these fears, as total drug induced deaths per 100,000 population generally increased from 1982-2000 (see Table 1). This phenomenon may be explained by the law of demand. If street level prices per weight of drugs are relatively stable, an increase in drug purity decreases the price of pure drug consumption. The phenomena of increased enforcement, increased consumption of drugs, and decreased drug prices are highlighted in Basov et al. [2001].

This study seeks to determine, in a simple, theoretical framework, whether current federal sentencing guidelines, in which dealers are punished according to the weight of drugs they possess at the time of arrest, contribute to an increase in pure drug consumption when law enforcement efforts are increased. If weight-based penalties trigger increased purity, and increased purity leads to a decrease in the price of pure drug consumption, an increase in the certainty of punishment may increase illicit drug use. Furthermore, this study seeks to determine whether this same undesirable result holds when penalties are, instead, increasing in the quantity of pure drugs at the time of arrest, an alternative penalty structure that would result in little extra cost for law enforcement agencies.

Five sections comprise the paper. A model of drug user and drug dealer behavior is presented in the next section. The following section characterizes the equilibrium of the model and explores the impact of increased enforcement under weight-based penalties. Pure drug penalties are then considered in the fourth section, and the final section concludes the paper.

MODEL

Consider a competitive drug market, as did Lee [1993]. The market consists of n drug dealers and m drug users. The representative drug user purchases a quantity of street level (retail level) drugs, q_r, from a dealer at a per unit retail price of p_r.[1] The purity of street level drugs is given by x and is known by the user at the time of purchase. For simplicity, equilibrium purity is always less than 100 percent, $0 < x^* < 1$, an assumption consistent with U. S. historical purity data (see Table 1).

User Behavior

The representative user derives utility from the quantity of pure drugs consumed where the quantity of pure drugs equals the quantity of retail drugs consumed times the purity of the retail drugs, $q_d = q_r x$.[2] The user also derives utility from the consumption of a licit market good, c. The user's utility function is separable and is given by

$$U = U(c) + U(q_d). \tag{1}$$

The user purchases drugs and the licit market good with income endowment, M. The price of the consumption good is p_c, and the price of pure drugs (the effective price of drugs) is p_d and is equal to the retail price of drugs divided by the purity of retail drugs, $p_d = p_r / x$.[3]

The user faces a pecuniary penalty in the event of arrest for drug possession.[4] The probability of arrest for drug possession is given by α. Consistent with federal drug sentencing guidelines, the severity of punishment increases in the weight of drugs possessed where the weight of drugs equals q_r (the quantity of retail drugs purchased by the user). The severity of punishment is given by $\theta(q_r)$ where θ is continuous and differentiable and where $\theta' > 0$ and $\theta'' > 0$.[5] Thus, the user's budget constraint is characterized by

$$M = p_c c + p_d q_d \qquad \text{with probability } 1 - \alpha$$

and

$$M = p_c c + p_d q_d + \theta(q_r) \qquad \text{with probability } \alpha.$$

Assuming that users are risk neutral, noting that $q_r = q_d/x$, and substituting the budget restrictions into (1), the drug user chooses q_d to maximize

$$U = U((M - p_d q_d - \alpha\theta(q_d/x))/p_c) + U(q_d) \tag{2}$$

given p_d, p_c, M, x, and α. The first-order condition for this maximization problem is

$$-U'(c)[(p_d + \alpha\theta'(q_d/x)(1/x))/p_c] + U'(q_d) = 0. \tag{3}$$

The second-order condition for a maximum requires that

$$-U'(c)[\alpha\theta''(q_d/x)(1/x^2)/p_c] + U''(c)[(p_d + \alpha\theta'(q_d/x)(1/x))/p_c]^2 + U''(q_d) < 0$$

which is satisfied under the assumption that $\theta'' > 0$.

Following equation (3), it is straightforward to show that the representative user's demand is a function of the price of pure drugs, purity, income, the probability of arrest for possession, and the price of licit consumption: $q_d = q_d(p_d, x, \mathrm{M}, \alpha, p_c)$. Using the implicit function theorem, drug consumption is easily shown to follow the law of demand, $\partial q_d/\partial p_d < 0$.[6] In addition, pure drug consumption increases as income increases, $\partial p_c/\partial M > 0$, decreases as the probability of arrest increases, $\partial q_d/\partial\alpha < 0$, and increases as purity increases, $\partial q_d/\partial x > 0$. I term this last effect the "possession effect" because an increase in purity reduces the severity of punishment if the user is captured for possession of a given quantity of pure drugs. The impact of the price of market consumption on drug consumption is indeterminate. Graphically, the demand curve is the usual shape with purity, income, probability of user arrest, and the price of market consumption as shift variables.

It is possible to simplify the expression for the demand of drugs by rearranging the equation for the effective price of drugs ($p_d = p_r/x$) so that purity is a function of the price of pure drugs and the price of street drugs. Substituting, the representative user's demand function becomes $q_d = q_d(p_d, (p_r/p_d), M, \alpha, p_c)$. Since the price of pure drugs now enters two arguments in the demand expression, the user's demand function is rewritten as $Q_d = Q_d(p_d, p_r, M, \alpha, p_c)$. It is straightforward to show that the new expression for the representative user's demand for drugs, Q_d, provides the following partial derivatives: $\partial Q_d/\partial p_r < 0$, $\partial Q_d/\partial M > 0$, and $\partial Q_d/\partial\alpha < 0$. In addition, an increase in the price of pure drugs decreases the quantity of drugs demanded not only through the law of demand but also through the "possession effect" (an increase in the price of pure drugs, with street level prices remaining constant, indicates that purity is decreasing and possession penalties are increasing): $\partial Q_d/\partial p_d = \partial q_d/\partial p_d + \partial q_d/\partial x\,[-p_r/p_d^{2}] < 0$. Graphically, user demand, Q_d, is the usual shape with the retail price of drugs, income, and the probability of user arrest for drug possession as shift variables.

