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Abstract

Myopic use of mind-altering substances is proposed to be equal to the product of the user's current levels of relative-deprivation feeling and substance-tolerance. If initially this product is sufficiently large the user is trapped in a deprivation-use-addiction vicious cycle. There may be a relatively high addiction and socioeconomic position steady state and a relatively low one. If the users are initially located in the high steady state, an increase in treatment is clearly socially desirable. In contrast, the possible improvement of users' socioeconomic position from increasing law-enforcement or socioeconomic opportunities might be dominated by a rise in users' addiction level. (*JEL* Classification: D91, I12)

Keywords: Relative deprivation, myopia, substance abuse, addiction

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1. Introduction

Although a direct association between mind-altering substance abuse and entrenched socioeconomic relative deprivation has not yet been tested a supportive indirect evidence is provided through an intervening factor — depression.¹ The empirical findings of Eibner *et al.* (2004) suggest that relative deprivation is associated with an increased likelihood of depression and the empirical studies of Aseltine *et al.* (1998), Swendsen and Merikangas (2000), Sitharthan *et al.* (2001) and Langbehn *et al.* (2006) reveal a co-existence of depression and addiction to mind-altering substances. The analysis of the implications of the possible relationship between the use of such addictive substances and entrenched relative deprivation for the individual user and for public-policy making is the objective of this paper.

We define relative deprivation as the individual's feeling of discontent stemming from a discrepancy between her perception of her fair socioeconomic position and her actual socioeconomic position: the greater the discrepancy between the individual's perceived fair position and actual position the more intense her feeling of relative deprivation. When relative deprivation is not temporary but entrenched the accumulated feeling of discontent might lead to depression. This definition, which underlies the proposed analysis, is based on Maslow's (1954) motivation theory with the distinction that the individual's distance from her perceived fair position, rather than the aspired position, is the yardstick for measuring her deprivation. It also bears resemblance to Sen's (1973) interpretation of the Gini coefficient as a measure of aggregate depression and to

¹ Causality tests may ideally be performed with panel data on individuals' consumption of mind altering substances and relative deprivation levels measured, as suggested by Yitzhaki (1979) and theoretically discussed in Ebert and Moyes (2000), by an index of the income gaps between them and more affluent people in their reference groups. Correlation may also be computed with cross-country observations on aggregate use of mind-altering substances and income, wealth and political inequalities.

Yitzhaki's (1979) use of the absolute Gini coefficient as an aggregate measure of relative deprivation where the normalized sum of the differences between one's income and the higher incomes in one's reference-group forms one's index of own relative deprivation.

Although unwelcome, entrenched relative deprivation can lead to positive outcomes: some (possibly resolute, farsighted, creative, moral) people harness relative deprivation to increase productive effort and attain significant achievements. In contrast, entrenched relative deprivation, notably when associated with race (Blau and Blau, 1982), causes some people to channel effort to aggression and crime. Casual observation suggests that some other victims, or self-perceived victims, of entrenched relative deprivation use strong mind-altering substances for relieving their depression and engage in stigmatizing and illegal income-generating activities to finance this expensive, productivity and trust-worthy-reputation-eroding type of consumption.

The relatively deprived individuals resorting to the consumption of strong mind-altering-substances are the subjects of our analysis. Their use of strong mind-altering substances temporarily relieves their suffering but might directly (through partial incapacitation) and indirectly (through induced engagement in stigmatizing and illegal jobs) erode their socioeconomic position and, in turn, intensify their future relative-deprivation suffering, increase their substance-dependence level and external costs for the society.

Unlike the Becker-Murphy (1988) type of rational-addiction models and, to a lesser extent, the O'Donoghue and Rabin's (2000) variant with time-inconsistent preferences, our analysis of relative deprivation and addiction is based on the paradigm of maximum immediate relief. We propose that maximizing immediate relief is an urgent

objective for relative-deprivation victims addicted to strong mind-altering substances. We argue that during the consumption process of strong mind-altering substances these users are likely to lose sight of intertemporal considerations and be overcome by an urge to attain maximum immediate relief. Every moment they use, in complete disregard of the implications for their future well-being, a quantity that minimizes their current suffering.²

The paper is structured as follows. Following a derivation of the immediately most relieving level of substance use, section 2 presents a structural system of interrelationships between deprivation, consumption of, and addiction to, a strong mind-altering substance and articulates the condition for the existence of a deprivation-addiction vicious cycle. Section 3 displays the possible co-evolutions of the individual's socioeconomic position and addiction in phase-plane diagrams. Section 4 analyzes the effectiveness of treatment and law-enforcement, as well as the effectiveness of a public effort in improving the socioeconomic opportunities for relative-deprivation sufferers.

2. Model: myopic use and vicious cycle

The description of the possible interrelationships between the user's socioeconomic position, her relative deprivation, her consumption level of, and addiction to, a strong mind-altering substance, and her earnings employs the following notations:

S_t the user's actual socioeconomic position at time t - a combined index of her current socioeconomic conditions ($S_t \in R_+$);

S_t^F the user's perception of her fair socioeconomic position at time t ;

D_t the intensity of the user's suffering from relative deprivation at t ;

² Using O'Donoghue and Rabin's (2000) terminology, their β is equal to zero.

