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Monopoly and Competition in Addictive Markets

Sean Murray

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MONOPOLY AND COMPETITION IN ADDICTIVE MARKETS

Abstract

This paper models monopoly markets on which demand is addictive as defined by Stigler and Becker; and hence dynamic. It is shown that the monopolists' equilibrium is unique and stable and the time path taken to reach it is also unique. The comparative statics and comparative dynamics of these markets are analysed. It is proved formally that the harmfully (beneficially) addictive monopolist will produce to the left (right) of the equality between marginal revenue and marginal cost, and that the latter may produce where marginal revenue is negative. The model is applied to policy problems in drug-related crime. It is shown that supply-directed policies result in more crime in both long and short runs under monopoly than under competition. The reverse holds true under demand-directed policies. Demand-directed policies cause less crime than supply-directed policies, whether competition or monopoly obtains.
where $Q^*$ is long-run or target consumption. Long-run equilibrium at $E_0$ implies that consumption is just sufficient to offset depreciation and to maintain consumption capital intact. Through $E_0$ there runs a short-run demand curve $DD$, steeper than $D'D^*$. Let price fall to $P_1$. Short-run consumption rises to $Q_1$. Consumption is more than sufficient merely to maintain capital, which is now being accumulated. The increase in consumption capital raises demand, and the short-run demand curve will shift rightwards, continuing to do so until long-run equilibrium is reached at a new target level of consumption capital, and at a new target level of consumption, $Q^*_2$.

Fig. II. illustrates the case of beneficial addiction. The short-run demand curve $DD$ is flatter than the long-run demand curve $D'D^*$. A fall in price from $P_0$ to $P_1$ raises short-run consumption to $Q_1$. Capital accumulates and reduces demand, the short-run demand curve shifts leftwards and a new long-run equilibrium is in time reached at $Q^*_2$.

Interpret the demand curves of Figs. I and II as market demand curves, and $P^0$ and $P^1$ as horizontal marginal cost curves, and these diagrams can do duty to analyse competitive addictive markets. (Their stability is proved in the next section). The dynamics and comparative statics of these markets are straightforward.

The analysis is more difficult under monopoly. Since the slopes of the long and short-run demand curves differ, then the monopolist can never equate marginal cost simultaneously with both long and short-run marginal revenues. Furthermore, the monopolist
will never be in equilibrium if long-run marginal cost (LRMC) equals long-run marginal revenue (LRMR). Were the two equal, then the monopolist, in a maleficiently addictive market could, at a trivial loss of long-run profit, reduce quantity, increase short-run price, and by this stratagem increase the present value of profit. Therefore the monopolist, in long-run equilibrium (if such exists) will produce where LRMR exceeds LRMC. A formal proof of this proposition is provided in Section III.

But precisely where will that equilibrium occur? The value of short-run profit depends (given the discount rate and the other parameters) on its duration, and hence on the speed of adjustment of the short-run demand curve. Therefore, only a well-specified dynamic intertemporal model can answer the question. This paper attempts such a model. 1)  

The plan of the paper is now set out. The succeeding section develops the formal model and from it fashions the analytical tools employed in the subsequent phase-diagrammatic analyses. For the case of maleficent addiction, Sections II and III between them provide an analytical solution for the monopolist's equilibrium, which is shown to be unique and to lie to the left of the equality of LRMR and LRMC. Equilibrium is stable and the time-path followed by price and quantity to attain it is unique if the monopolist maximizes profit. It is shown that the value of the monopoly right is greater, the higher is the arbitrary initial price. The comparative-static and comparative-dynamic effects of a rise in marginal cost are analysed. Section IV
uses the analytical armoury of the earlier sections to evaluate, to
the extent that theory can, some policies directed at drug-related
crime. Under plausible assumptions, anti-narcotics policies which
are directed towards reducing supply will result in more crime under
competition than under monopoly. The reverse, again under plausible
assumptions, is true of policies directed at reducing demand.
Whether competition or monopoly obtains, demand-directed policies
cause less crime than supply-directed policies, both in the short and
long runs. Section V establishes, for the case of beneficent
addiction, propositions equivalent (mutatis where appropriate mutandis)
to those of Sections II and III for maleficent addiction. Inter alia,
it shows that a monopolist in a beneficially addictive market may
produce where marginal revenue is negative, even though marginal cost
is positive, another conclusion at variance with that of the textbooks.
II. THE MODEL

In this section we formalize the model described in the introduction. We show that competitive equilibrium is unique and stable. Then we set up and solve the monopolist's intertemporal maximization problem. We show that the time paths followed by the monopolists, beneficial and maleficent, in Q and Q* space are unique and derive the equations of the respective stable paths, and of the singularities along which the rates of change of Q and Q* are zero. These are the tools which will be used for the phase-diagrammatic analyses of the rest of the paper.