Dealer Behavior

Representative drug dealer profits may also be stated in terms of pure drugs supplied where dealer profits equal drug revenues minus drug costs. Revenues equal the price of pure drugs times the quantity of pure drugs supplied, $p_d q_s$. Costs include the purchase of pure drugs and the transformation (cutting) of these drugs into street level purity. Transformation costs are generally small [Coomber, 1999]. The marginal cost of purchasing and transforming pure drugs is constant and given by c.

Dealer costs also include potential pecuniary drug selling penalties. The probability of arrest for dealing drugs is given by ρ. Consistent with federal drug sentencing guidelines, the severity of punishment increases in the weight of drugs sold where the weight of drugs sold equals the quantity of pure drugs sold divided by purity, q_s/x. The severity of punishment is given by $\Psi(q_s/x)$ where Ψ is continuous and differentiable and where $\Psi' > 0$ and $\Psi'' > 0$.[7]

Given these specifics, the representative dealer's costs are given by

$$C = cq_s + \rho\Psi(q_s/x). \tag{4}$$

From equation (4), the marginal cost of selling drugs is given by

$$MC = \partial C/\partial q_s = c + \rho\Psi'(q_s/x)/x \tag{5}$$

where marginal costs are positive implying that costs are increasing in the quantity of drugs supplied. Using the assumption that $\Psi'' > 0$, equation (5) shows that marginal costs are increasing in the quantity of drugs sold, in the cost of purchasing and transforming drugs, and in the probability that a dealer is arrested, but are decreasing in the purity of drugs:

$$\partial \mathrm{MC}/\partial q_s = \rho\Psi''(q_s/x)/x^2 > 0, \tag{6}$$

$$\partial MC/\partial \mathrm{c} = 1 > 0, \tag{7}$$

$$\partial MC/\partial \rho = \Psi'(q_s/x)/x > 0, \text{ and} \tag{8}$$

$$\partial MC/\partial x = -(\rho/x^2)[\Psi'(q_s/x) + (q_s/x)\Psi''(q_s/x)] < 0. \tag{9}$$

Inequalities (6) – (8) give straightforward results while inequality (9) requires only a brief discussion. Intuitively, an increase (decrease) in the purity of drugs decreases (increases) the weight of drugs supplied and, consequently, expected dealer penalties. Thus, the marginal cost of supplying drugs is reduced (increased). Graphically, inequalities (6) – (9) imply that the dealer's marginal cost curve is an upward sloping function of q_s, that an increase in the cost of purchasing and transforming drugs or an increase in the probability of dealer arrest shifts the marginal cost curve up, and that an increase in purity results in a downward shift in the marginal cost curve.

Given revenue and cost specifications, expected dealer profits are

$$\pi = p_d q_s - c q_s - \rho\Psi(q_s / x). \tag{10}$$

Drug dealers in competitive markets are price takers. Since the price variable in this model is the price of pure drugs, price taking implies that the street price of drugs and drug purity are determined exogenously. Thus, the representative dealer maximizes equation (10) by choosing the quantity of pure drugs to supply given the street price and the street purity (and, consequently, the effective price) of drugs. The first-order condition for this maximization problem is

$$p_d - c - \rho\Psi'(q_s / x)/x = 0 \tag{11}$$

which implies that, at the optimal quantity of drugs supplied, marginal revenue equals marginal cost. The second-order condition for a maximum requires that

$$-\rho\Psi''(q_s / x)/x^2 < 0, \tag{12}$$

a condition satisfied under the assumption that $\Psi'' > 0$.

Equation (11) suggests that quantity supplied is a function of the effective price of pure drugs, purity, the marginal cost of drugs, and the certainty of punishment: $q_s = q_s(p_d, x, c, \rho)$. Using the implicit function theorem, the quantity of drugs supplied is increasing in the effective price of drugs, $\partial q_s / \partial p_d > 0$. I call this effect the "revenue effect". In other words, an increase in marginal revenue (via the effective price of drugs) increases the quantity of drugs at which marginal revenue intersects the marginal cost curve (see Figure 1).

An increase in the purity of drugs decreases the weight of drugs supplied and, thus, expected dealer penalties. In response, the dealer increases the supply of drugs, $\partial q_s / \partial x > 0$, which I term the "trafficking effect" of an increase in purity. This is equivalent to a downward shift in the marginal cost curve, implying that the marginal cost curve intersects marginal revenues at a higher quantity (see Figure 2). As well, quantity supplied is decreasing in both the marginal cost of purchasing and transforming raw drugs and the certainty of punishment: $\partial q_s / \partial c < 0$ and $\partial q_s / \partial \rho < 0$. These two cases are graphically interpreted as an upward shift in the marginal cost curve (see Figure 2).

Because the street level price of drugs is stable, an increase in the effective price of drugs indicates a decrease in purity as $x = p_r / p_d$. Substituting this expression into the representative dealer's drug supply gives $q_s = q_s(p_d, (p_r / p_d), c, \rho)$. Since the price of pure drugs enters two arguments in the supply of drugs, this expression is rewritten as $Q_s = Q_s(p_d, p_r, c, \rho)$ (so that p_d enters only one argument in the supply function).

