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The Effects of Taxation on Income-Producing Cromes with Variable Leisure Time

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I. INTRODUCTION

The existing literature on the effects of taxation on income-producing crimes lays claim to several important implications: first, that a pure income tax regime maintains the (efficient) level of crime with respect to risk neutral offenders (Png and Zolt (1989), Zolt (1989), Polinsky and Shavell (1998), Tabbach (2003)); second, that a tax regime such as the current U.S. income tax laws under which legal and criminal income are taxable but fines are nondeductible reduces criminal activities unambiguously (Png and Zolt (1989)), Zolt (1989), Tabbach (2003)); third, that a shift from a pure income tax to the current U.S. income tax laws will also reduce crime (Png and Zolt (1989), Zolt (1989), Tabbach (2003)).[1] The papers obtaining these results assume either explicitly or implicitly that the amount of time offenders devote to leisure activities is fixed, so the choice they face is strictly between legal and criminal income-producing activities.[2] The aim of this note is to examine the robustness of these results when leisure time can vary.[3] This is of interest because the assumption that leisure time is fixed is unrealistic and restrictive. Moreover, the disregard of the labor-leisure choice seems particularly odd when taxation is considered given that the criminal choice problem is constructed as a labor supply, time-allocation decision under uncertainty. As is well known, the key insights from models of taxation and labor supply hinge on the effects of taxation on the labor-leisure choice.[4] Thus, analyzing the effects of taxation on income-producing crimes while assuming that leisure time is predetermined sheds doubt on the claims made.

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[1] The latter two claims are obtained regardless of offenders' aversion or indifference to risk.

[2] See Tabbach (2003). In Png and Zolt (1989), Zolt (1989), and in Polinsky and Shavell (1998) the assumption that taxation does not affect the level of production is implicit and it is equivalent to assuming leisure time is fixed. Note that Hillman and Katz (1984) account for variable leisure time but their analysis does not deal with the effects on crime of a pure income tax regime or the current U.S. income tax laws, but only with a tax imposed solely on legal activities.

[3] Similar steps are taken with respect to the basic tax evasion model, see Andersen (1977), Baldry (1979), Pencavel (1979) and in the taxation and risk taking literature, see, for example, Cowell (1981).

[4] See, for example, Hausman (1985).

Although allowing leisure time to vary adds more realism to the model, it is not without costs. In general, unless some strong restrictions are imposed on the utility function, the effects of taxation on crime become more complex and the results more ambiguous. This occurs because variable leisure time adds to the analysis two well-known tax effects. On the one hand, taxation reduces time allocated to both legal and criminal activities because it makes leisure relatively cheaper than market activities (substitution effect). On the other hand, because taxation reduces wealth, it increases time allocated to market activities as long as leisure is a normal good (income effect). If, however, offenders are assumed to be risk neutral and the utility function is assumed to be separable, then the income effects essentially disappear and unambiguous results emerge. A pure income tax regime then will reduce both legal and criminal activities unambiguously, while the current U.S. income tax laws will reduce crime, but they will have an ambiguous effect on work. In addition, a shift from a pure income tax regime to the current U.S. income tax laws will have its expected effect of reducing crime.

The note proceeds as follows. Section II develops the model of taxation and crime with variable leisure time. Section III examines the effects of different income tax regimes on legal and criminal activities. Section IV concludes.

II. THE MODEL

To analyze the effects of taxation on crime while allowing leisure time to vary, the model found in Tabbach (2003) is employed but modified to include leisure time as an argument in the utility function. Following Schmidt and Witte (1984), it is assumed that there is no disutility associated with either legal or criminal activities, aside for the reduction in leisure time. Assume then that individuals optimally allocate their time between three activities: crime, work, and leisure, at the beginning of a given period. A fraction a of a total amount of time T, normalized to one, is allocated to criminal activities, a fraction b to legal activities, and the remainder, a fraction $1-a-b$ to leisure, where $0 \leq a \leq 1$ and $0 \leq b \leq 1$. The after-tax returns from legal activities are safe in the sense that they are given with certainty by the function $W(b,t)=(1-t)w(b)$, where t is the proportional tax in place. These returns are assumed to be marginally decreasing with time allocated to legal activities, so $W_b > 0$ and $W_{bb} < 0$, where as usual subscripts indicate partial derivatives. The after-tax returns from crime, on the other hand, are risky in the sense that they are conditional upon two states of the world: punishment at the end of the period with (subjective) probability p, and non-punishment, with (subjective) probability $1-p$, where p is constant and exogenously determined.[5] If successful, offenders receive the after-tax returns from their crime that take a monetary or monetary-like form, and are given by the function $C(a,t)=(1-t)c(a)$, assumed to be marginally decreasing with time allocated to criminal activities so $C_a > 0$ and $C_{aa} < 0$. If offenders are punished, the after-tax returns from crime are reduced by an after-tax fine, given by the function $F(a,\delta,t)=(1-\delta t)f(a)$, where δ ($0 \le \delta \le 1$) is the degree of deductibility of fines. This after-tax fine is assumed to exhibit increasing marginal severity, so $F_a > 0$ and $F_{aa} > 0$. It is also assumed that individuals have initial wealth, W^0, that is sufficient to pay any amount of fines.[6]