- q_t the user's consumption of the mind-altering substance at t ;
- q_t^o the most relieving consumption of the mind-altering substance at t ;
- \hat{q} a non-negative scalar indicating the upper-bound of a non-addictive level of consumption of the mind-altering substance;
- \bar{q} a non-negative scalar indicating the maximum socially admissible level of consumption of the mind-altering substance — the critical level of use beyond which the substance is perceived by the society to be abused;³
- \tilde{q}_t the user's extent of substance abuse at t ;
- p a positive scalar indicating a time-invariant and flat (for simplicity) price of the mind-altering substance;
- c a positive scalar indicating the user's time-invariant instantaneous spending on the consumption of goods (excluding the mind-altering substance);
- A_t the user's addiction level (i.e., stock of addictive capital) at t ;
- m_t the user's position-maturation rate (the natural rate of improvement of her socioeconomic position through experience and seniority) at t ;
- ψ a positive scalar indicating the user's intrinsic rate of position-maturation
- μ a positive scalar denoting the user's marginal utility (satisfaction) from status;
- α a positive scalar indicating the marginal effect of the addictive consumption level on the rate of the gross increase of the user's addictive capital stock;
- β a positive scalar indicating the rate of depreciation of the user's addictive capital stock — the rehabilitation coefficient;

³ While $\bar{q} > 0$ in the case of alcohol (e.g., social drinking), it is likely that $\bar{q} = 0$ in the case of strong mind-altering drugs such as opium, heroine and cocaine.

- γ a positive scalar denoting the user's substance-tolerance coefficient;
- δ_1 a positive scalar indicating the direct marginal degradation (constant, for simplicity) of the user's socioeconomic position caused by her consumption of the mind-altering substance through partial incapacitation;
- δ_2 a positive scalar indicating the indirect marginal degradation (constant, for simplicity) of the user's socioeconomic position caused by her consumption of the mind-altering substance through loss of reputation from engagement in illegal and/or stigmatizing income-generating activities, sentencing and punishment;
- y_t^l the user's legal income at t;
- r a positive scalar indicating a time-invariant and flat (for simplicity) rate of return on the user's socioeconomic position in legal, non-stigmatizing activities; and
- y_t^i the user's income at t from illegal and/or stigmatizing activities.

In our description of entrenched relative deprivation the user's perception of her fair socioeconomic position is persistent (i.e., $S_t^F = S^F$ for every t) and is not downwardly biased. Furthermore, the returns to experience and seniority decrease and hence the user's position-maturation rate diminishes when her actual socioeconomic position converges to her perceived fair socioeconomic position with $\lim_{S \rightarrow 0} m_t = \psi$ and, in view of her non-downwardly biased perception, with $\lim_{S \rightarrow S^F} m_t = 0$. We display these assumptions by the following explicit form

$$m_t = \psi \left[1 - \frac{S_t}{S^F} \right] \quad (1)$$

which rules out perks — the user cannot attain a greater socioeconomic position than her self-perceived fair one at every instance (i.e., $S_t \leq S^F$).

In assessing the intensity of the individual's suffering from entrenched relative deprivation we make the following assumptions. The individual derives utility from consuming goods (c) and status — actual socioeconomic position. Since we assume, as indicated in equation (4), that incomes from illegal and stigmatizing activities bridge the gap between spending and income generated by legal and non-stigmatizing activities, we take the individual's consumption of goods to be independent of her actual socioeconomic position and time-invariant (e.g., set at a level that matches her self-perceived fair socioeconomic position). We also take the individual's utility from consuming goods to be separable from her utility from status. Consequently, the individual's utility from consuming goods can be eliminated from her relative-deprivation function. For tractability, we take the marginal utility from status to be constant (μ). The individual's instantaneous suffering from relative deprivation is intensified by the discrepancy between the utility from her perception of her fair socioeconomic position (μS^F) and the utility from her actual socioeconomic position (μS_t). It is convexly moderated by her instantaneous consumption of the mind-altering substance. However, the moderating effect of the substance-consumption diminishes with the individual's level of tolerance to the substance — the product of her substance-tolerance coefficient and stock of addictive capital. Consistently with these assumptions, we display the intensity of the user's suffering from relative deprivation at t by:

$$D_t = \left[\mu(S^F - S_t) - \frac{q_t}{\gamma A_t} \right]^2. \quad (2)$$

PROPOSITION 1: The myopically most relieving mind-altering-substance consumption is given by

$$q_t^o = \gamma A_t \mu(S^F - S_t). \quad (3)$$

(See Appendix A for proof.)

The myopically most relieving mind-altering-substance consumption is equal to the product of the individual's current substance-tolerance level (γA_t) and her current discontent level ($\mu(S^F - S_t)$). Correspondingly, a myopic user is defined as a person consuming q_t^o every instance.

It is observed that many users of strong mind-altering substances participate in illegal and/or stigmatizing income-generating activities.⁴ We assume that the myopic user's gap between spending and earning from legal, non-stigmatizing sources is bridged by an income generated by illegal and/or stigmatizing activities:

$$y_t^{il} = c + pq_t^o - y_t^l \quad (4)$$

where

$$y_t^l = rS_t. \quad (5)$$

⁴ In some western and southern states of the United States the majority of the inmates are addicts who financed their consumption of illicit drugs by stealing and prostitution.

The rate of accumulation of the myopic user's addictive capital stock rises with her consumption beyond the non-addictive level ($q_t^o - \hat{q}$) and declines with the rehabilitation coefficient β :

$$\dot{A}_t = [\alpha(q_t^o - \hat{q}) - \beta]A_t \quad (6)$$

where $A_t > 0$ for every t .

The myopic user's socioeconomic position improves in accordance with her position-maturation rate and deteriorates with her extents of substance abuse and engagement in illegal and stigmatizing income-generating activities:

$$\dot{S}_t = m_t S_t - \delta_1 \tilde{q}_t - \delta_2 y_t^{il} \quad (7)$$

where her position-maturation rate is given by (1) and her instantaneous extent of substance abuse is

$$\tilde{q}_t = q_t^o - \bar{q}. \quad (8)$$

PROPOSITION 2: If $S_0 < S^F$ and the initial myopically most relieving mind-altering-substance consumption ($q_0^o = \gamma A_0 \mu(S^F - S_0)$) exceeds $\hat{q} + \beta/\alpha$ and $[\delta_1 \bar{q} + \delta_2 (rS_0 - c) + \psi(1 - \frac{S_0}{S^F})S_0]/(\delta_1 + \delta_2 p)$, then the myopic user is trapped in a deprivation-use-addiction vicious cycle.