FIGURE 1
An Increase in Marginal Revenue Increases the Quantity of Drugs Supplied

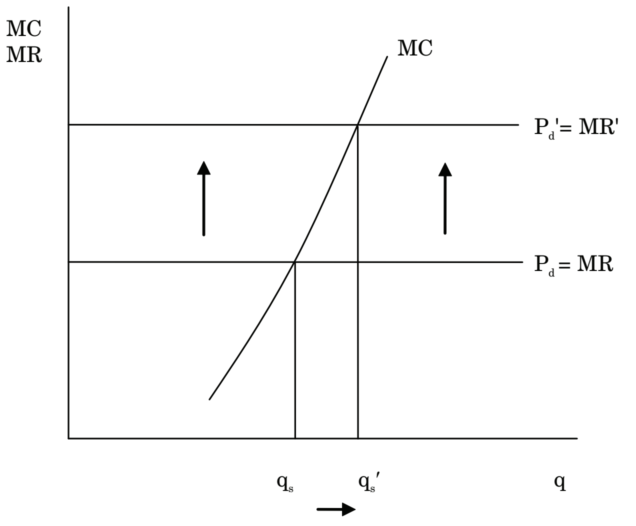
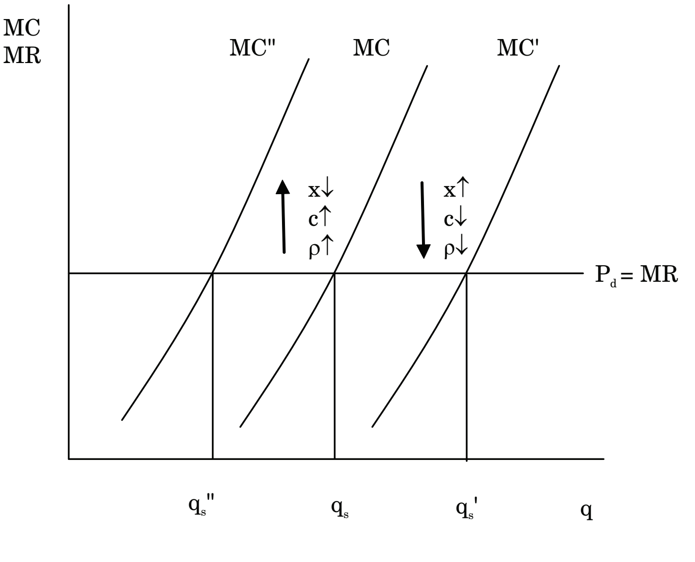


FIGURE 2
The Impact of a Change in Purity (*x*), Drug Transformation Costs (*c*), and the Certainty of Dealer Punishment (ρ) on the Quantity of Drugs Supplied.



It is straightforward to show that the new expression for the representative dealer's supply of drugs, Q_s, yields the following partial derivatives: $\partial Q_s/\partial p_r > 0$, $\partial Q_s/\partial c < 0$, and $\partial Q_s/\partial \rho < 0$. Furthermore, the new expression for the representative dealer's supply of drugs indicates that, on the one hand, an increase in the price of pure drugs increases the quantity of drugs supplied by increasing the effective price of drugs (i.e., the "revenue effect"), but, on the other hand, an increase in price of pure drugs decreases the supply of drugs by increasing the severity of punishment, ceteris paribus (i.e., the "trafficking effect"). Graphically, an increase in the price of pure drugs implies not only an increase in marginal revenue but also a decrease in purity and a shift up in the marginal cost curve (see Figure 3). Thus, the total impact of a change in the effective price on quantity supplied, $\partial Q_s/\partial p_d = \partial q_s/\partial p_d + \partial q_s/\partial x\ [-p_r/p_d^2]$, is ambiguous and is determined by applying the implicit function theorem to equation (11):

$$\text{(13)}\qquad \text{sign}(\partial Q_s/\partial p_d) = \text{sign}[1 - (\rho/p_r)(\Psi'(q_s/x) + ((q_s p_d)/p_r)\ \Psi''(q_s/x))].$$

If $1 > (\rho/p_r)(\Psi'(q_s/x) + ((q_s p_d)/p_r)\Psi''(q_s/x))$, an increase in the effective price of drugs increases the quantity of drugs supplied as the benefits reaped from an increase in revenues outweigh the expected punishment costs of an increase in purity (with street level prices remaining constant). In other words, the "revenue effect" dominates the "trafficking effect". In this case, the supply of drugs is increasing in price. If the "trafficking effect" dominates the "revenue effect", $1 < (\rho/p_r)(\Psi'(q_s/x) + ((q_s p_d)/p_r)\Psi''(q_s/x))$, an increase in the effective price of drugs decreases the quantity of drugs supplied as increased costs from decreased purity outweigh increased revenues. In this case, the supply of drugs is decreasing in price.

FIGURE 3
An Increase in Price Shifts the Marginal Cost Curve Up to Either MC' (Quantity Supplied Increases) or MC" (Quantity Supplied Decreases)

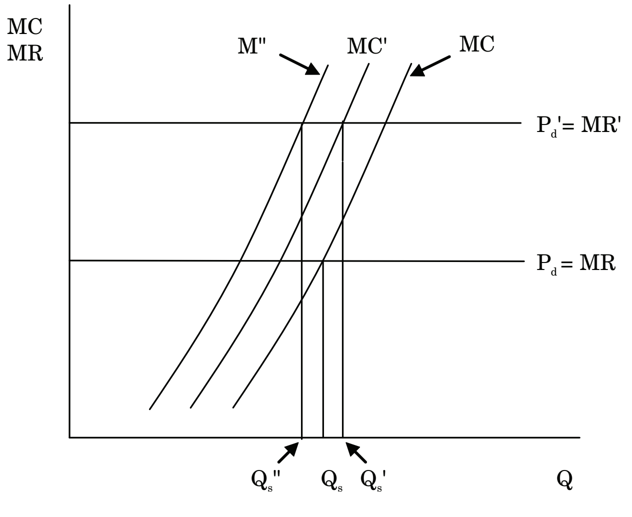


FIGURE 4
The Representative Dealer's Supply Curve if
$1 > (\rho/p_r)(\Psi'(q_s/x) + ((q_s p_d)/p_r)\Psi''(q_s/x))$