Assuming full compliance with the tax laws and that revenues from taxation are used to finance government spending that enters the utility function in a separable way,[7] the criminal choice problem is to choose a and b that maximize expected utility:

(1) $$E[U(W,L)] = (1-p)U(X,L) + pU(Y,L).$$

Where:

(2) $$Y = W^0 + W(b,t) + C(a,t) - F(a,t,\delta)$$

$$X = W^0 + W(b,t) + C(a,t)$$

[5] See generally Schmidt and Witte (1984). See also Png and Zolt (1989).

[6] This assumption is required to rule out the need to resort to nonmonetary sanctions, namely, imprisonment.

[7] See Tabbach (2003)

are terminal wealth at the end of the period given punishment and non-punishment respectively, $L = 1 - a - b$ is the time allocated to leisure activities, and $U(W, L)$ is the individual's von Neumann-Morgenstern utility function defined over wealth and leisure. It is assumed that $U_W > 0$, $U_{WW} = 0$ or $U_{WW} < 0$, implying risk neutrality or risk aversion respectively, and $U_L > 0$, $U_{LL} < 0$, implying decreasing marginal utility of leisure. It is also assumed that $U_{LW} = 0$, which means that the rate at which the marginal utility of leisure changes is independent of wealth and vice versa. This strong assumption amounts to assuming "separability". As will be shown, without this restriction, no comparative static result of any interest appears unambiguous. The first order conditions for a local maximum (assuming positive values for all three variables a, b, and L) are:

(3) $$H_a = \frac{\partial EU}{\partial a} = (1-p)[U_X(X,L)C_a - U_L(X,L)] + \\ + p[U_Y(Y,L)(C_a - F_a) - U_L(Y,L)] = 0$$

(4) $$H_b = \frac{\partial EU}{\partial b} = (1-p)[U_X(X,L)W_b - U_L(X,L)] + \\ + p[U_Y(Y,L)W_b - U_L(Y,L)] = 0$$

These first order conditions imply that in equilibrium offenders choose the optimal a and b, denoted, $a*$ and $b*$, simultaneously, so that the net after-tax marginal returns to time spent in legal and criminal activities is zero. These net after-tax marginal returns include the marginal disutility of decreasing leisure time, which in turn depends on both a and b. For risk neutrality and separability, these first order conditions reduce to:

(3') $$H_a = U_X(X,L)(C_a - pF_a) - U_L(X,L) = 0$$

(4') $$H_b = U_X(X,L)W_b - U_L(X,L) = 0$$

Which also imply that[8]:

[8] Note that (5) holds by virtue of risk neutrality alone.

(5) $C_a - pF_a = W_b$

It is assumed throughout that the parameters of the model take on values that result in an interior solution.[9]

III. COMPARATIVE STATIC RESULTS

A. The Effects on Crime of a Pure Income Tax Regime

Examine first the effects on crime of a pure income tax regime—a tax regime under which legal and criminal income are taxable and fines are fully deductible—for risk neutral offenders. Such a regime is captured by setting $\delta = 1$, so expected wealth becomes:

(6) $$EW = W^0 + (1-t)(w(b) + c(a) - pf(a))$$

The effects on crime of imposing a pure income tax regime or of increasing tax rates under such a regime can be investigated by differentiating the first order conditions (3') and (4'), understood to hold for $\delta = 1$, with respect to t and solving for $\frac{\partial a^*}{\partial t}$. We obtain:

(7) $$\frac{\partial a^*}{\partial t} = \frac{1}{|H|}\left[H_{ba}\frac{\partial H_b}{\partial t} - H_{bb}\frac{\partial H_a}{\partial t} \right]$$

Where:

(8) $$|H| = \begin{vmatrix} H_{aa} H_{ba} \\ H_{ab} H_{bb} \end{vmatrix}$$

[9] The second order conditions are satisfied by assuming decreasing marginal returns from legal and criminal activities, increasing marginal severity of punishment, decreasing marginal utility of leisure, and risk neutrality or risk aversion with income. See also discussion below.