(See Appendix A for proof and discussion.)

3. The phase portraits of socioeconomic position and addiction

The structural system presented in the previous section can be reduced (by substitution) into the myopic user's motion-equations of addiction and socioeconomic position:

$$\dot{A}_t = \{\alpha[\gamma\mu(S^F - S_t)A_t - \hat{q}] - \beta\}A_t \quad (9)$$

$$\dot{S}_t = \psi(1 - \frac{S_t}{S^F})S_t + \delta_2 r S_t - (\delta_1 + \delta_2 p)\gamma\mu(S^F - S_t)A_t + \delta_1 \bar{q} - \delta_2 c. \quad (10)$$

As demonstrated in Appendix B, the steady-state (SS) levels of the myopic user's socioeconomic position and addiction are:

$$S_{SS}^{1,2} = 0.5(S^F / \psi) \{ (\psi + \delta_2 r) \pm \underbrace{[(\psi + \delta_2 r)^2 - 4((\delta_1 + \delta_2 p)(\hat{q} + \beta / \alpha) + \delta_2 c - \delta_1 \bar{q}) / (S^F / \psi)]^{0.5}}_{\Delta} \} \quad (11)$$

and

$$A_{SS}^{1,2} = \frac{\beta + \alpha \hat{q}}{\alpha \gamma \mu (S^F - S_{SS}^{1,2})}. \quad (12)$$

PROPOSITION 3: If the maximum socially admissible level of consumption of the mind-altering substance (\bar{q}) is larger than $\frac{(\delta_1 + \delta_2 p)(\hat{q} + \beta / \alpha) + \delta_2 c - 0.25(\psi + \delta_2 r)^2}{\delta_1}$

but smaller than $\frac{(\delta_1 + \delta_2 p)(\hat{q} + \beta / \alpha) + \delta_2 c}{\delta_1}$, then two internal real steady states exist.

(See Appendix A for proof and Figure 1 for illustration.)

Insert Figure 1 here.

As shown in Appendix B and illustrated in Figure 1, $\frac{d\dot{A}}{dS} > 0$, $\frac{d\dot{S}}{dA} = < 0$.

Consequently, the steady state with the relatively low socioeconomic position and level of addiction (hereafter, the low steady state) is a saddle point, whereas the steady state with the higher socioeconomic position and level of addiction (hereafter, the high steady state) is an asymptotically stable spiral. The low steady state is approachable from south-

west by a trajectory displaying increasing addiction, yet improving socioeconomic position. It is also approachable from north-east by a trajectory displaying decreasing addiction, but deteriorating socioeconomic position.

As also demonstrated in the Appendix B (equation B13), the intercept of the isocline $\dot{A}=0$ is greater, equal to, or smaller than the intercept of the isocline $\dot{S}=0$ when \bar{q} is smaller, equal to, or greater than $\{(\delta_1 + \delta_2 p)[\hat{q} + (\beta/\alpha)] + \delta_2 c\} / \delta_1$. Recalling Proposition 3, an internal steady state does not exist when the intercept of the isocline $\dot{S}=0$ is at least as large as the intercept of the isocline $\dot{A}=0$. Consequently, the case of a unique internal steady state ($\Delta=0$) is depicted by the tangency point between the isoclines, as displayed by Figure 2. It is a saddle point with $S_{SS} = 0.5(1 + \delta_2 r / \psi)S^F$ and

$$A_{SS} = \frac{\beta + \alpha \hat{q}}{\alpha \gamma \mu [1 - 0.5(1 + \delta_2 r / \psi)] S^F}.$$

Insert Figure 2 here.

If the maximum socially admissible level of consumption of the mind-altering substance is equal to the upper-bound indicated in Proposition 3, $\{(\delta_1 + \delta_2 p)[\hat{q} + (\beta/\alpha)] + \delta_2 c\} / \delta_1$, there exists an asymptotically unstable corner steady state as displayed by Figure 3.

Insert Figure 3 here.

4. Implications for public policy

In addition to the aforementioned private costs, the consumption of illicit strong mind-altering substances generates public costs. Analyses and discussion of measures for moderating these costs have been focused on law-enforcement and treatment (cf., Gerstein *et al.*, 1994; Rydell *et al.*, 1996; Caulkins *et al.*, 1997; Crane *et al.*, 1997; Behrens *et al.*, 1997; Tragler *et al.* 2001; Levy *et al.*, 2006). In the present framework of entrenched relative deprivation and maximum immediate relief, government and public organizations can also affect the use of mind-altering substance by investing, or reducing, effort in improving the socioeconomic opportunities for myopic users. Let g_t^{TR} denote the public effort invested in treatment at t , g_t^{LE} the public effort invested in law-enforcement at t , and g_t^{SE} the public effort in improving the socioeconomic opportunities for myopic users. These policy instruments are incorporated into the model through the following assumptions.

The rate of depreciation of the user's addictive capital stock rises with the public treatment effort: $\beta(g_t^{TR})$ with $\beta' > 0$.

The price of the (illicit) mind-altering substance and the user's indirect marginal socioeconomic-position degradation (through engagement in illegal income-generating activities) caused by her consumption of this substance rise with law-enforcement effort: $p(g_t^{LE})$ and $\delta_2(g_t^{LE})$ with $p_1', \delta_2' > 0$.