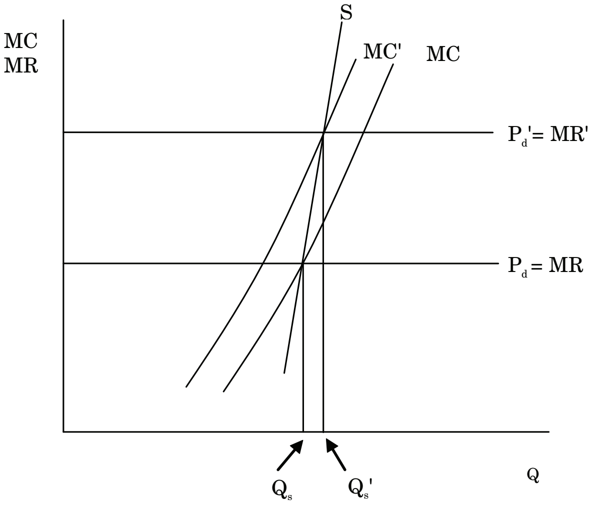
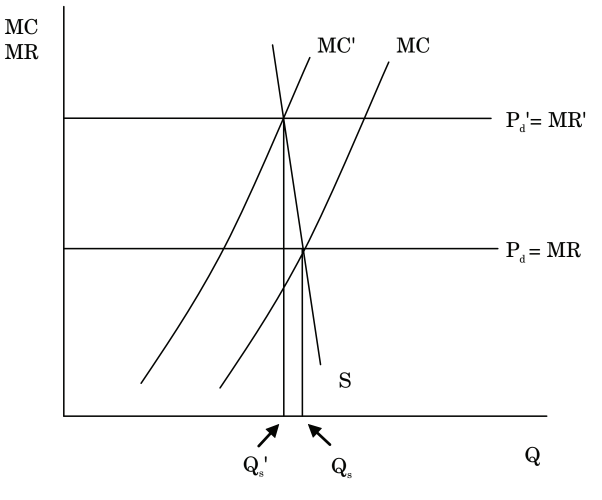


FIGURE 5
The Representative Dealer's Supply Curve if
$1 < (\rho/p_r)(\Psi'(q_s/x) + ((q_s p_d)/p_r)\Psi''(q_s/x))$



Interestingly, market supply is not the horizontal sum of each dealer's marginal cost curve. Figures 4 and 5 show that the representative dealer's supply curve is the set of all the possible marginal revenue / marginal cost intersections over various price levels. If equation (13) is positive, quantity supplied increases as price increases and the supply curve is upward sloping (see Figure 4). If equation (13) is negative, the supply curve is downward sloping equation (see Figure 5). The market supply curve is the horizontal sum of all n dealer supply curves.

EQUILIBRIUM AND COMPARATIVE STATICS

The equilibrium of the model is now defined. After the definition is given, the impact of an increase in the probability that users and dealers are arrested is considered.

Equilibrium

An equilibrium in the competitive drug market implies an effective (pure) drug price, p_d^*, and a retail (street) price, p_r^*, such that market supply, $nQ_s(p_d^*,p_r^*,c,\rho)$, equals market demand, $mQ_d(p_d^*,p_r^*,M,\alpha,p_c)$:

$$nQ_s(p_d^*,p_r^*,c,\rho) - mQ_d(p_d^*,p_r^*,M,\alpha,p_c) = 0.$$

Consistent with several studies, this paper assumes that the retail price and the weight of the sales unit of street level drugs are constant over time while the purity of street level drugs is variable. Grund [1998] and Neaigus et al. [1998] provide motivation for this assumption by maintaining that heroin has historically been sold as dime or nickel bags implying a price of \$10 or \$5, respectively. While each bag has an established weight, the purity of these bags is variable. As well, Inciardi [1987] notes that powder cocaine is typically retailed by the gram though Hamid [1992] allows also for half gram and other purchases. The street price per gram of various weights of cocaine, however, remains relatively stable over time. Grossman, Chaloupka, and Brown [1996] find a 78 percent decrease in the price per pure gram of cocaine from 1978 to 1987, a decrease "traced to a large increase in purity from 32 percent in the former year to 73 percent in the latter year and to a modest 12 percent decline in the money price of one gram of cocaine not adjusted for purity at the same time as the CPI rose by 75 percent".[8] Poret [2002] notes that dealers do not increase street prices of drugs but decrease the quantity of pure drugs (i.e., decrease drug purity) per dose in order to increase drug prices.

Because the street level price of drugs is assumed stable, the equilibrium for the street level drug market can be defined in terms of only the price of pure drugs. An equilibrium implies an effective price of drugs, p_d^*, such that market supply, $nQ_s(p_d^*,p_r,c,\rho)$, equals market demand, $mQ_d(p_d^*,p_r,M,\alpha,p_c)$:

$$nQ_s(p_d^*,p_r,c,\rho) - mQ_d(p_d^*,p_r,M,\alpha,p_c) = 0.$$

Obviously, the equilibrium effective price of drugs coupled with the constant retail price of drugs determine the "equilibrium" purity of drugs sold and purchased, $x^* = p_r / p_d^*$.