The second order conditions for a local maximum imply that $|H|>0$, $H_{bb}<0$, and $H_{aa}<0$. However, to determine the sign of $\frac{\partial a^*}{\partial t}$ requires knowledge of the values of H_{ba}, H_{bb}, $\frac{\partial H_b}{\partial t}$, and $\frac{\partial H_a}{\partial t}$. Direct calculations of these terms yields:

(9) $$H_{ba}=U_{LL}(X,L)<0,$$

(10) $$H_{bb}=U_X(X,L)(1-t)^2 w''(b)+U_{LL}(X,L)<0,$$

(11) $$\frac{\partial H_b}{\partial t}=-U_X(X,L)(1-t)w'(b)<0,$$

and

(12) $$\frac{\partial H_a}{\partial t}=-U_X(X,L)(1-t)(c'(a)-pf'(a))<0.$$

Inserting these terms back to (7) yields:

(13) $$\frac{\partial a^*}{\partial t}=\frac{(U_X(X,L))^2(1-t)^2(c'(a)-pf'(a))w''(b)}{|H|}<0$$

which implies that a pure income tax regime reduces crime. The economic explanation of this result is simple. Because the relative expected returns from legal and criminal activities are not altered by a pure income tax regime, there is no substitution effect between legal and criminal activities. In addition, the risk effects of a pure income tax or its effects on the willingness of offenders to bear risk are irrelevant for risk neutral offenders.[10] Moreover, because of risk neutrality and separability, the changes in wealth associated with taxation do not affect the demand for legal, criminal, or leisure activities. The only effect that a pure income tax regime creates is a substitution effect between leisure and income-producing activities due to the fact that leisure is not taxed. This substitution effect leads to a reduction in time allocated to both legal and criminal activities and, therefore, to a reduction in the level of crime, as indicated by (13).[11]

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[10] On these effects see Tabbach (2003).

[11] The explicit effect of a pure income tax on legal activities is given in equation (B2) in appendix B.

It is important to note that this result critically depends on the assumption of separability and risk neutrality.[12] If, for example, we assume that $U_{LW} > 0$, which amounts to assuming that the marginal utility of leisure is increasing with income and vice versa, or, in other words, that the richer you become the more you value leisure at the margin, while maintaining the assumption of risk neutrality, (13) becomes (see appendix A):

(13')
$$\frac{\partial a^*}{\partial t} = \frac{-U_X(X,L)(1-t)^2 w''(b)}{|H|} \frac{\partial H_a}{\partial t}$$

Because $\frac{\partial H_a}{\partial t}$ cannot be signed (see appendix A), neither can $\frac{\partial a^*}{\partial t}$.

The reason why the effects of a pure income tax regime on risk neutral offenders become ambiguous once the assumption of separability is dropped for the assumption $U_{LW} > 0$ is rather simple. Now, in addition to the substitution effect between leisure and income-producing activities, there is also an income effect in play: taxation makes offenders, at least in expected terms, poorer. This income effect reduces the demand for leisure and therefore increases the demand for legal and criminal activities to the extent that leisure is a normal good, which is guaranteed by the assumption $U_{LW} > 0$.

As shown, a pure income tax regime does not maintain the *absolute* level of legal and criminal activities for risk neutral offenders when leisure time can vary. Seemingly, a pure income tax regime will maintain the *relative* level of legal and criminal activities, that is, the proportion $\frac{a^*}{b^*}$, because the relative expected returns from legal and criminal activities are not altered. This, however, is true in only the unlikely event that the ratio of the rates at which the expected marginal returns from legal and criminal activities change equals the ratio of the optimal time allocation between criminal and legal activities. That is, where (see appendix B):

[12] With respect to risk aversion, Tabbach (2003) shows that a pure income tax regime results in indeterminacy even when leisure time is predetermined due to conflicting risk and income effects.

(14) $$\frac{w''(b^*)}{c''(a^*) - pf''(a^*)} = \frac{a^*}{b^*}$$

If the former ratio is greater (smaller) than the latter ratio, then the relative time allocated to criminal activities will increase (decrease) and correspondingly the relative time allocated to legal activities will decrease (increase).