The model is:

\[(1) \quad Q = \gamma + \alpha Q^* - \beta P \quad ; \quad \gamma, \beta > 0.\]

For maleficent addiction: \(0 < \alpha < 1.\)

For beneficent addiction: \(\alpha < 0.\)

\[(2) \quad Q^* = \phi(Q - Q^*) \quad ; \quad \phi > 0.\]

\[(3) \quad C = \theta Q \quad ; \quad \theta > 0.\]

Furthermore, to ensure a positive \(Q^*\) and \(P\) in long-run equilibrium:

\[\frac{\gamma}{\beta} > \theta.\]

\(Q\) is quantity, \(Q^*\) is long-run or target demand, \(C\) is total cost and the dot indicates a time-derivative. Equation (1) is the short-run demand curve, the position of which is determined by \(Q^*\), which changes only over time, as specified by (2) according to the difference between actual consumption \(Q\), and \(Q^*\). If one sets
\[ Q^* = 0, \quad \text{then} \]

(4) \[ Q = Q^*. \]

Upon substitution for \( Q \) from (4) into (1) then one obtains the equation of the long-run demand curve \( D^*D^* \):

(5) \[ P = \frac{Y}{\beta} - \frac{(1-\alpha)}{\beta} Q^* \]

and \( DD \) is steeper (flatter) then \( D^*D^* \) if addiction is harmful (beneficial). To keep matters simple (3) supposes that marginal cost is constant.

We now establish stability of equilibrium under competition. Set marginal cost \( \theta \) equal to \( P \) and substitute in (1), then substitute for \( Q \) from the resulting equation into (2):

(6) \[ Q^* = \phi \left\{ \frac{\beta y}{\beta} - \theta \right\} - \phi (1 - \alpha) Q^* \]

For both harmful and beneficial addiction, long-run equilibrium is globally stable (and \( \therefore \) unique). Long-run equilibrium output is:

(7) \[ Q^* = \frac{\beta (\gamma - \theta)}{(1-\alpha)} \]

which as one might expect, is lower under beneficial than under maleficent addiction.

We now extend the model to the case of a monopolistic market. The monopolist's problem is to choose \( Q \) and \( Q^* \) so as to maximize the present value of profit,

(8) \[ (P - \theta) Q \]

subject to the constraint in (2). Hence the maximand is:
\( H = \int_0^{\infty} e^{-rt} \left[ \frac{Y}{B} + \frac{a}{B} Q^* - \frac{1}{B} Q - \theta \right] Q^* \lambda \phi (Q-Q^*) + \lambda Q^* \, dt \)

where \( r \) is the exogenously given discount rate. \(^2\)

Maximizing with respect to \( Q \) and \( Q^* \) yields:

\[
\frac{\delta H}{\delta Q} = e^{-rt} \left[ (\frac{Y}{B} + \frac{a}{B} Q^* - \frac{1}{B} Q - \theta - \frac{1}{B} Q) + \lambda \phi \right] = 0
\]

\[
\frac{\delta H}{\delta Q^*} = e^{-rt} \frac{a}{B} Q - \lambda \phi + \lambda \dot{Q} = 0
\]

Differentiating (10) with respect to time we obtain:

\[
\dot{\lambda} = \frac{r}{\phi} e^{-rt} \left( \frac{Y}{B} + \frac{a}{B} Q^* - \frac{1}{B} Q - \theta - \frac{1}{B} Q \right) - \frac{e^{-rt} a}{\phi} \frac{Q^*}{Q} \\
+ \frac{e^{-rt}}{\phi} \left\{ 2 \frac{1}{B} \frac{Q^*}{Q} \right\}
\]

Substituting for \( \dot{\lambda} \) from (12) into (11), having substituted for \( Q^* \) from (2) into (12) yields:

\[
\lambda \phi = e^{-rt} \left\{ - \frac{r}{\phi} \frac{2}{B} Q + \frac{a}{B} \left( 1 + \frac{r}{\phi} \right) Q^* + \frac{1}{B} \frac{2}{\phi} \dot{Q} \right\}
\]

