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To How Many Customers Should A Drug Dealer Sell?

by

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Abstract

This paper presents a simple economic model of a drug dealer's decision about how many customers to supply. The model relates the number of customers (i.e., the branching factor of the distribution network) to a quantity discount factor describing the extent to which prices are marked up from one distribution level to the next and the ratio of selling costs to product costs. Solving the model allows one to infer characteristics of the domestic distribution network from basic assumptions about individual and market level equilibria.

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1. Introduction

Illicit drugs pose challenging problems for public policy to which quantitative analysis can contribute. For example, at present, we have only a very imperfect understanding of the multi-level domestic distribution network which moves drugs from their point of import to the retail level. This paper seeks to improve that understanding by examining one critical decision all dealers face: to how many customers should they sell?

Because prices increase rapidly as one moves to smaller transaction sizes, dealers have an incentive to skip levels in the distribution network and sell to more, lower level customers, thereby increasing their revenues. On the other hand, increasing the number of sales also increases costs, including the risk of being detected by enforcement agents. Thus every dealer must trade off these competing incentives.

The model presented below formalizes this trade-off. If one is willing to assume that dealers' real-world behavior is close to what is defined as optimal in the model's framework, then the model's solution allows one to infer various characteristics of the markets, including how many dealers there are, how retail prices respond to enforcement, and how profitable drug dealing is.

Although the model is very simple, in some sense it has one too many degrees of freedom. Data are so scarce that it is not possible to estimate empirically all of the parameters. Thus, to draw some inferences, one must first posit a belief about a general characteristic of drug market equilibria. For example, when analyzing models of conventional markets, one often assumes that free entry leads to zero long-run economic profits. Some analysts have made this assumption with respect to drug markets (e.g., Reuter and Kleiman, 1986); others have explicitly rejected it (e.g., Boyum, 1992).

This paper remains agnostic on such issues. Rather, it presents a framework which allows the reader to make any of a variety of assumptions and observe the implications for quantities of interest, including the number of customers to whom a dealer sells. If the implied values of these quantities are beyond the range of what seems reasonable, then the reader may need to revise those prior

beliefs. If not, the reader can draw some comfort from the fact that his or her qualitative beliefs about drug market equilibria are consistent with his or her beliefs about these quantities.

2. Model of Branching Factor Selection

The first subsection below posits a mathematical model of the fundamental trade-off governing a dealer's decision about how many customer to supply. The second argues that this highly abstract model is not patently unreasonable, the third presents the mathematical solution, and the fourth shows how the solution can be applied. The following section extends the model to a chain of dealers.

2.1. Model Statement

Consider a potential drug dealer who can buy a drug in units of lot size x for a price per lot of $P(x) = \alpha x^\beta$. The potential dealer will, if it is profitable, find f customers and set up a business buying lots of size x , dividing them into f bundles of size x/f , and selling them to the customers at price:

$$P\left(\frac{x}{\phi}\right) = \alpha \left(\frac{x}{\phi}\right)^\beta = P(x) \phi^{-\beta}. \quad (1)$$

Suppose the costs of recruiting and supplying customers are linear in the number of customers and can be divided into two components: an on-going costs (c_1) which is incurred each time a sale is made and a one-time cost (c_2) incurred when the customer is recruited. Suppose further that the planning horizon extends over T cycles of buying, dividing, and reselling and that the discount factor per cycle is r . This discount factor may reflect the risk of being put out of business as well as the normal time-value of money.

The dealer can maximize profits (P) by solving the following problem:

$$\begin{aligned} \text{Max}_{\phi} \Pi &= \sum_{i=0}^T (\phi P(x) \phi^{-\beta} - P(x) - c_1 \phi) \rho^i - c_2 \phi & (2) \\ &= (P(x) \phi^{1-\beta} - P(x) - c_1 \phi) \left(\frac{1 - \rho^{T+1}}{1 - \rho} \right) - c_2 \phi, \end{aligned}$$

subject to the constraint that $P(f^*) \geq 0$. If $P(f^*) < 0$, the individual will not sell drugs.