The economic explanation of these results is as follows: after the imposition of a pure income tax regime, the new equilibrium still requires that the expected marginal returns from legal and criminal activities will be equal, but this equality takes place for a higher value (because taxation reduces the marginal utility from market activities). Thus, the relative change in the optimal allocation of time between criminal and legal activities will depend on the rate at which the expected marginal returns from legal and criminal activities change, and it will remain the same only if that ratio equals the ratio of the optimal time allocation between criminal and legal activities, as indicated in (14).

B. The Effects on Crime of Taxing Legal and Criminal Income and Disallowing Deductions for Fines

Consider next a tax regime such as the current U.S. income tax laws under which legal and criminal income are taxable but fines are nondeductible.[13] This regime is captured by setting $\delta = 0$, so terminal wealth becomes:

(15) $$Y = W^0 + (1-t)(w(b) + c(a)) - f(a)$$

$$X = W^0 + (1-t)(w(b) + c(a))$$

The response of offenders to imposing (or increasing tax rates under) such a tax regime can be investigated by differentiating the first order condition (3') and (4'), understood to

[13] See James v. United States 366 U.S. 213 (1961) (taxable income accrues if the taxpayer acquires earnings, lawfully or unlawfully, without the consensual recognition, express or implied, of an obligation to repay and without restriction as to their disposition) and section 162(f) of the Internal Revenue Code (2003) ("no deduction shall be allowed…for any fine or similar penalty paid to the government for the violation of any law"), which codified the decision in Tank Truck Rentals, Inc. v. Commissioner 356 U.S. 30 (1958). See also generally Tabbach (2003A).

hold for $\delta = 0$, with respect to t and solving for $\frac{\partial a^*}{\partial t}$. We obtain (7), where now in addition to (8), (9) and (10) we have:

(16) $$\frac{\partial H_b}{\partial t} = -U_X(X,L)w'(b) < 0$$

and

(17) $$\frac{\partial H_a}{\partial t} = -U_X(X,L)c'(a) < 0$$

Inserting these terms to (7) yields:

(18) $$\frac{\partial a^*}{\partial t} = \frac{(U_X(X,L))^2(1-t)^2 w''(b)c'(a)}{|H|} + \frac{U_{LL}(X,L)(c'(a)-w'(b))}{|H|} < 0$$

The economic interpretation of this result is also simple. Imposing a tax regime that disallows deductions for fines creates two substitution effects. It reduces the expected returns from criminal activities proportionally more than it reduces the returns from legal activities, thus inducing offenders to substitute work for crime. In addition, the tax reduces the relative price of leisure, thus inducing offenders to substitute also leisure for crime (and work). These two substitution effects imply then that a tax regime that disallows deductions for fines will reduce crime.[14] As can be expected, this result also depends upon the assumption of separability (see appendix C). The reason again is simple. Assuming $U_{LW} > 0$ implies that leisure is a normal good, so taxation generates an income effect as well that operates to reduce the demand for leisure and increase the demand for legal and criminal activities. This income effect works in the opposite direction to the substitution effects discussed above, so the net result is indeterminate. This result also depends upon the assumption of risk neutrality (see appendix D). The reason is similar, but a little bit more complicated. Because of separability, the income effect generated by taxation does not affect the marginal utility of leisure. However, even

[14] The effect of such a tax regime on legal activities, however, is ambiguous because the two substitution effects are conflicting.

ignoring its effects on the willingness of offenders to bear risk and other potential effects, the income effect increases the marginal utility of income – assuming the utility function is concave with respect to income – thus increasing the marginal utility of market activities. This increase means that the demand for legal and criminal activities will rise. Under separability and risk aversion (with constant absolute risk aversion), the income effect works again in opposite direction to the substitution effects, so the net effect is still indeterminate.[15]

C. The Effects on Crime of Changes in the Degree of Deductibility δ (Punishment)

Lastly, analyze the effects on crime of switching from a deductibility regime to a nondeductibility regime, which amounts to analyzing the effects on crime of changes in the degree of deductibility δ. Terminal wealth for some positive δ becomes:

$$(19) \qquad Y = W^0 + (1-t)(w(b)+c(a)) - (1-\delta t)f(a)$$

$$X = W^0 + (1-t)(w(b)+c(a))$$

Differentiating the first order conditions (3') and (4'), understood to hold for $0 < \delta < 1$, with respect to δ and solving for $\frac{\partial a^*}{\partial \delta}$, we obtain:

$$(20) \qquad \frac{\partial a^*}{\partial \delta} = \frac{1}{|H|}\left[H_{ba}\frac{\partial H_b}{\partial \delta} - H_{bb}\frac{\partial H_a}{\partial \delta} \right]$$