The user's intrinsic position-maturation rate rises with the public investment of effort in improving socioeconomic opportunities to marginalized (and self-perceived marginalized) people: $\psi(g_t^{SE})$ with $\psi' > 0$.

Consequently,

$$\dot{A}_t = \{\alpha[\gamma\mu(S^F - S_t)A_t - \hat{q}] - \beta(g_t^{TR})\}A_t \quad (13)$$

$$\dot{S}_t = \psi(g_t^{SE})(1 - \frac{S_t}{S^F})S_t + \delta_2(g_t^{LE})[rS_t - c] - [\delta_1 + \delta_2(g_t^{LE})p(g_t^{LE})]\gamma\mu(S^F - S_t)A_t + \delta_1\bar{q}. \quad (14)$$

Suppose, for simplicity, that the costs of investing extra effort in any of the three public policy instruments are identical (i.e., the public planner's cost function is a convex function of the total effort, $C_1(g_t^{TR} + g_t^{LE} + g_t^{SE})$). Then, in addition to the user's benefit, the change in the social costs inflicted by the user should be taken into account in evaluating the relative desirability of increasing the public effort in any of the abovementioned three activities. The social costs (C_2) inflicted by the individual user stem from her engagement in illegal-income-generating activities, which rises with her level of addiction and decreases with her socioeconomic position. A cost-effective policy may be based on setting g_t^{TR} , g_t^{LE} and g_t^{SE} to minimize $\int_0^{\infty} e^{-\rho t} [C_1(g_t^{TR} + g_t^{LE} + g_t^{SE}) + C_2(y_t^{il})] dt$ subject to the addiction and socioeconomic position motion equations 13 and 14 and the illegal-earning equation $y_t^{il} = c + p\gamma A_t \mu(S^F - S_t) - rS_t$, where ρ represents the public-planner's rate of time preference. Due to the complexity of this problem we illustrate the policy implications of the equation system 13 and 14 in Figures 4, 5 and 6 by considering the two-internal-steady-state scenario indicated in Proposition 3 and by assuming that the myopic users are identical and initially located in either the high or the low steady state and that the increment in the application of any of the government's policy measures is small and designed to lead the myopic users to the nearest new steady state.⁵ We refer to a policy

⁵ In the case of the low steady state, the policy change places the user on a convergent arm.

change that brings about an improvement in the myopic users' socioeconomic position and also a moderation of their addiction level as clearly socially desirable. In other cases, the moderating effect of a reduced (due to improved socioeconomic position) relative deprivation on the use of mind-altering substances might be dominated by a substantial rise in the level of addiction. In such cases, the cost for the society from users' engagement in illegal-generating activities increases when the rise in the legal earnings (due to improved socioeconomic position) is smaller than the extra spending on the mind-altering substance.

PROPOSITION 4: If the myopic users are initially in the high steady state, an increase in treatment effort is clearly socially desirable. If the myopic users are initially in the low steady state, it is not clearly socially desirable to increase treatment effort.

(See Appendix A for proof and Figure 4 for illustration.)

Insert Figure 4 here.

PROPOSITION 5:

- i. If $(\delta'_2 p + \delta_2 p')\gamma\mu(S^F - S)A > \delta'_2(rs - c)$, an increase in law-enforcement effort lowers the myopic users' addiction level and erodes their socioeconomic position when they are initially in the high steady state, or improve their socioeconomic position and intensifies their addiction when they are initially in the low steady state.⁶

⁶ Clearly, $(\delta'_2 p + \delta_2 p')\gamma\mu(S^F - S)A > \delta'_2(rs - c)$ when the users' legal income cannot even support their consumption of all other goods.

- ii. If $(\delta'_2 p + \delta_2 p')\gamma\mu(S^F - S)A < \delta'_2(rs - c)$, an increase in law-enforcement effort improves the myopic users' socioeconomic position and intensifies their addiction when they are initially in the high steady state, or decreases the users' addiction level and deteriorates their socioeconomic position when they are initially in the low steady state.
- iii. If $(\delta'_2 p + \delta_2 p')\gamma\mu(S^F - S)A = \delta'_2(rs - c)$ an increase in law-enforcement effort does not change the myopic users' socioeconomic position and addiction level.

(See Appendix A for proof and Figure 5 for illustration.)

Insert Figure 5 here.

PROPOSITION 6: If the myopic users are initially in the high steady state an increase in the government effort in improving their socioeconomic opportunities enhances their socioeconomic position but intensifies their addiction. If the myopic users are initially in the low steady state an increase in the government effort in improving their socioeconomic opportunities moderates their addiction but deteriorates their socioeconomic position.

(See Appendix A for proof and Figure 6 for illustration.)

Insert Figure 6 here.

5. Conclusion

This paper analyzes the implications of the possible relationships between the use of strong mind-altering, addictive substances and entrenched relative deprivation for the individual users and for public policy making when immediate relief is paramount. The myopic user's consumption of mind-altering substances is proposed to be equal to the product of her current levels of relative deprivation and substance-tolerance. If initially this product is sufficiently large the myopic user is trapped in a deprivation-use-addiction vicious cycle. An initial failure to attain the perceived fair socioeconomic position makes her feel relatively deprived; which generates her addiction-intensified consumption of the mind-altering substance for obtaining immediate relief; which aggravates her addiction, intensifies her engagement in illegal and stigmatizing income-generating activities and depreciates her socioeconomic position; which heightens her feeling of relative deprivation; and so on and so forth. The analysis reveals the possible existence of an internal steady state with relatively low addiction level and socioeconomic position and an internal steady state with relatively high addiction level and socioeconomic position. If the users are initially located in the high steady state an increase in treatment is clearly socially desirable from the perspectives of the individual users' and the society. The analysis also shows that an increase in the effort to enforce laws and improve users' socioeconomic opportunities may improve the users' socioeconomic position. However, the moderating effect of a reduced relative deprivation on the use of mind-altering substances might be dominated by a substantial rise in the level of addiction. In such cases, the cost for the society from users' engagement in illegal-generating activities

increases when the rise in the legal earnings is smaller than the extra spending on the mind-altering substance.