Now eliminate \( \lambda \phi \) from (13) and (10) to obtain the differential equation (14), which, together with (2), describes a system of two first-order linear differential equations in \( Q \) and \( Q^* \):

\[
\begin{bmatrix}
\dot{Q} \\
\dot{Q}^*
\end{bmatrix} =
\begin{bmatrix}
- \frac{(Y}{B} - \theta) (1 + \frac{r}{\phi}) & \frac{aB}{2} \\
0 & \phi - \frac{1}{2} r
\end{bmatrix}
\begin{bmatrix}
Q \\
Q^*
\end{bmatrix}
\]

\[
\begin{bmatrix}
\dot{Q} \\
\dot{Q}^*
\end{bmatrix} =
\begin{bmatrix}
\phi \\
\phi
\end{bmatrix}
\begin{bmatrix}
Q \\
Q^*
\end{bmatrix}
\]
Call the above matrix $A$. The trace of $A$ is:

\[(15) \quad \text{tr.}(A) = r > 0\]

The determinant is

\[(16) \quad \det(A) = \phi[(\alpha - 1) + r (\frac{\alpha}{2} - 1)] < 0\]

both for maleficient addiction ($0 < \alpha < 1$) and beneficent addiction ($\alpha < 0$). I.e, for each case we have a saddlepoint. There is therefore only one stable path for $Q$ and $Q^*$ which it were well that the monopolist, in the interest of maximizing profit, should follow. The equation of this stable path, which is derived in the appendix, is

\[(17) \quad Q = \left(1 - \frac{m_2}{n_2}\right) \bar{Q}^* + \frac{m_2}{n_2} Q^*\]

where the bar indicates a steady state value, and

\[(18) \quad \frac{m_2}{n_2} = \frac{\alpha(\phi + \frac{1}{2} r)}{(\phi + r) - \lambda_2}\]

Setting $Q = 0$ in (14) one gets :

\[(19) \quad Q = \frac{(\frac{\gamma}{B} - \delta)(1 + \frac{r}{\phi})}{\phi + r} + \frac{\alpha(\phi + \frac{1}{2} r)}{(\phi + r)} Q^*\]

Equations (17), (18), (19) and (4) (the forty-five degree line in $Q$, $Q^*$ space which specifies a zero rate of change of $Q^*$) constitute the tool-kit with which we shall attempt to analyse addictive markets, to which task we now bend ourselves.
III. HARMFUL ADDICTION

The dynamics of the harmfully addictive monopolistic market are illustrated in Fig. III. The curve labelled $Q^*$ is the curve of equation (4) and shows combinations of $Q$ and $Q^*$ which yield a zero rate of change of $Q^*$. Its slope is unity, since a one-unit increase in $Q$ will raise $Q^*$ by $\phi$, as will a one-unit fall in $Q^*$, and in long-run equilibrium the two are equal. The curve labelled $QQ$ is the curve of (19), along which $Q$ is zero. Its slope is:

\[
\frac{dQ}{dQ^*} \bigg|_{Q=0} = \frac{a\phi(2 + \frac{r}{\phi})}{\phi + \frac{r}{\phi}}
\]

which is less than unity, since we have shown that:

\[
\det(A) = \phi[-(\phi+r) + \frac{a}{2} \phi(2 + \frac{r}{\phi})] < 0
\]

which implies that the denominator of (20) exceeds the numerator. Hence $QQ$ is flatter than $Q^*$. Given the direction of the arrows in the picture then it is clear that the slope of the stable arm $S^0S^0$ in Fig. III. must be flatter than that of $QQ$, as indeed it is, since its slope, given in (18) differs from (20) only in the addition of the positive number $-\lambda_2$ (where $\lambda_2$ is the negative root) to the denominator.

We have established that the monopolist will settle down in the long run to a unique quantity and therefore to a unique price. The time-path followed to attain that long-run equilibrium is also unique. Stability is assured by the assumption that profit is maximized.
Consider first the monopolist's long-run equilibrium.

Solving equations (18) and (19) for \( \bar{Q}^* \) we have

\[
(21) \quad \gamma - \frac{2}{\beta} (1-a) \bar{Q}^* = \theta + \frac{a \frac{r}{\beta} \phi^2 \bar{Q}^*}{(1+\frac{r}{\phi})}
\]

But the sum of the two terms on the left hand side is LRMR, and \( \theta \) is LRMC. Thus our equilibrium occurs where:

\[
(22) \quad LRMR = LRMC + \frac{a \frac{r}{\beta} \phi^2 \bar{Q}^*}{(1+\frac{r}{\phi})}
\]

In general, in a malicently addictive market, equilibrium will occur to the left of the intersection of LRMC and LRMR, i.e. at a lower output than that of the static monopolist. The smaller is the interest rate \( r \), or the larger is the adjustment speed \( \phi \), then the smaller will be the difference between the equilibrium of our static and dynamic monopolists. In the limit, when either \( r \) is negligible or \( \phi \) infinite, the dynamic monopolist will, in the long-run, produce where \( LRMC = LRMR \).