Equivalently, the dealer can maximize π , the profit per period:

$$\text{Max}_{\phi} \pi = P(x) (\phi^{1-\beta} - 1) - k \phi, \quad (3)$$

where,

$$k = \left(\left(\frac{1 - \rho}{1 - \rho^{T+1}} \right) c_2 + c_1 \right). \quad (4)$$

The constant k can be thought of as the sum of direct costs per sale (c_1) and the initial start up cost of identifying the customer (c_2) amortized over the expected number of transactions. Note, some of the costs represented by k are dollar costs and some are familiar non-monetary costs such as the value of the dealer's time. The majority, however, are probably compensation for the risk of arrest and incarceration by enforcement agents and the risk of fraud and violence by other market participants. Hence, the dealer's accounting or dollar profits per period may be significantly greater than the optimal economic profit π^* .

Dividing the objective function in (3) by the constant $P(x)$ yields an expression in which the parameters k and $P(x)$ appear only as the ratio $k/P(x)$, implying that the solution will be a function only of the ratio of these quantities, not of each separately.

2.2. Discussion of Model

Is this model reasonable? It is certainly stylized, but it is not altogether unreasonable. The ability to purchase arbitrary quantities of a drug at a certain price is just another way of saying that the supply curve for lots of size x is flat, which is certainly what one would expect if the dealer in question were small enough to be a price taker and may even be true at the industry level (Caulkins, 1990; Kleiman, 1991). The loglinear model of price as a function of transaction size is well-established. (Brown and Silverman, 1974; Caulkins and Padman, 1993; DiNardo, 1993)

Ethnographic reports have long described the basic task of mid-level dealers as purchasing packets of drugs, dividing, and reselling them. (Preble and Casey, 1969; Moore, 1977) Dealers may also "cut" (or dilute) drugs and, in the case of cocaine may "rock it up" (convert powder cocaine into crack), but the costs of such processing are modest on a percentage basis, so they can be ignored as long as the transaction sizes (x and X/f) are understood to be in terms of pure weight. (Caulkins, 1993; Caulkins, 1994)

Dealers make many decisions besides choosing the number of customers to supply, e.g. what level of violence to employ in punishing customers who are delinquent in their payments. Leaving these decisions out of the model implicitly assumes that those decisions are made appropriately and that, when they are, selling costs are linear, as described.

It is a greater abstraction to assume that all f customers are recruited at once and impose identical costs on the dealer. Presumably dealers actually recruit customers slowly as they meet people that they believe are sufficiently "trustworthy" in the sense of not being an informant or undercover agent. Likewise some customers may be easier (less costly) to sell to than others. For example, the dealer might sell to a family member who is not only highly trustworthy but also is seen on a regular basis in controlled, private settings where transactions can be conducted safely. Nevertheless, this assumption of homogeneity of customers is similar in spirit to the familiar microeconomic assumptions of large numbers of identical and indistinguishable actors in competitive markets.

The notion of modeling dealers as profit or utility maximizers might seem far-fetched, to some. Dealers do not, after all, generally hold MBAs and usually face difficult trade-offs under considerable uncertainty. Nevertheless, most dealers are at least trying to maximize their own welfare, and there is a rich tradition of applying utility maximizing models to criminal behavior. (E.g., Becker 1976)

In short, the model posited above is highly stylized and has in no way been validated. Nevertheless, it may not be an entirely unreasonable abstraction of one important decision that dealers face.

2.3. Solution of the Model

Solving the dealer's optimization problem is a straight-forward calculus exercise. The optimal branching factor is:

$$\phi^* = \left(\frac{(1 - \beta) P(x)}{k} \right)^{1/\beta} \quad (5)$$

and the profit per period obtained by employing this optimal branching factor is:

$$\pi^* = \left(\beta \phi^{*1-\beta} - 1 \right) P(x). \quad (6)$$

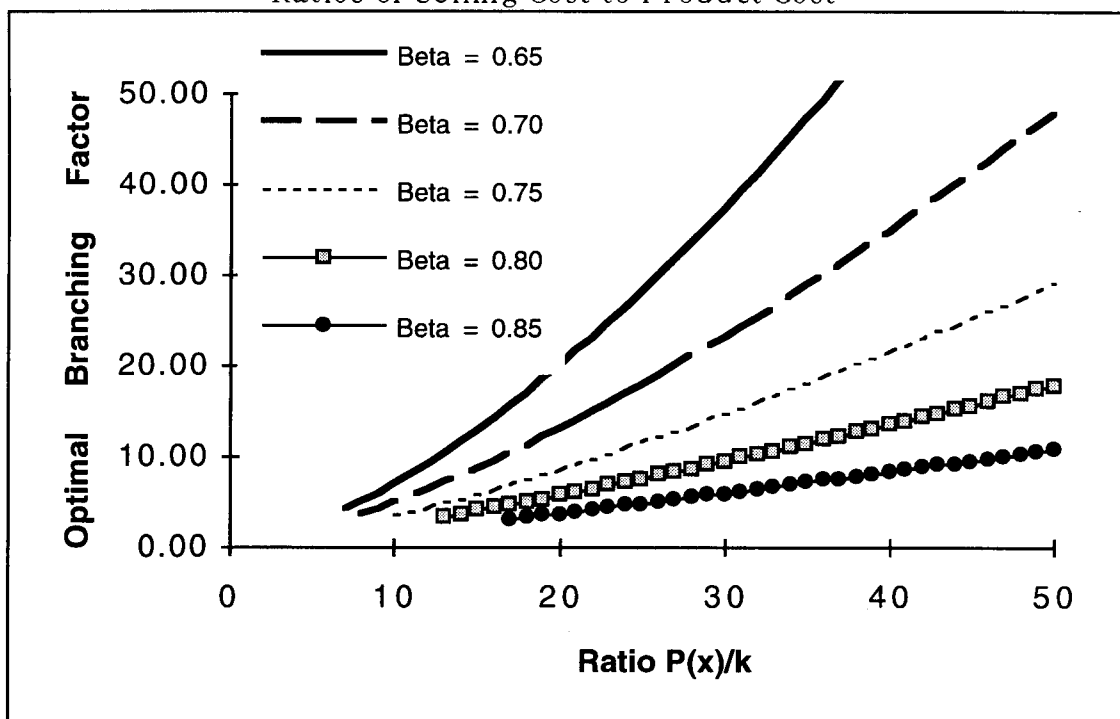
A necessary and sufficient condition for profitability ($\pi^* > 0$) can be stated in terms of the ratio of the costs per transaction divided by the price the dealer pays for drugs:

$$\pi^* > 0 \text{ iff } \frac{k}{P(x)} < (1 - \beta) \beta^{\beta/(1-\beta)}. \quad (7)$$

The quantity discount parameter b is between 0.65 and 0.85 for many drugs (Caulkins and Padman, 1993; Caulkins 1994). Figure 1 shows how the optimal branching factor varies with the ratio of $P(x)/k$ for various values of b . Not surprisingly the lower the relative cost of making a sale (the smaller k is relative to $P(x)$), the larger the optimal branching factor (f) and the smaller the price

markup as one moves down the distribution chain (i.e., the larger b is).

Figure 1: Optimal Branching Factor for Various Ratios of Selling Cost to Product Cost



The dealer's total revenues per period are $f P(X/f) = P(x) f^{1-b}$. These revenues can be divided into three components: the amount spent purchasing the drugs, compensation for the costs of selling, and economic profit.

The fraction of gross revenues used to purchase drugs (f) is:

$$f = \frac{P(x)}{P(x) \phi^{1-\beta}} = \phi^{\beta-1} \quad (8)$$

If the branching factor equals the profit maximizing branching factor (i.e., $f = f^*$), this fraction is:

$$f^* = \phi^{*\beta-1} = \left(\frac{k}{(1-\beta)P(x)} \right)^{(1-\beta)/\beta}. \quad (9)$$

If the costs of selling drugs ($k f$) are mostly non-pecuniary, then the accounting profit margin is one minus the fraction of revenues allocated to buying drugs and "doubling one's money" corresponds to $f = 0.5$.