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Appendix A: Proofs of Propositions

Proof of Proposition 1: $d^2D_t / dq_t^2 = 2/(\gamma A_t)^2 > 0$ and q_t^o is obtained by solving

$$dD_t / dq_t = 2 \frac{1}{\gamma A_t} [\mu(S^F - S_t) - \frac{q_t^o}{\gamma A_t}] = 0.$$

Proof of Proposition 2: As indicated in equation 2, an initial failure to attain the perceived fair socioeconomic position ($S_0 < S^F$) renders the user feeling relatively deprived. As indicated by equation 3, this feeling generates an addiction-intensified consumption q_0^o of the mind-altering substance by the myopic user for obtaining maximum immediate relief. As implied by equation 6, this substance-consumption level aggravates the user's addiction so long that $q_0^o > \hat{q} + \beta / \alpha$. As implied by equations 4, 5, 7 and 1, this substance-consumption level also intensifies the user's and deteriorates directly (through partial incapacitation and loss of trust-worthy reputation) and indirectly (through increased engagement in illegal and stigmatizing income-generating activities) the user's socioeconomic position so long that $q_0^o > [\delta_1 \bar{q} + \delta_2 (rS_0 - c) + \psi(1 - \frac{S_0}{S^F})S_0] / (\delta_1 + \delta_2 p)$. As indicated by equation 2, this deterioration of the user's socioeconomic heightens the user's feelings of relative deprivation, and combined with the intensified addiction increases, as can be seen from equation 3, the myopic user's mind-altering-substance consumption in the following instance ($q_1^o > q_0^o$). And so on and so forth.

Proof of proposition 3: If $\bar{q} = \frac{(\delta_1 + \delta_2 p)(\hat{q} + \beta/\alpha) + \delta_2 c}{\delta_1}$, then $\Delta = (\psi + \delta_2 r)^2$ and \exists an

interior steady state. If $\bar{q} = \frac{(\delta_1 + \delta_2 p)(\hat{q} + \beta/\alpha) + \delta_2 c - 0.25(\psi + \delta_2 r)^2}{\delta_1}$, then $\Delta = 0$ and

there exists a unique interior steady state. Recalling that Δ rises with \bar{q} , then

$$0 < \Delta < (\psi + \delta_2 r)^2 \text{ for any}$$

$$\frac{(\delta_1 + \delta_2 p)(\hat{q} + \beta/\alpha) + \delta_2 c - 0.25(\psi + \delta_2 r)^2}{\delta_1} < \bar{q} < \frac{(\delta_1 + \delta_2 p)(\hat{q} + \beta/\alpha) + \delta_2 c}{\delta_1}.$$

Proof of Proposition 4: By differentiating equations 13 and 14, $\frac{\partial \dot{A}}{\partial g^{TR}} = -\beta'A < 0$ whereas

$$\frac{\partial \dot{S}}{\partial g^{TR}} = 0. \text{ This implies, as displayed by the dashed curve in Figure 4, that an increase in}$$

treatment effort shifts the isocline $\dot{A} = 0$ downward but does not shift the isocline $\dot{S} = 0$.

While the new high steady state reveals an improvement in the user's socioeconomic position and moderation of her addiction level, the new low steady state reveals that the moderation in the user's addiction level is accompanied by a deterioration of her socioeconomic position. Thus, an increase in treatment effort is clearly socially desirable when users are initially in the high steady state, but is not clearly socially desirable when they are initially in the low steady state.

Proof of Proposition 5: By differentiating equation 14,

$$\frac{\partial \dot{S}}{\partial g^{LE}} = -(\delta_2' p + \delta_2 p') \gamma \mu (S^F - S) A + \delta_2' (rS - c). \text{ Recalling that } S_{SS} < S^F \text{ and } p_1', \delta_2' > 0,$$

then in the vicinity of steady state $\frac{\partial \dot{S}}{\partial g^{LE}} \stackrel{<}{=} 0$ as $(\delta_2' p + \delta_2 p') \gamma \mu (S^F - S) A \stackrel{>}{=} \delta_2' (rS - c)$.

Hence, an increase in g^{LE} shifts the isocline $\dot{S} = 0$ downward (upward) when

$(\delta_2' p + \delta_2 p') \gamma \mu (S^F - S) A$ is greater (smaller) than $\delta_2' (rS - c)$. As $\frac{\partial \dot{A}}{\partial g^{LE}} = 0$, the isocline

$\dot{A} = 0$ remains in its initial location.

Proof of Proposition 6: by differentiating equation 13 and 14 and recalling that $S_{SS} < S^F$

and $\psi' > 0$, $\frac{\partial \dot{A}}{\partial g^{SE}} = 0$ and $\frac{\partial \dot{S}}{\partial g^{SE}} = \psi' (1 - \frac{S_t}{S^F}) S > 0$ at the vicinity of steady state. Hence, an

increase in the government effort in improving the position-maturation rate of myopic users is represented by a shift upward of the isocline $\dot{S} = 0$ while the isocline $\dot{A} = 0$ remains in its initial location, as displayed by Figure 6.