The reason for this general result is to be found in the dynamics of the addictive market. Suppose the monopolist were operating to the left of the steady-state equilibrium described by (22). Since LRMR there exceeds LRMC the monopolist can increase long-run profit by expanding his long-run output \( Q^* \), that is by moving down the long-run demand curve \( D^* \). But according to equation (2) he can only do so by raising \( Q \) above \( Q^* \), that is by cutting price and moving down the short-run demand curve at his current \( Q^* \) and foregoing current profit. His decision to expand is thus an investment decision. He will continue to expand until
the investment cost is just counterbalanced by the increment to the present value of future profit. If the adjustment speed $\phi$ is infinite the monopolist need not drop his price along the short-run demand curve but may move along $D^* D^*$, incurring no investment costs in adding to future profit. If $r$ is zero, then the present value of any increment to profit is infinite. In either of these cases profit is maximized where $LRMC = LRMC$. But for any finite $\phi$ or positive $r$, it is maximized to the left of that equality.

Let us now examine the effects on the system of an increase in the marginal cost of the monopolist, starting from long-run equilibrium at $E_0$. Both $QQ$ and $SS$ in Fig. III. will shift downwards. (The former shift is omitted in the interests of clarity. The shift in $Q^* Q^*$ is of course zero.) The downward shift in $SS$ is, from (17) and (21):

$$\frac{\delta Q}{\delta \theta} = -(1 - \frac{m_2}{n_2}) \left[ \frac{\beta}{(2(1-\alpha)+(2-\alpha)r)} \right] < 0$$

$Q^*$ can change only over time. So when marginal cost rises, there will be an instantaneous reduction in $Q$ at constant $Q^*$, a discrete movement from $E_0$ to $E_1$ on $S'S'$, the new $SS$ curve vertically below $E_0$. Thereafter there will be a smooth movement along $S'S'$, $Q$ and $Q^*$ falling together as required for stability, until eventually equilibrium is reached at $E_2$. The short-run fall in $Q$ (from $E_0$ to $E_1$) is less than the long-fall to $E_2$, and $Q$ does not overshoot.
One can gain more insights into the dynamic and comparative-dynamic behaviour of the model if one looks at it in price-quantity space, rather than in $Q - Q^*$ space. Substitute for $Q^*$ from the stable path equation (17) into the demand curve (1). The result is:

\[(25) \quad P = \frac{\alpha}{\beta} - \frac{\alpha n_2}{\beta m_2} \left(1 - \frac{m_2}{n_2}\right) Q^* + \frac{1}{\beta} \frac{n_2}{m_2} \left[\alpha - \frac{m_2}{n_2}\right] Q.\]

This equation is the only relationship between price and quantity which satisfies the stable path. Its slope is

\[(24) \quad \frac{\delta P}{\delta Q} = \frac{1}{\beta} \frac{(\phi + r - \lambda_2)}{\phi + \frac{\lambda_2}{2}} \left[1 - \frac{\phi + r}{\phi + \frac{\lambda_2}{2}}\right] > 0\]

(whether addiction is maleficent or beneficent), and is drawn in Fig. IV. as A A. (For the time being, apart from $D^*D^*$ and DD, ignore the other curves in the picture).

Suppose one starts at the point B in Fig. III, and let the corresponding point in Fig. IV. also be B. The system moves from B down the stable path $S^0S^0$ towards $E_0$, both $Q$ and $Q^*$ falling. These movements exert conflicting forces on price according to the demand equation

\[P = \frac{\alpha}{\beta} + \frac{\alpha}{\beta} Q^* - \frac{1}{\beta} Q\]