The second component of gross revenues is compensation for the risks and costs of selling. As a fraction of gross revenues, these risks and costs (rc) are:

$$rc = \frac{k \phi}{P(x) \phi^{1-\beta}} = \frac{k \phi^\beta}{P(x)}. \quad (10)$$

If $f = f^*$, this reduces to $rc^* = 1 - b$.

The return on sales (economic profit divided by gross revenues) is:

$$r = \frac{P(x) \phi^{1-\beta} - P(x) - k \phi}{P(x) \phi^{1-\beta}} = 1 - \phi^{\beta-1} - \frac{k \phi^\beta}{P(x)}. \quad (11)$$

When $f = f^*$, this reduces to:

$$r^* = \beta - \left(\frac{k}{(1-\beta)P(x)} \right)^{(1-\beta)/\beta}. \quad (12)$$

The above expressions implicitly consider the dealer's cost of purchasing drugs ($P(x)$) to be an ongoing business expense. Alternately, the dealer might consider these outlays to be an investment. Then, again assuming that the dollar costs of selling are small, one can calculate the net dollar return to investment, i.e., the ratio of net dollar revenues to the original outlay, as:

$$g = \frac{P(x)\phi^{1-\beta} - P(x)}{P(x)} = \phi^{1-\beta} - 1. \quad (13)$$

Similarly, the economic return to investment (i.e., the economic profit divided by the size of the original investment) is:

$$h = \frac{P(x)\phi^{1-\beta} - P(x) - k\phi}{P(x)} = \phi^{1-\beta} - 1 - \frac{k\phi}{P(x)}, \quad (14)$$

which equals

$$h^* = \beta \left(\frac{(1-\beta)P(x)}{k} \right)^{(1-\beta)\beta} - 1, \quad (15)$$

if $f = f^*$.

2.4. Applying the Model

The results derived above are expressed in terms of the quantity discount factor (b) and the ratio of the cost of making a sale (k) to the cost of buying the drugs which are subsequently resold ($P(x)$). The first can be measured empirically, but the author is not aware of any data pertaining to the second. Thus, the model cannot be solved directly; it has one too many degrees of freedom.

However, it is possible to back compute the ratio $k/P(x)$ from any other single piece of information and then solve for the remaining quantities. For example, suppose one believed from ethnographic studies that dealers at the market level of interest spend 50% of their gross revenue buying the drugs they subsequently resell and from analyzing price data that $b = 0.75$. Then if one were willing to assume that the optimization model above reflects dealers' behavior, Equation (9) implies that $k/P(x) = 0.03125$. From this one could infer that the branching factor is $f^* = 16$, the profit per period is $p^* = P(x)/2$, the return on sales is $r = 25\%$, the net dollar return on investment is $g = 100\%$, and the economic return on investment is $h = 50\%$. Given (1) any piece of information about a dealer's business, (2) an empirically-derived estimate of b ,

and (3) the assumption that the branching factor is optimal in the sense of the model above, one can compute all the other quantities.

The model can also serve as a collection of "conversion factors" which enforce consistency on beliefs about a dealer's costs and revenues. For example, suppose one ethnographic study reported that dealers "double their money" and another found that dealers sell to ten customers. Are these reports compatible? Equation (13) implies that they can be only if $b = 0.70$. If price data indicated otherwise, one would have reason to doubt the veracity of at least one of the two studies.

Finally, given two pieces of information in addition to b , one can estimate how close to optimal dealers' behavior is. Reuter et al. (1990) report that the average annual gross income of daily street sellers in Washington D.C. in the late 1980's was \$81,600, their net income was \$43,200, and their compensation for the death, injury, and incarceration risks of selling was \$21,600, suggesting that $rc = 0.265$ and $f = 0.47$. These figures can be used directly to compute the economic return on sales $r = 1 - rc - f = 0.265$, the net dollar return on investment $g = 1/f - 1 = 1.13$, and the economic return on investment $h = 0.56$. (Column 1 in Table 1.)