Comparative Statics

The impacts of changes in the certainty of dealer and user punishment and of changes in other exogenous variables on the equilibrium pure price (and, thus, the equilibrium purity) and the equilibrium quantity traded of drugs is now determined (with the primary emphases on changes in the certainty of dealer and user punishment).

Using the equilibrium condition above, if the probability of arrest for users is increased, the impact to the equilibrium effective price and the equilibrium quantity of drugs traded depends on the shape of the supply curve

$$\partial p_d^* / \partial \alpha = m(\partial Q_d / \partial \alpha) / [n(\partial Q_s / \partial p_d) - m(\partial Q_d / \partial p_d)]. \tag{14}$$

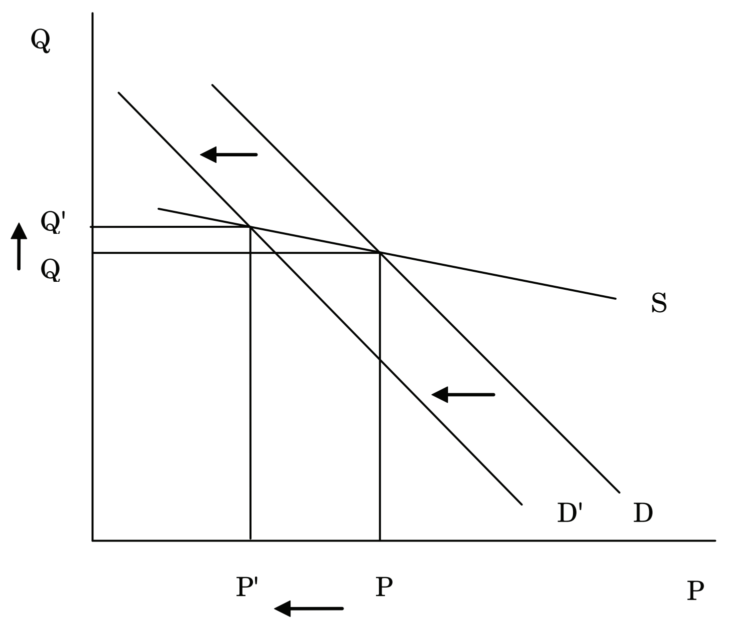
Since the numerator of equation (14) is negative, the impact of an increase in the certainty of user punishment on equilibrium purity is given by the sign of the denominator - the difference between the slopes of the market supply curve and the market demand curve evaluated at the equilibrium effective price of drugs (assuming that quantity is graphed on the y-axis).

If equation (13) is positive, the representative dealer's supply curve is increasing in the effective price of drugs, market supply is upward sloping in the effective price of drugs, and equation (14) is negative; equilibrium effective price decreases with the probability of arresting drug users (which is equivalent to an increase in the purity of drugs, ceteris paribus). Using equation (14) and substituting into the expression for Q_s, it is easily shown that, if equation (13) is positive, drug use is decreased when user enforcement is increased.

If equation (13) is negative, the representative dealer's supply curve and the market supply curve are decreasing in the effective price of drugs; the impact of user enforcement on the effective price of drugs and the quantity of drugs traded depends on difference between the slope of the market supply curve and the slope of the market demand curve. If the slope of the supply curve is greater than, in absolute value, the slope of the demand curve, the denominator of equation (14) is negative and equilibrium effective price increases (the purity of drugs decreases). Under this scenario, pure drug use is reduced. If the slope of the market supply curve is less than the slope of the market demand curve in absolute value, the denominator of equation (14) is positive and equilibrium effective price decreases (purity increases) while drug use increases. In this final case, a policy designed to reduce drug consumption by targeting the arrest of drug users actually increases drug consumption and drug purity (see Figure 6).

The same general comments can be made of the other factors that influence demand. If equation (13) is positive, any factor that increases (decreases) demand (i.e., an increase (decrease) in income assuming that drug use is a normal good) will increase (decrease) both the quantity of drugs traded and the effective price of drugs (resulting in a decrease (increase) in drug purity). If equation (13) is negative and the slope of the supply curve is greater than, in absolute value, the slope of the demand curve, any factor that increases (decreases) demand will increase (decrease) the quantity of drugs traded and decrease (increase) the effective price of drugs. If equation (13) is negative and the slope of the supply curve is smaller than, in absolute value, the slope of the demand curve, any factor that increases (decreases) demand decreases (increases) the quantity of drugs traded and increases (decreases) the effective price of drugs.

FIGURE 6
The Impact of an Increase in the Certainty of User Punishment if the Slope of the Market Supply Curve is Negative and is Less than the Slope of the Market Demand Curve (in Absolute Value)



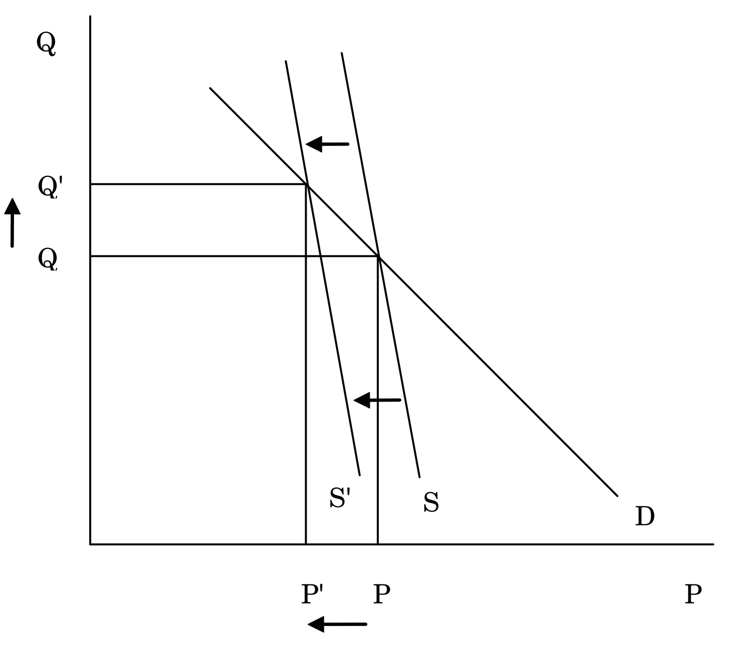
An increase in the probability that dealers are arrested can have similar, unanticipated results. From the equilibrium condition, the impact to equilibrium purity and the quantity of drugs traded once again depends on the shape of the supply curve