A one unit fall in $Q^*$ (a leftward shift in the short-run demand curve) will cause a fall in price of $\frac{\alpha}{\beta}$?. A one unit fall in $Q$ (a movement up the short-run demand curve) will cause a rise in price of $\frac{1}{\beta}$?. If $Q$ and $Q^*$ were to fall at the same rate (i.e. if $\frac{\delta Q}{\delta Q^*}$ were unity along $S^0S^0$) then the effect of $Q$ on price
would dominate \( \frac{\alpha}{\beta} \leq \frac{1}{\beta} \) and price would rise. But \( Q \) and \( Q^* \) do not fall at the same rate. A one-unit fall in \( Q^* \) along \( S^0 \) \( S^0 \) is accompanied, (for stability) by a fall in \( Q \) of only

\[
\frac{\alpha (\phi + \frac{1}{r})}{(\phi + r) - \lambda_2}
\]

which is less than \( \alpha \). Hence the upward pressure exerted on price by the fall in \( Q \) is dominated by the downward pressure of the fall in \( Q^* \) and \( A \ A \), the stable path in price quantity space, is upward sloping.

The \( A \ A \) curve is a useful tool. Among other things, it shows that the value of the monopoly right is higher, the higher is the arbitrary initial price 5). The difference in the present values of the monopoly rights as between any two starting points depends only on the present values of profit in the transition from the starting point to the long-run equilibrium at \( E_0 \), since at \( E_0 \) the present values will be identical. The present value of \( (P-\theta) Q \) in the transition from the point \( B \) to \( E_0 \) is greater than in the transition from \( C \) to \( E_0 \). The higher is initial price (the farther up the \( A \ A \) curve we start) the greater the value of the monopoly right.

It also sheds more light on the comparative-dynamics. An upward shift in marginal cost \( \theta \) will shift the \( A \ A \) curve of Fig.IV upwards to \( A'A' \). If we differentiate (23), the equation of \( A \ A \), we get

\[
\frac{\delta P}{\delta \theta} = -\frac{\alpha}{\beta} n_2 \left(1 - \frac{m_2}{n_2} \right) \frac{\delta Q^*}{\delta \theta} > 0
\]
Since $Q^*$ can only change over time, there will be a discrete jump, shown in Fig. IV, from $E_0$ to $E_1$, (the intersection of $A'A'$ with the short-run demand curve of the original equilibrium), corresponding to the same discrete jump in Fig. III. Since quantity undershoots in the short-run, price must overshoot, which is only another way of saying that $AA$ slopes upwards. From $E_1$ the market will move smoothly down $A'A'$ to $E_2$, the short-run demand curve shifting leftwards as $Q^*$ falls. We now turn to apply the model to some problems of policy.
The model can be used to shed light on some questions of policy interest. I give two such applications here. First, will anti-narcotic policies directed at the demand side result in more crime under monopoly than under competition? Second, will supply side policies result in more crime under monopoly than under competition? Let crime be a function of expenditure on the drug, (suppressing other arguments in the crime supply function - see Becker (6)) according to:

\[ D = f(PQ); \quad f' > 0; \]

where \( D \) is the monetary value of external crime costs.

First, consider a given reduction in the long-run supply of heroin caused by upward shifts in marginal cost curves (in turn caused by some anti-narcotic policy). Let the reduction in long-run supply be from \( E_0 \) to \( E_2 \) on the long-run demand curve \( D^*D^* \) of Fig IV. In the long-run, expenditure, and therefore crime, will be the same whether monopoly or competition obtains. But what of the transition? Will transitory external costs in terms of crime be greater or smaller under competition than under monopoly? The answer depends only on the price-elasticity of demand of the short-run demand curve at \( E_0 \).

Under competition, the upward shift in marginal cost required to effect a long-run movement from \( E_0 \) to \( E_2 \) in Fig IV. is that from the horizontal line through \( E_0 \) (not drawn) to \( MC' \), running
through $E_2$. Such a shift will cause a jump from $E_0$ to $E_3$, and thereafter a smooth movement along $MC'$ to $E_2$. Under monopoly the increase in marginal cost is that required to shift $AA$ up to $A'A'$, passing through $E_2$. There will be a jump from $E_0$ to $E_1$, followed by a smooth movement down $A'A'$ to $E_2$.

The answer to the question therefore depends only on whether the integral over time of expenditure is greater in the transition from $E_1$ to $E_2$ than from $E_3$ to $E_2$. (The areas under $A'A'$ and $MC'$ do not shed any light on the problem). Let us make the plausible assumption that $DD$ is price-inelastic at $E_0$. Then total expenditure is greater at $E_1$ than at $E_3$.