Alternately, one can use the methods described in Caulkins (1994) to estimate that $b = 0.77$ for low-level cocaine dealers in Washington D.C. in the late 1980's. This information, together with the estimates of f and rc and Equations 8 and 10 can be used to estimate the ratio $k/p(x) = 0.0212$. The values of r , g , and h which are optimal according to the model for $b = 0.77$ and $k/p(x) = 0.0212$ (Table 1, Column 2) are very similar to those compute directly. One should not infer from this, however, that dealers behave optimally for many reasons, including the fact that parallel calculations using median values of earnings from Reuter et al. (Table 1, Column 3) suggests that dealers may not demand sufficient compensation for the risks they incur.

Table 1: Applying the Model to Retail Dealers in Washington, DC

<u>Quantity</u>	Direct <u>Estimation</u>	Optimality Calculation Based on:	
		<u>Estimate of Mean Earnings</u>	<u>Estimate of Median Earnings</u>
r	0.265	0.279	0.060
g	1.13	1.04	1.04
h	0.56	0.57	0.14
f		26.6	35.5
k/p(x)		0.0212	0.0320

3. Extending Model to the Domestic Distribution Network

The model above describes the actions of one dealer, but drugs are distributed through a network of dealers. This section extends the analysis to chains of dealers to draw inferences about how many dealers there are and the ability of enforcement to raise prices.

3.1. Estimating the Number of Drug Dealers

If f_1 is the branching factor for first-level dealers, then there are $1/f_1$ retail dealers per user. Likewise, if f_2 is the branching factor at the second level, then there are $1/(f_1 f_2)$ second-level dealers per user. Extending this reasoning, the number of dealers per customer (z) is:

$$z = \frac{1}{\phi_1} \left(1 + \frac{1}{\phi_2} \left(1 + \frac{1}{\phi_3} \left(1 + \frac{1}{\phi_4} \dots \right) \right) \right) \quad (16)$$

Branching factors are probably different at different levels, but a rough indication of the number of dealers per user can be obtained by considering the special case in which the branching factor f is the same at all levels. Since the vast majority of dealers are first or second-level dealers, assuming that the branching factor at higher levels is the same as it is at the first level or two will not produce

estimates which are seriously in error.¹ Hence, the number of dealers per customer is approximately

$$z = \sum_{i=1}^{\infty} \left(\frac{1}{\phi}\right)^i = \frac{1}{\phi - 1}. \quad (17)$$

where f is the branching factor at lower market levels.

Suppose one believed that dealers spend a fraction f of their gross revenues buying drugs. Then by Equation (8)

$$z = \frac{1}{f^{1/(\beta-1)} - 1}. \quad (18)$$

Since about 5 million Americans used cocaine in the last year and the quantity discount factor for cocaine is typically about 0.75, if cocaine dealers almost "double their money" ($f = 0.55$) then Equation (19) implies there are 500,000 active cocaine dealers. This is loosely consistent with the notion that about 250,000 of the roughly 400,000 people incarcerated for drug law violations in the US sold cocaine and that cocaine sellers spend about one-third of their time incarcerated. (Reuter et al., 1990) Note, this is not a robust estimate; it is very sensitive to the values of both f and b , and so is offered for illustrative purposes only.

Parallel expressions can be written for the number of dealers per user if one has knowledge about the net dollar return to investment (g), the return on sales (r), or the economic return on investment (h).

3.2. Effects of Enforcement

A principal goal of drug enforcement is to impose costs on sellers, forcing them to raise prices and, as a result, inducing users to consume less. In terms of the model, increasing enforcement would

¹Branching factors are probably lower at higher market levels, suggesting that this approximation will produce a lower bound. On the other hand, higher level dealers often have employees who might be considered to be dealers.

increase k , the cost of making a sale. It is tempting to assume that doubling k would double retail prices, but this model suggests that is probably not the case.

To analyze how changes in k affect prices:

- 1) Estimate the baseline value of b empirically.
- 2) Assume that before k increases, branching factors are optimal and the market equilibrium is characterized by a particular behavior.
- 3) Assume that after k increases, dealers adapt (e.g., by changing the branching factor or price markups) so that the new branching factors are again optimal and the new equilibrium is characterized by the same behavior.
- 4) Infer what the new value of b must be.
- 5) Calculate the change in prices from the change in b .