Appendix B: Steady states and phase-plane diagram

In steady state,

$$\{\alpha \gamma \mu (S^F - S_{SS}) A_{SS} = \beta + \alpha \hat{q}\} \Rightarrow \{A_{SS} = \frac{\beta + \alpha \hat{q}}{\alpha \gamma \mu (S^F - S_{SS})}\} \quad (\text{A1})$$

$$\psi (1 - \frac{S_{SS}}{S^F}) S_{SS} + \delta_2 r S_{SS} - (\delta_1 + \delta_2 p) \gamma \mu (S^F - S_{SS}) A_{SS} + \delta_1 \bar{q} - \delta_2 c = 0 \quad (\text{A2})$$

By substituting A1 into A2:

$$\psi (1 - \frac{S_{SS}}{S^F}) S_{SS} + \delta_2 r S_{SS} - (\delta_1 + \delta_2 p) (\hat{q} + \beta / \alpha) + \delta_1 \bar{q} - \delta_2 c = 0 \quad (\text{A3})$$

which can be expressed as

$$-\frac{\psi}{S^F} S_{SS}^2 + (\psi + \delta_2 r) S_{SS} - [(\delta_1 + \delta_2 p)(\hat{q} + \beta / \alpha) + \delta_2 c - \delta_1 \bar{q}] = 0 \quad (\text{A4})$$

or, equivalently, as

$$S_{SS}^2 - (\psi + \delta_2 r)(S^F / \psi) S_{SS} + [(\delta_1 + \delta_2 p)(\hat{q} + \beta / \alpha) + \delta_2 c - \delta_1 \bar{q}](S^F / \psi) = 0. \quad (\text{A5})$$

Consequently,

$$S_{SS}^{1,2} = 0.5\{(\psi + \delta_2 r)(S^F / \psi) \pm \sqrt{[(\psi + \delta_2 r)^2 (S^F / \psi)^2 - 4[(\delta_1 + \delta_2 p)(\hat{q} + \beta / \alpha) + \delta_2 c - \delta_1 \bar{q}](S^F / \psi)]}\} \quad (\text{A6})$$

or, equivalently,

$$S_{SS}^{1,2} = 0.5(S^F / \psi)\{(\psi + \delta_2 r) \pm \sqrt{[(\psi + \delta_2 r)^2 - 4[(\delta_1 + \delta_2 p)(\hat{q} + \beta / \alpha) + \delta_2 c - \delta_1 \bar{q}]/(S^F / \psi)]}\}. \quad (\text{A7})$$

By substituting $\dot{A} = 0$ into equation 9

$$\alpha[\gamma\mu A(S^F - S) - \hat{q}] - \beta = 0 \quad (\text{A8})$$

and hence the isocline $\dot{A} = 0$ is given by

$$A|_{\dot{A}=0} = \frac{(\beta / \alpha) + \hat{q}}{\gamma\mu(S^F - S)} \quad (\text{A9})$$

and $\frac{dA}{dS}, \frac{d^2A}{dS^2} > 0$. That is, the isocline $\dot{A} = 0$ is displayed by a convex curve in the phase-

plane diagram spanned by S and A. By differentiating equation 9 with respect to S,

$\frac{d\dot{A}}{dS} > 0$ as $A = 0.5 \frac{(\beta / \alpha) + \hat{q}}{\gamma\mu(S^F - S)}$, and in recalling that $A = \frac{(\beta / \alpha) + \hat{q}}{\gamma\mu(S^F - S)}$ along the isocline

$\dot{A} = 0$, $\frac{d\dot{A}}{dS} > 0$ as displayed by the vertical arrows in the phase-plane diagrams.

By substituting $\dot{S} = 0$ into equation 10

$$\psi(1 - \frac{S}{S^F})S + \delta_2 rS - (\delta_1 + \delta_2 p)\gamma\mu(S^F - S)A + \delta_1 \bar{q} - \delta_2 c = 0. \quad (\text{A10})$$

Hence the isocline $\dot{S} = 0$ is given by

$$A|_{\dot{S}=0} = \frac{\psi(1 - \frac{S}{S^F})S + \delta_2 rS + \delta_1 \bar{q} - \delta_2 c}{(\delta_1 + \delta_2 p)\gamma\mu(S^F - S)} \quad (\text{A11})$$

Noting that $\psi(1 - \frac{S}{S^F})S \geq 0$ and peaks at $0.5S^F$ and that the numerator also includes the positive linear term, $\delta_2 rS$, then the numerator peaks at $0.5S^F < S^* < S^F$. Noting further that the denominator is positive and linearly decreasing in S , we obtain that the isocline $\dot{S} = 0$ can be displayed as an inverted U-shaped curve in the phase-plane diagram spanned by S and A which peaks at \tilde{S} greater than S^* but smaller than S^F , and satisfying (by differentiation of A11 with respect to S)

$$[(\psi + \delta_2 r) - 2\psi\tilde{S}/S^F](\delta_1 + \delta_2 p)\gamma\mu(S^F - \tilde{S}) + (\delta_1 + \delta_2 p)\gamma\mu[\psi(1 - \frac{\tilde{S}}{S^F})\tilde{S} + \delta_2 r\tilde{S} + \delta_1 \bar{q} - \delta_2 c] = 0 \quad (\text{A12})$$

By differentiating equation 10 with respect to A ,

$$\dot{S}_t = \psi(1 - \frac{S_t}{S^F})S_t + \delta_2 rS_t - (\delta_1 + \delta_2 p)\gamma\mu(S^F - S_t)A_t + \delta_1 \bar{q} - \delta_2 c$$

$\frac{d\dot{S}}{dA} = -(\delta_1 + \delta_2 p)\gamma\mu(S^F - S) < 0$ (so long that $S < S^F$) as displayed by the horizontal arrows in the phase-plane diagrams.