$$\partial p_d^* / \partial \rho = - n(\partial Q_s / \partial \rho) / [n(\partial Q_s / \partial p_d) - m(\partial Q_d / \partial p_d)]. \tag{15}$$

Since the numerator of equation (15) is positive, equation (15) is positive if market supply is upward sloping in the effective price of drugs (if equation (13) is positive); equilibrium effective price increases with the probability of arresting drug dealers (equivalent to a decrease in the purity of drugs). In this case, the quantity traded of drugs also decreases.

If, however, market supply is downward sloping in the effective price of drugs (equation (13) is negative), the impact of dealer enforcement on the effective price and the quantity of drugs traded again depends on the difference in the slopes of the market supply and demand curves. If the slope of the supply curve is less than the slope of the demand curve in absolute value, the denominator of equation (15) is positive and the equilibrium effective price of drugs increases and drug use decreases (purity decreases). If the slope of the supply curve exceeds the slope of the demand curve in absolute value, equation (15) is negative and equilibrium drug use increases while the effective price of drugs decreases. In this final case, a policy designed to reduce drug consumption by targeting the arrest of drug dealers increases drug consumption and drug purity (see Figure 7).

FIGURE 7
The Impact of an Increase in the Certainty of Dealer Punishment if the Slope of the Market Supply Curve is Negative and is Greater than the Slope of the Market Demand Curve (in Absolute Value)



Similar comments can be made of the other factors that influence supply. If equation (13) is positive, any factor that increases (decreases) supply (i.e., a decrease (increase) in the cost of purchasing and transforming raw drugs) will increase (decrease) the quantity of drugs traded and decrease (increase) the effective price of drugs (resulting in an increase (decrease) in drug purity). If equation (13) is negative and the slope of the supply curve is less than the slope of the demand curve in absolute value, any factor that increases (decreases) supply will decrease (increase) the effective price of drugs and increase (decrease) the quantity of drugs traded. If the slope of the supply curve is greater than the slope of the demand curve in absolute value, any factor that increases (decreases) supply increases (decreases) the effective price of drugs and decreases (increases) the quantity of drugs traded.

As noted in the introduction, the U.S. experience is consistent with increased drug enforcement, decreased effective drug prices, increased purity, and, perhaps, increased drug consumption [Basov et al., 2001].[9] From the above analysis, it is only possible for an increase in enforcement to increase both the purity of drugs (decrease the effective price of drugs) and the quantity of drugs traded when the supply curve for drugs is downward sloping in the effective price of drugs (upward sloping in the purity of drugs). If the slope of the supply curve is greater than the slope of the demand curve in absolute value, an increase in dealer enforcement increases purity and the quantity of drugs traded. If the slope of the supply curve is less than, in absolute value, the slope of the demand curve, an increase in user enforcement increases purity and the quantity of drugs traded. It is important to note that, in these cases, drug use increases, and the increase represents a failure in illicit drug policy. This is roughly consistent with increased U.S. overdoses from 1982-2000 (see Table 1).[10]

Obviously, a word of caution must be extended. As has been shown, factors other than enforcement can impact the drug equilibrium. Even when the supply and demand curves have the usual slopes, any factor that increases the supply of drugs may, in fact, increase both drug purity (decrease the effective price of drugs) and the quantity of drugs traded. For example, Basov et al. [2001] suppose that declining production costs, increased taxes on legal goods, movement of drug markets away from monopoly power, and better methods to decrease the likelihood that drug dealers are detected have increased market supply, even in the face of increased drug enforcement. Therefore, federal drug policy cannot be blamed for increased drug use and drug purity. On the other hand, the possibility that federal drug policies may have adverse, unintended consequences should cause policymakers to reconsider the penalty structure for punishing users and dealers.

PENALTIES INCREASING IN THE QUANTITY OF PURE DRUGS SUPPLIED: AN ALTERNATE PENALTY STRUCTURE

An alternative penalty structure for drug users and drug dealers is now considered; punishment, for both users and dealers, increases in the quantity of pure drugs supplied. In particular, users and dealers have severity of punishment functions $\theta(q_d)$ and $\Psi(q_s)$, respectively, where θ and Ψ are continuous and differentiable and where $\theta' > 0$, $\theta'' > 0$, $\Psi' > 0$, and $\Psi'' > 0$. Applying the change in user punishment to equation (2), the first order condition for the representative user's maximization problem is given by

$$-U'(c)[(p_d + \alpha\theta'(q_d))/p_c] + \mathrm{U}'(q_d) = 0, \tag{16}$$

and the second-order condition for a maximum requires that

$$-\mathrm{U}'(c)[\alpha\theta''(q_d)/p_c] + \mathrm{U}''(c)[(p_d + \alpha\theta'(q_d))/p_c]^2 + \mathrm{U}''(q_d) < 0$$

which is satisfied under the assumption that $\theta'' > 0$.