One defining market behavior might be that in equilibrium drug dealers' economic profits are zero. Obviously dealers' accounting profits are large, but there are essentially no technological barriers to entry, so if dealers' profits exceeded fair compensation for the considerable risks they endure, others might become dealers, bidding down wages until there were no excess profits. Even if one does not believe dealers and potential dealers are so rational, it is instructive to run through the calculations.

When economic profits are zero, the optimal economic return on sales (r^*) and economic return on investment (h^*) are zero, so Equations (12) and Equation (15) imply that

$$\frac{P(x)}{k} = \frac{\beta^{1/(\beta-1)}}{(1-\beta)} \quad (19)$$

If k increased to mk for $m > 1$ then initially it would be optimal for dealers to sell to fewer people (Equation 5) and their profits would become negative (Equation 15). If economic profits eventually

returned to their previous levels and $r^* = h^* = 0$ again.² Equation (15) implies the new quantity discount factor b' would satisfy:

$$\beta' \left(\frac{(1-\beta') P(x)}{m k} \right)^{1-\beta'} = \beta' \left(\frac{(1-\beta') \beta^{1/(\beta-1)}}{m(1-\beta)} \right)^{1-\beta'} = 1, \quad (20)$$

i.e.,

$$\frac{\beta'^{1/(\beta-1)}}{(1-\beta')} = \frac{\beta^{1/(\beta-1)}}{m(1-\beta)}. \quad (21)$$

This equation can be solved numerically to find the new equilibrium quantity discount factor (b) for various values of m .

Changes in b can be related to changes in price. For convenience and because dealing networks are less structured at very small transaction sizes, take the price of one gram to be the benchmark retail price. Suppose k increased for all dealers who buy less than x grams, and $P(x)$ remains unchanged. Then the new retail price is

$$P'(1) = P(1) * (x)(b-b') \quad (22)$$

E.g., if initially $b = 0.75$ and the cost of selling increased by 10% ($m = 1.1$) for drug dealers who obtain their supplies less than a kilogram at a time, then the quantity discount parameter would decrease to $b' = 0.7143$, and the retail price would become

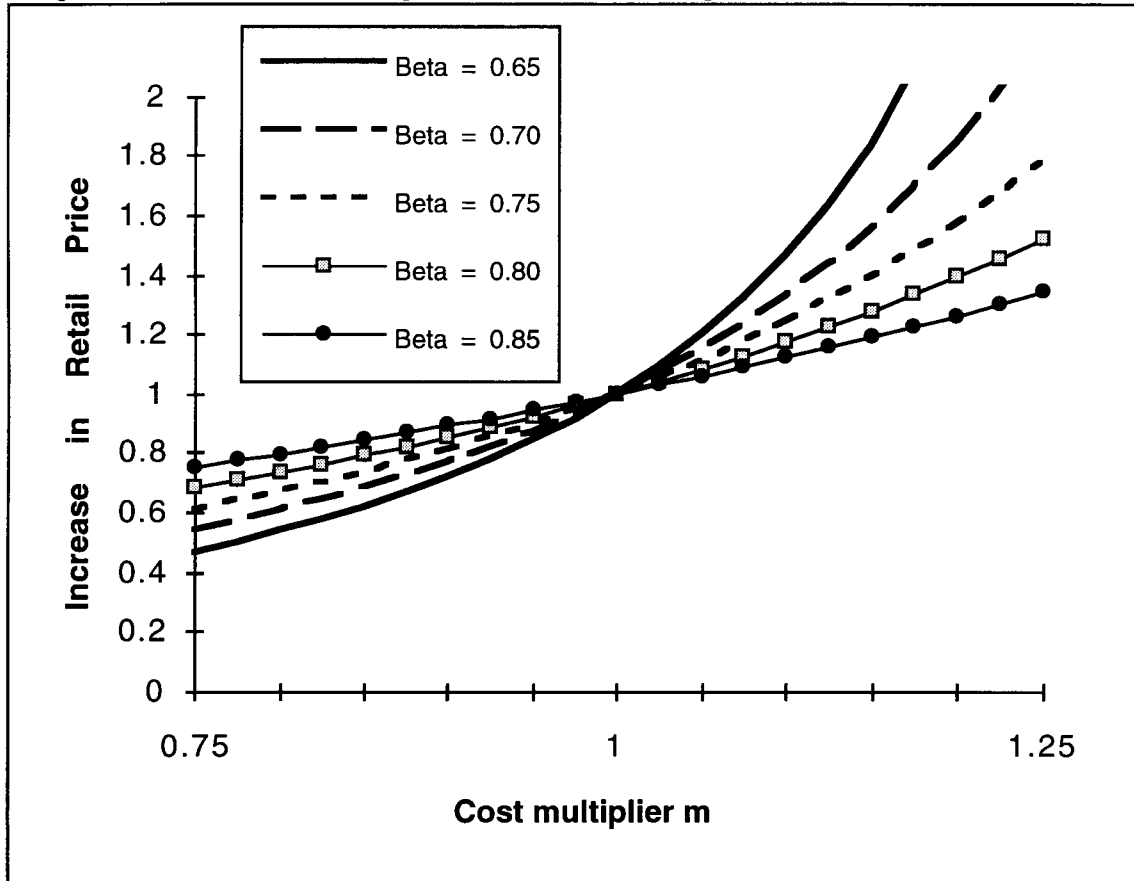
$$P'(1) = P(1) * (1000)(0.75 - 0.7143) = 1.24 P(1). \quad (23)$$