Fig. V, which measures expenditure $(PQ)$ on the vertical axis and time $(t)$ on the horizontal, illustrates the argument. The curve labelled $MM$ represents the time path of expenditure under monopoly. The monopolist starts at time zero, at the point $E_1$, with a relatively high total expenditure $PQ(E_1)$. He then moves down $A'A'$, both price and quantity falling continuously, and expenditure asymptoting towards $PQ^*$, expenditure at $E_2$. The curve $CC$ illustrates the behaviour of expenditure under competition. The competitive industry will begin at $E_3$, with a relatively low expenditure $(PQ(E_2))$, in Fig. V.) and will move along $MC'$, quantity falling at a constant price $P$, and total revenue again asymptoting towards $PQ^*$ Thus if $DD$ is price-inelastic the $MM$ curve will lie uniformly above the $CC$ curve. The transition from $E_0'$ to $E_2'$ will involve a greater cost in terms of crime under monopoly than under competition. (If the $DD$ curve is price elastic, then the positions of $MM$ and $CC$ are reversed, as is the conclusion.)
Next, let us examine the effects of any given reduction in quantity caused by any demand-side policy directed at reducing the parameter $\gamma$. Assume that the policy-maker in a competitive market wishes to reduce consumption from the equilibrium quantity $\bar{Q}^*_0$ to $\bar{Q}^*_1$ in Fig. VI. He manipulates $\gamma$ to shift the long-run demand curve downwards until it passes through the intersection of LRMC with the vertical line through $\bar{Q}^*_1$. The new long-run demand curve is $D^*_1 D^*_1$. $Q^*$ is fixed at $\bar{Q}^*_0$ in the short-run. The market will shift discretely to the point $E_1$, the intersection of MC with the short-run demand curve $D_1 D_1$ passing through $\bar{Q}^*_0$ on the new long-run demand curve $D^*_1 D^*_1$. After this discrete jump there is a smooth transition along MC to $E_2$.

Under monopoly, the $D^* D^*$ curve must also shift downwards. However, the AA curve may shift upwards or downwards according to:

\[
\frac{\delta P}{\delta \gamma} = \frac{1}{\beta} - \frac{1}{\beta} \frac{\left( \phi + r - \frac{\lambda_2}{\psi + \frac{r}{\psi}} \right)}{\left( \phi + \frac{r}{\psi} \right)} \left( 1 - \frac{m_2}{n_2} \right) \frac{dq^*}{dy} > 0.
\]

Since $\frac{dq^*}{dy} > 0$, from equation (19), i.e. a fall in $\gamma$ will reduce steady state consumption, and that force exerts upward pressure on the AA curve. However, from equations (5) and (19) we have:

\[
\frac{dP}{dy} = \frac{1}{\beta} \left( 1 - a \right) \frac{d\tilde{q}}{dy} > 0
\]

a fall in $\gamma$ must reduce steady-state price. Let us assume
first of all that the short-run movement in \( P \) is in the same
direction as that of the long-run change, i.e. that the AA curve
shifts downwards. The condition for this is:

\[
\left[ \frac{2(1-a)(\phi+r)+ar}{\beta(\phi+r)} \right] - \alpha \left[ \frac{\phi+r-\lambda_2}{\alpha(\phi+r)} \right] > 0
\]  

(29)

(The downward shift in AA cannot of course exceed the
downward shift in \( D^*D^* \), otherwise \( \bar{Q}^* \) would rise). The policy-
maker manipulates \( \gamma \) so as to choose the long-run \( D^*_2D^*_2 \) and
\( A^2A^2 \) curves which intersect on the vertical line through \( \bar{Q}^*_1 \) at
the point \( E_4 \) in Fig. VII. Such a point must exist since \( \bar{Q}^* \) is
continuous in \( \gamma \) - see (21). \( Q^* \) is fixed in the short-run, and
the market will jump to \( E_3 \), the intersection of \( A^2A^2 \) with the
short-run demand curve passing through \( \bar{Q}^*_0 \) on \( D^*_2D^*_2 \). The system
will then move smoothly down \( A^2A^2 \) to \( E_4 \).

Under competition, price is constant (equal to marginal cost)
as between the two long-run equilibria. Under monopoly, it must, as
we have seen, fall. Hence the \( D^*_2D^*_2 \) curve of Fig. VII lies
below the \( D^*_1D^*_1 \) curve of Fig. VI. Moreover, the \( D^*_2D^*_2 \) curve of
Fig. VII lies uniformly below the \( D^*_1D^*_1 \) curve of Fig. VI.