Note further that by substituting $S = 0$ into A9 and A11:

$$\text{Intercept (isocline } \dot{A} = 0) - \text{Intercept (isocline } \dot{S} = 0) = \frac{[(\beta/\alpha) + \hat{q}](\delta_1 + \delta_2 p) + \delta_2 c - \delta_1 \bar{q}}{(\delta_1 + \delta_2 p)\gamma\mu S^F}.$$

Hence,

$$\text{Intercept (isocline } \dot{A} = 0) - \text{Intercept (isocline } \dot{S} = 0) \stackrel{>}{<} 0 \quad (\text{A13})$$

as $\bar{q} \stackrel{<}{>} \{(\beta/\alpha) + \hat{q}\}(\delta_1 + \delta_2 p) + \delta_2 c / \delta_1$

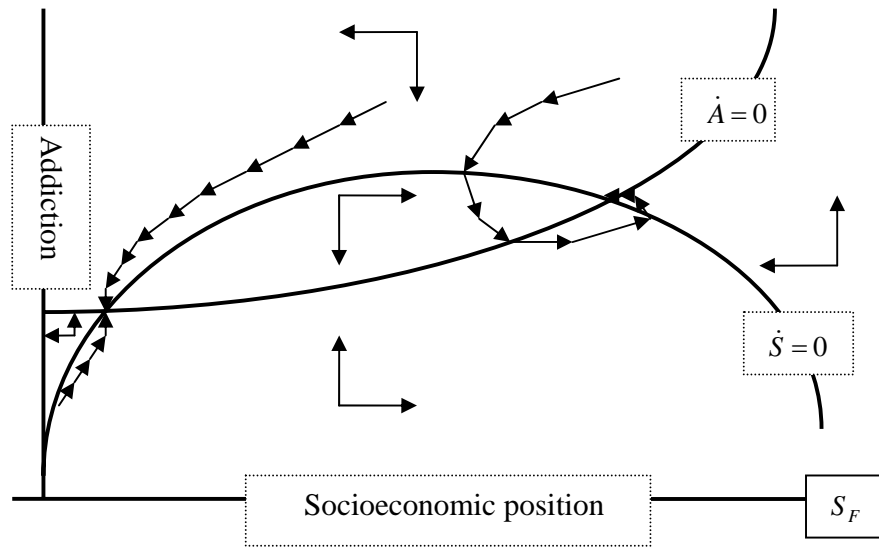