Under penalties that increase in pure drugs, it is easy to show that the representative user's demand is a function of the price of pure drugs, income, the probability of arrest for possession, and the price of licit consumption, $Q_d = Q_d(p_d,\mathrm{M},\alpha,p_c)$, where the signs of the partial derivatives are the same as above. Of note, there is no "possession effect" which induces users to purchase more pure drugs when purity rises; an increase in purity no longer reduces the severity of punishment for possessing drugs. An increase in purity increases the demand for drugs only by decreasing the price of pure drugs.

Applying the new penalty structure for dealers to equation (10), the first-order condition for the dealer's maximization problem becomes

$$p_d - c - \rho\Psi'(q_s) = 0. \tag{17}$$

The second-order condition for a maximum requires that

$$-\rho\Psi''(q_s) < 0$$

which is, again, satisfied under the assumption that $\Psi'' > 0$.

Equation (17) suggests that quantity supplied is a function of the effective price of pure drugs, the marginal cost of drugs, and the certainty of punishment, $Q_s = Q_s(p_d,c,\rho)$, where the signs for the partial derivatives are as before. Quantity supplied, with the new penalty structure, is not, however, a function of purity as an increase in purity no longer decreases dealer penalties (the "trafficking effect" no longer impacts the dealer). Therefore, the dealer's supply curve, under the new specification for dealer penalties, unambiguously increases in price (decreases in purity). A downward sloping supply curve, therefore, is not possible.

Assuming that the retail price of drugs is exogenous, an equilibrium for this model is an effective price, $p_d{}^*$, that satisfies:

$$nQ_s(p_d{}^*, \mathrm{c}, \rho) - mQ_d(p_d{}^*, M, \alpha, p_c) = 0. \tag{18}$$

Applying the implicit function to equation (18), an increase in user enforcement decreases the equilibrium effective price of drugs (purity is increased) and decreases drug use while an increase in dealer enforcement increases the effective price of drugs (decreases purity) and decreases drug use. In other words, if the supply curve for illicit drugs is decreasing in the effective price of drugs under the current weight-based penalty structure, policy makers would be wise to change to a penalty structure under which both user and dealer penalties increase in the quantity of pure drugs.

This penalty structure may be achieved without a serious increase in the cost of law enforcement. Confiscated substances are already tested to determine whether they contain illicit drugs. Sentences are then given based on the weight of the drugs seized without reference to the quantity of pure drugs seized except in the case where substances are "of unusually high purity" [USSC, 2004]. Since drugs are already weighed and tested to see if a minimum purity level is achieved, it would not be overly costly to determine the actual purity and to multiply the purity by the weight of drugs confiscated to determine the quantity of pure drugs confiscated.

CONCLUSION

It is well documented that illicit drug policies create unintended consequences. This paper adds to this literature by showing that, under certain conditions, increases in the certainty that drug dealers or drug users are captured increases the purity of street level drugs. This may increase drug consumption as the increase in purity decreases effective drug prices, defined as the price per pure unit of drugs. This finding depends on the assumption of weight-based penalties for illicit drug dealing, where dealers are punished based on the weight of drugs in their possession at the time of arrest. In other words, dealers respond to increased enforcement by reducing the weight of drugs sold through increased purity.

This paper also shows that a switch from weight-based drug penalties to penalties based on the quantity of pure drugs in possession eliminates the finding that an increase in dealer or user enforcement increases the purity of drugs consumed. This switch would likely result in little extra cost for enforcement agencies and, perhaps, little political resistance.

NOTES

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1. The assumption is made that the user knows that all dealers peddle a homogeneous product. Thus, the user does not experience search costs.
2. I assume that, since drug purity is known to the user at the time of a drug purchase, street level drugs are easily titrated into the quantity of pure drugs that the user desires. If, for example, the user desires to purchase 2 grams of pure cocaine and the street level purity of 1 gram of cocaine is 50 percent, the user purchases 4 grams of street level cocaine.
3. If the street price of a gram of 50 percent pure cocaine is $200, the price of a pure gram of cocaine equals $400.
4. In this model, penalties are pecuniary while federal sentencing guidelines provide for months of jail time.
5. Federal sentencing guidelines specify that drug possession sentences increase at an increasing rate [USSC, 2004]. It is assumed that users don't purchase enough drugs to be sentenced as dealers.
6. Many previous studies have posited that, even though many illicit drug substances are addictive, the demand for illicit drugs varies to some degree with the price of drugs [Silverman and Spruill, 1977; Roumasset and Hadreas, 1977; Nisbet and Vakil, 1972]. More recent studies attempting to estimate the price elasticity of demand for illicit drugs use price series corrected for purity differences, $p_d = p_r / x$ [DiNardo, 1993; Saffer and Chaloupka, 1999; and Grossman and Chaloupka, 1998].

After making these corrections, DiNardo [1993] finds that cocaine participation is not significantly related to the price of cocaine; however, Saffer and Chaloupka [1999] and Grossman and Chaloupka [1998], find that drug demand is responsive to changes in price. The later paper employs the rational addiction framework of Becker and Murphy [1988] to estimate a long-run price elasticity of total cocaine consumption [annual participation multiplied by frequency of use] of –1.35, a finding that counters the oft-made assumption of price inelasticity for addictive drug consumption.