Provided the price-elasticity of demand on \( D^*_1D^*_1 \) at \( E_1 \) is less than
unity, then expenditure at \( E_3 \) is less than at \( E_1 \). Draw an
imaginary horizontal line through \( E_3 \) and extend it to cut \( D^*_1D^*_1 \).
At that intersection, if demand is price inelastic at \( E_1 \), expenditure
will be less than at \( E_1 \), and clearly greater than at \( E_3 \). Hence
expenditure at \( E_3 \) is less than at \( E_1 \), and declines continuously
to \( E_4 \), at which it is clearly less than at \( E_2 \). Under monopoly
(provided AA shifts downwards) supply-side policies result in less drug-related crime, both long-run and transitory, than under competition.

If the AA curve shifts upwards, then the short-run response is ambiguous. In that case it is conceivable that short-run price might rise and that total expenditure might for a time be greater under monopoly than under competition. However, long-run price must unambiguously fall under monopoly, and it is constant under competition at the same output. Hence the integral over all time of the value of drug-related crime must be less under monopoly. From a comparison of Figs. VI and VII with Fig. IV, it is obvious that, for a given reduction in quantity, demand-directed policies result in less crime than supply-directed policies, not only in the long-run but also in the transition from one equilibrium to another, whether monopoly or competition prevails.
V. BENEFICIAL ADDICTION

Fig. VIII shows the phase-diagram. Since $\alpha$ is negative, $QQ$ slopes downwards, as does $S^0S^0$, which is flatter than $QQ$. Again because $\alpha$ is negative, the monopolists' long-run equilibrium will, except if $r$ is zero or $\phi$ infinite, occur to the right of the textbook equilibrium, i.e. he will produce an output greater than that at which $LRMR$ equals $LRMC$. If he were producing at that equality he could always at a trivial loss of long-run profit, substantially increase his short-run profit by dropping his price along the short-run demand curve (which is flatter than the long-run demand curve), thereby keeping price for a time above that obtaining along the long-run curve. His equilibrium will occur where the gain in short-run profit from this activity is just offset by the present value of the loss in long-run profit.

Will the beneficent monopolist ever produce as much as the competitive market? No. The competitive market will produce where marginal cost equals price:

\begin{equation}
\tilde{Q}^* = \frac{\frac{\gamma}{\beta} - \theta}{\frac{1}{\beta}(1-\alpha)}
\end{equation}

The monopolist will produce where:

\begin{equation}
\bar{Q}^* = \frac{\frac{\gamma}{\beta} - \theta}{\left[\frac{1}{\beta}(1-\alpha) + \frac{1}{\beta}(\phi+r-\alpha\phi)\right]}
\end{equation}
I.e. he will never make long-run absolute losses.

However, if $Q$ is sufficiently small he will produce where marginal revenue is negative, as equation (19) shows.

A rise in marginal cost $\theta$ will shift $S^0S^0$ down at $\bar{Q}^*$ by:

$$
\frac{\delta Q}{\delta \theta} = - (1 - \frac{m_2}{n_2}) \{ \frac{\beta}{(2-\alpha)} \} < 0
$$

and there will be a discrete movement from $E_0$ to $E_1$ on $S^1S^1$. $Q$ falls below its new long-run equilibrium level and climbs back up $S^1S^1$ to $E_2$.

The slope of the AA curve in price quantity space is upward. Suppose we are at $E_1$ on $S^1S^1$, heading for $E_2$. $Q$ is rising (a movement down the short-run demand curve). $Q^*$ is falling causing a rightward shift of the short-run demand curve ($\alpha < 0$). The slope of AA is:

$$
\frac{\delta P}{\delta Q} = - \frac{1}{\beta} \left( 1 - \frac{\delta r - \lambda}{\delta r} \right) > 0
$$

We are at $E_1$ on $S^1S^1$, heading for $E_2$. $Q$ is rising, we are moving down the short-run demand curves and this exerts a downward pressure on price. $Q^*$ is falling, and since $\alpha$ is negative this exerts an upward pressure on price (this shifts the short-run demand curves rightward). As in the maleficient case the influence of $Q^*$ dominates and price rises. Fig.IX illustrates the AA curve.
A rise in $\delta$ will shift the $AA$ curve upwards to $A'A'$. There will be a discrete jump to $E_1$. Since quantity overshoots, price undershoots, and thereafter a smooth movement up $A'A'$ to $E_2$ occurs. Again, the higher the initial price the higher the value of the monopoly right. The reader is left to draw the remaining inferences.
APPENDIX: ROOTS, SOLUTION, AND STABLE PATH.