In other words, increasing k by 10% would increase retail prices by a little less than 25%.

Figure 2 generalizes this example. It shows how the price of one gram varies as a function of m for several initial values of b , assuming k increased for all dealers buying less than one kilogram.

²Boyum (1992) points out that negative economic profits may not drive drug dealers out of business because the familiar competitive pressures associated with negative accounting profits would not be present. Likewise Reuter (personal communication) has speculated that there may be "barriers to exit".

Figure 2: How Increasing the Costs of Selling Increases Retail Prices



Parallel calculations can be made based on other assumptions about the market's long run equilibria. If dealers spend a fraction f^* of their revenues buying drugs, then by Equation (9):

$$\frac{P(x)}{k} = \frac{f^{\beta/(\beta-1)}}{(1-\beta)} \quad (24)$$

If after transaction costs went up the market returned to an equilibrium in which this same fraction f^* of gross revenues were spent purchasing drugs, the new quantity discount factor b' would satisfy:

$$\frac{f'^{\beta/(\beta-1)}}{(1-\beta')} = \frac{f^{\beta/(\beta-1)}}{m(1-\beta)} \quad (25)$$

Consider a situation in which again initially $b = 0.75$ and k increases by 10% for all dealers who buy less than one kilogram, but this time market equilibria are characterized by dealers doubling their money ($f = 0.5$). Equation (25) implies the new value of b would be 0.7435, so by Equation (23) the price of one gram increase by less than 5%. Similar calculations can be made based on the investment model (Equations 13-15).

Together with Figure 2, these calculations imply that price increases induced by increases in the cost of selling drugs: (1) are not equal in percentage terms to the change in k , (2) are not even proportional to the change in k , (3) depend on the initial value of the quantity discount factor b , and (4) depend on what behavior determines market equilibria. There is a simple reason why changes in price are not proportional to change in k . Changing k affects the branching factor (f) and, hence, the number of transactions as well as the cost per transaction.

4. Summary

One decision drug dealers face is: to how many customers should the dealer sell? This paper presents a simple model of that choice whose solution is expressed in terms of three quantities: a quantity discount parameter, the branching factor, and the ratio of selling costs to the drug's purchase price.

The quantity discount parameter can be measured empirically. An equation for the branching factor expressed in terms of the other parameters follows from the assumption that dealers' choose the branching factor which maximizes profits. The third degree of freedom in the model can be eliminated by making one further assumption about market equilibria based either on empirical observations (e.g., about the fraction of revenues used to purchase the drugs which are subsequently resold) or theory (e.g., free entry drives economic profits to zero in the long run).

There is no consensus in the literature about what determines equilibria for illicit drugs markets, so this paper does not commit to any one theory. Nevertheless, it provides a framework with which people can evaluate various hypotheses, a tool for policy analysis.

and one clear lesson: it is not safe to assume that changing the costs of selling drugs will lead to proportional changes in retail prices.

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