Figure 1. A phase portrait with two internal steady states

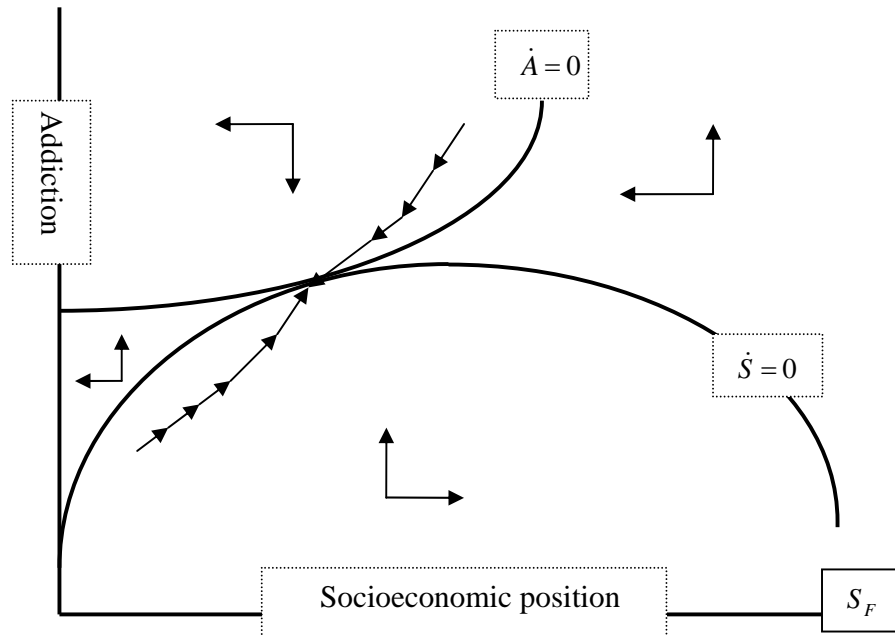


Figure 2. A phase portrait with a unique internal steady state

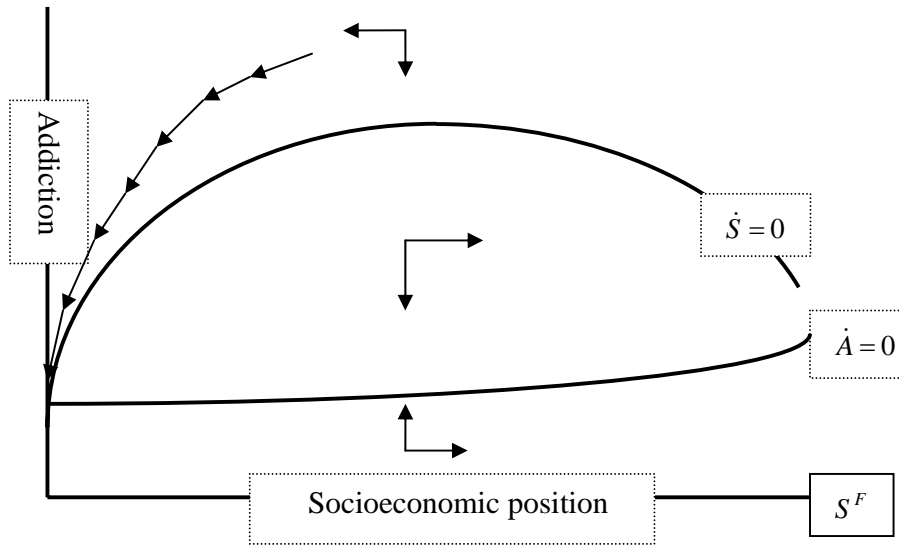


Figure 3. A phase portrait with a corner steady state

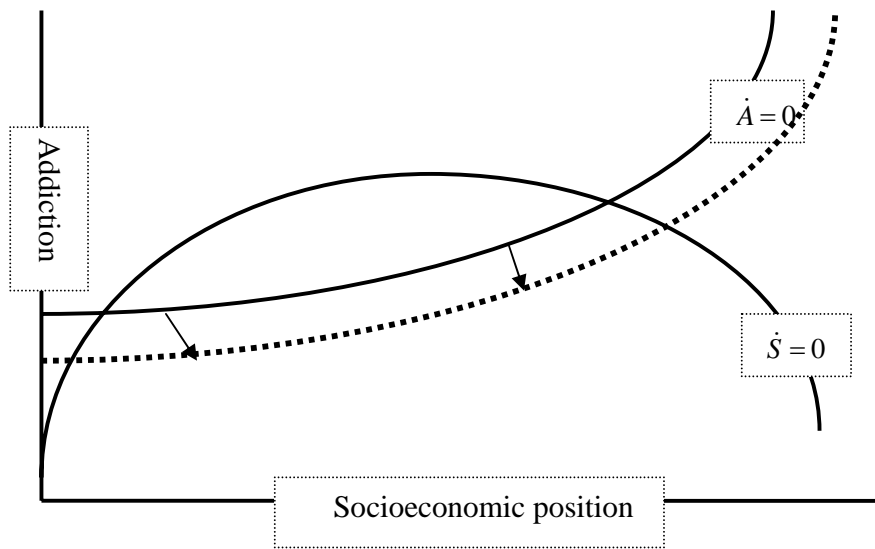


Figure 4. The effect of an increase in treatment effort

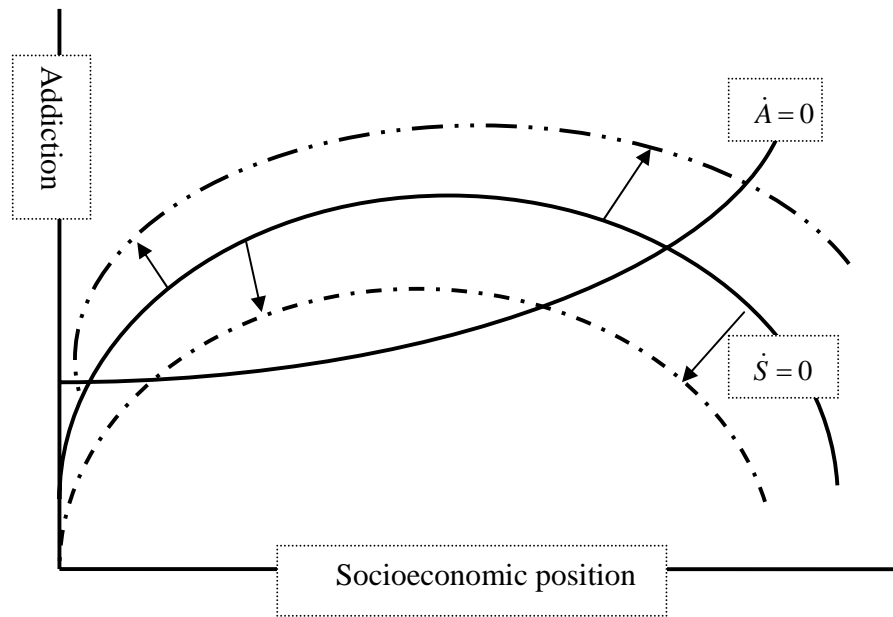


Figure 5. The effect of an increase in law-enforcement effort

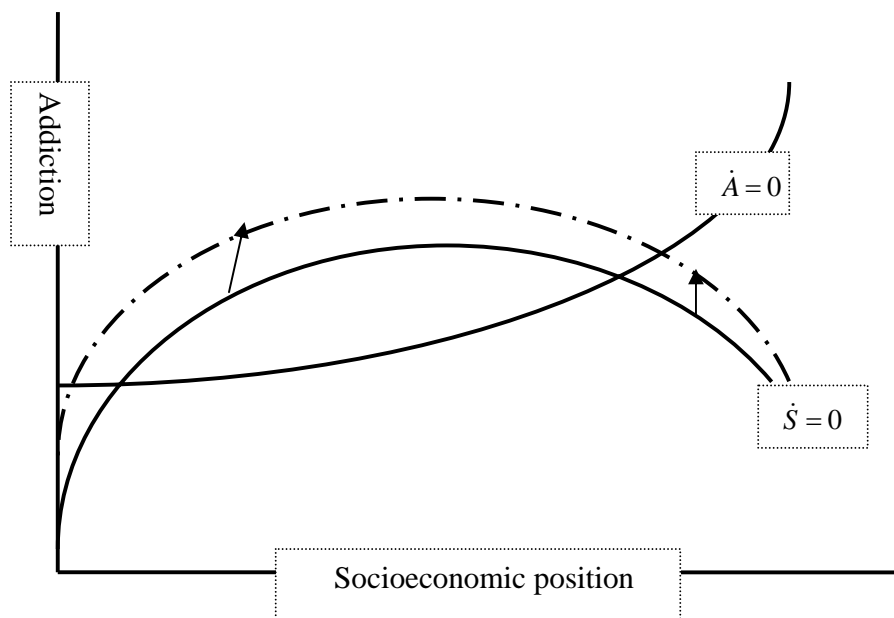


Figure 6. The effect of improving the user's socioeconomic opportunities