The roots of the system of equations (14) and (2) are obtained from the characteristic equation:

\[
(i) \quad \begin{vmatrix} a_{11} - \lambda & a_{12} \\ a_{21} & a_{22} - \lambda \end{vmatrix} = \lambda^2 - \text{tr}(A) + \text{det}(A).
\]

Hence

\[
(ii) \quad \lambda_1, \lambda_2 = \frac{1}{2} \left\{ \text{tr}(A) \pm \sqrt{\text{tr}(A)^2 - 4 \text{det}(A)} \right\}
= \frac{1}{2} \left\{ r \pm \sqrt{r^2 - 4\phi(a-1) + r (\frac{a}{2} - 1)} \right\}
\]

Hence \( \lambda_1 > 0, \lambda_2 < 0. \)

The solutions of (13) and (2) are:

\[
(iii) \quad Q(t) = m_1 e^{\lambda_1 t} + m_2 e^{\lambda_2 t} + \bar{Q}
\]

and

\[
(iv) \quad Q^*(t) = n_1 e^{\lambda_1 t} + n_2 e^{\lambda_2 t} + \bar{Q}^*.
\]

where the \( m_1 \) and \( n_1 \) reflect the initial conditions. Unless the initial conditions are so chosen that \( m_1 = n_1 = 0 \), then the terms in the positive root \( \lambda_1 \) will eventually dominate and the system will shoot off. Setting \( m_1 \) and \( n_1 \) at zero, dividing (iii) by (iv), and remembering that \( \bar{Q}^* = \bar{Q} \), then we may solve for \( Q(t) \) as a function of \( Q^*(t) \).
(v) \[ Q(t) = (1 - \frac{m_2}{n_2}) \bar{Q}^* + \frac{m_2}{n_2} Q^* \]

We can solve for \( \frac{m_2}{n_2} \) from the characteristic vector:

(vi) \[
\begin{bmatrix}
  a_{11} - \lambda_2 & a_{12} \\
  a_{21} & a_{22} - \lambda_2
\end{bmatrix}
\begin{bmatrix}
  m_2 \\
  n_2
\end{bmatrix}
=
\begin{bmatrix}
  0 \\
  0
\end{bmatrix}
\]

(vii) \[
\begin{bmatrix}
  a_{11} - \lambda_2 & a_{12} \\
  a_{21} & a_{22} - \lambda_2
\end{bmatrix}
\begin{bmatrix}
  m_2 \\
  n_2
\end{bmatrix}
=
\begin{bmatrix}
  0 \\
  0
\end{bmatrix}
\]

From (vi):

(viii) \[
\frac{m_2}{n_2} = \frac{-a_{12}}{a_{11} - \lambda_2} = \frac{\alpha(\phi+\delta r)}{(\phi+r)-\lambda_2}
\]
FOOTNOTES

(1) After the work reported here had been done, I discovered the paper of Brennan, Buchanan and Lee (B.B.L.), whose idea is similar to mine and upon whose paper I comment elsewhere. B.B.L. try to solve a dynamic problem employing the method of comparative statics. In consequence all of their results but one are contradicted in this paper. I indicate in footnotes where our results differ.

(2) The constraint is:

\[ \lambda \phi(Q - Q^*) - \lambda Q^* \]

Integration by parts yields:

\[ \int -\lambda Q^* \, dt = [\lambda Q^*] + \int \lambda Q^* \, dt \]

which is then substituted into the constraint, the first term on the right-hand side being ignored.

(3) B.B.L. claim (Proposition 3, p. 541) that:

\[ \frac{dp}{dp_0} < 0 \]
where $\hat{P}$ is long-run profit-maximizing price and $P_0$ any arbitrary initial price. $\hat{P}$ is a continuously differentiable function of $P_0$, of which there is an infinity. Hence B.B.L. claim, for a partial equilibrium Marshallian model, that there exists in general an infinity of equilibria. Our result contradicts this extraordinary claim.

(4) Uniqueness and stability of the monopolist's time-path render otiose B.B.L.'s conjectures (pp. 542 et. seq.) about oscillating price-strategies.

(5) This is a contradiction of B.B.L.'s Proposition 2, (p.540).

(6) To enable us to make the comparisons of this section, we must assume that the monopolist and the competitive market are, in the initial long-run equilibrium, producing the same output under identical demand conditions. Hence we must make the artificial assumption that marginal costs differ sufficiently to induce them so to do.
REFERENCES