7. Federal sentencing guidelines generally specify that drug trafficking sentences increase at an increasing rate, as a step function, for up to 400 grams of heroin, 2 kilograms of cocaine, or 400 kilograms of marijuana. Street level dealers would generally hold quantities of illicit drugs below these thresholds. Penalties increase but at a decreasing rate for larger weights [USSC, 2004].
8. See their footnote 14.
9. Kuziemko and Levitt [2004] find that state level pure drug prices were decreasing in the 1980's and were relatively stable in the 1990's. They also temper the present discussion by finding that increases in overall drug arrests lead to increased pure drug prices, holding other potential influences constant. Freeborn [2004], however, distinguishes between the arrest rate for drug sales and drug possession and, preliminarily, finds the opposite - an increase in the arrest rate for sales decreases the effective price of drugs (the coefficient for the arrest rate for drug possession is not significant).
10. If users do not know for certain the purity of drugs consumed, this impact may be exacerbated.

REFERENCES

Basov, S., Jacobson, M., and Miron, J. Prohibition and the Market for Illegal Drugs: An Overview of Recent History. *World Economics*, October 2001, 133-57.

Becker, G. and Murphy, K. A Theory of Rational Addiction. *Journal of Political Economy*, August 1988, 675-700.

Benson, Bruce L, et al. Is Property Crime Caused by Drug Use or by Drug Enforcement Policy? *Applied Economics*., July 1992, 679-92.

Coomber, R. The Cutting of Heroin in the United States in the 1990s. *Journal of Drug Issues*, Winter 1999, 17-36.

Demleitner, N. Organized Crime and Prohibition: What Difference does Legalization Make? *Whittier Law Review*, Vol 15, 1994, 613-646.

DiNardo, J. Law Enforcement, the Price of Cocaine, and Cocaine Use. *Mathematical and Computer Modelling*, January 1993, 53-64.

Executive Office of the President [EOP]. Consult with America: A Look at How Americans View the Country's Drug Problem. Washington, D.C.: Office of National Drug Control Policy, 1996.

Executive Office of the President [EOP]. National Drug Control Strategy. Washington, D.C.: Office of National Drug Control Policy, Various Years.

Freeborn, B. The Effect of Law Enforcement on Criminal Behavior: Looking at Cocaine Dealer Package Choice and Prison. Unpublished manuscript, College of William and Mary, 2004.

Grossman, M. and Chaloupka, F. The Demand for Cocaine by Young Adults: A Rational Addiction Approach. *The Journal of Health Economics*, August 1998, 427-74.

Grossman, M., Chaloupka, F., and Brown, C. The Demand for Cocaine by Young Adults: A Rational Addiction Approach. National Bureau of Economic Research Working Paper 5713, 1996.

Grund, J. From the Straw to the Needle? Determinants of Heroin Administration Routes, in *Heroin in the Age of Crack-Cocaine*, edited by J. Inciardi and L. Harrison. Thousand Oaks, CA: Sage Publications, 1998, 215-258.

Hamid, A. The Developmental Cycle of a Drug Epidemic: The Cocaine Smoking Epidemic of 1981-1991. *Journal of Psychoactive Drugs*, October 1992, 337-48.

Inciardi, J. Beyond Cocaine: Basuco, Crack, and Other Coca Products. *Contemporary Drug Problems*, Fall 1987, 461-92.

Kuziemko, I. and Levitt, S. An Empirical Analysis of Imprisoning Drug Offenders. *Journal of Public Economics*, August 2004, 2043-66.

Lee, L. Would Harassing Drug Users Work? *Journal of Political Economy*, October 1993, 939-59.

Miron, J. Violence and the U.S. Prohibitions of Drugs and Alcohol. *American Law and Economics Review*, Spring 1999, 78-114.

Murphy, S. Deaths: Final Data for 1998. *National Vital Statistics Reports*, July 2000. Hyattsville, Maryland: Centers for Disease Control and Prevention / National Center for Health Statistics.

Neaigus, A., Atillasoy, A., Friedman, S., Andrade, X., Miller, M., Ildefonso, G., and Des Jarlais, D. Trends in the Noninjected Use of Heroin and Factors Associated with the Transition to Injecting, in *Heroin in the Age of Crack-Cocaine*, edited by J. Inciardi and L. Harrison. Thousand Oaks, CA: Sage Publications, 1998, 131-159.

Nisbet, T. and Vakil, F. Some Estimates of Price and Expenditure Elasticities Among UCLA Students. *Review of Economics and Statistics*, November 1972, 474-475.

Office of National Drug Control Policy. *The Price of Illicit Drugs: 1981 Through the Second Quarter of 2000*, 2001.

Poret, S. Paradoxical Effects of Law Enforcement Policies: The Case of the Illicit Drug Market. *International Review of Law and Economics*, December 2002, 465-93.

Rasmussen, D. and Benson, B. *The Economic Anatomy of a Drug War*. Lanham, Maryland: Rowman & Littlefield Publishers, Inc., 1994.

Rasmussen, D., Benson, B., and Sollars, D. Spatial Competition in Illicit Drug Markets: The Consequences of Increased Drug Enforcement. *Review of Regional Studies*, Winter 1993, 219-236.

Reuter, P. and Caulkins, J. Redefining the Goals of National Drug Policy: Recommendations from a Working Group. *American Journal of Public Health*, August 1995, 1058-63.

Roumasset, J. and Hadreas, J. Addicts, Fences, and the Market for Stolen Goods. *Public Finance Quarterly*, April 1977, 247-272.

Saffer, H. and Chaloupka, F. The Demand for Illicit Drugs. *Economic Inquiry*, July 1999, 401-411

Silverman, L. and Spruill, N. Urban Crime and the Price of Heroin. *Journal of Urban Economics*, January 1977, 80-103.

Thornton, M. *The Economics of Prohibition*. Salt Lake: University of Utah Press, 1991.

United States Sentencing Commission [USSC]. *Guidelines Manual*. §2D1.1 [Nov. 2004], 2004.

Warburton, C. *The Economic Results of Prohibition*. New York, New York: AMS Press, 1932.