Where now:

$$(21) \qquad \frac{\partial H_b}{\partial \delta} = 0 .$$

[15] It should be noted that if the multi-attribute absolute risk aversion function is decreasing, the income effect with respect to criminal activities itself becomes ambiguous. On the one hand, the reduction in the level of wealth increases the marginal utility of market activities, leading to an increase in the demand for crime. On the other hand, the (equal) reduction in the level of wealth reduces the willingness of offenders to bear risk, thus reducing the demand for crime. Disregarding other possible effects, these two effects alone operate in opposite directions, so the net income effect is ambiguous.

(22) $\frac{\partial H_a}{\partial \delta} = pU_X(X,L)tf'(a) > 0$

The second order conditions for a local maximum imply that $|H| > 0$ and $H_{bb} < 0$, so we can conclude that $\frac{\partial a^*}{\partial \delta} > 0$.

The economic explanation for this result is similar to the one given above and need not be repeated here. Somewhat surprisingly, this result also depends on separability and risk neutrality (unless the uncommon assumption of constant or increasing absolute risk aversion is adopted). If we assume that $U_{LW} > 0$, while maintaining risk neutrality, then:

(20') $\frac{\partial H_b}{\partial \delta} = -pU_{LY}(Y,L)tf(a) < 0$

(21') $\frac{\partial H_a}{\partial \delta} = pU_X(X,L)tf'(a) - pU_{LY}(Y,L)tf(a)$

Because $\frac{\partial H_a}{\partial \delta}$ cannot be signed (the first term is positive while the second term is negative), $\frac{\partial a^*}{\partial \delta}$ cannot be signed either. If, however, $\frac{\partial H_a}{\partial \delta} \geq 0$, which follows if $\frac{U_Y(Y,L)}{U_{YL}(Y,L)} \geq \frac{f(a)}{f'(a)}$, then because H_{ba}, $H_{bb} < 0$, we can conclude that $\frac{\partial a^*}{\partial \delta} > 0$. If, on the other hand, $\frac{\partial H_a}{\partial \delta} < 0$, which follows if $\frac{U_Y(Y,L)}{U_{YL}(Y,L)} < \frac{f(a)}{f'(a)}$, then $\frac{\partial a^*}{\partial \delta}$ will be indeterminate.

If we relax the assumption of risk neutrality and assume instead risk aversion, while maintaining the assumption of separability, then, in addition to $H_{bb} < 0$:

$$(22)\qquad \frac{\partial H_a}{\partial \delta} = pU_{YY}(Y,L)((1-t)c'(a)-(1-\delta t)f'(a))tf(a) + pU_Y(Y,L)tf'(a) > 0$$

$$(23)\qquad \frac{\partial H_b}{\partial \delta} = pU_{YY}(Y,L)(1-t)w'(b)tf(a) < 0$$

but,

$$(24)\qquad H_{ba} = (1-p)U_{XX}(X,L)(1-t)^2 c'(a)w'(b) + + pU_{YY}(Y,L)((1-t)c'(a)-(1-\delta t)f'(a))(1-t)w'(b) + U_{LL}(X,L)$$

is not signed. It is apparent that if $H_{ba} < 0$, then $\frac{\partial a^*}{\partial \delta} > 0$, but that otherwise $\frac{\partial a^*}{\partial \delta}$ cannot be signed. H_{ba} is negative, however, only if the multi-attribute function of absolute risk aversion is constant or increasing with income (see appendix E). One can conclude then that for risk aversion and separability a shift from a deductibilty regime to a nondeductibility regime will reduce crime unambiguously only if offenders exhibit constant or increasing absolute risk aversion. If, however, the common assumption of decreasing absolute risk aversion is employed, the effects of changes in the degree of deductibility cannot be unambiguously determined.

IV. CONCLUSION

The aim of this note has been to examine the effects on crime of income taxation when the amount of time allocated to leisure is variable. The results show that unless strong restrictions are placed on the utility function—in particular that offenders exhibit risk neutrality and that the utility function is separable—no clear results can be obtained. In particular, in contrast to previous results, a pure income tax regime no longer maintains the (efficient) level of crime with respect to risk neutral offenders. Similarly, the current U.S. income tax laws no longer reduce crime unambiguously. Moreover, even the effects on crime of a shift from a deductibility regime to a nondeductibility regime (at least for small values of tax rates) are no longer unambiguously determined. This occurs because with variable leisure time taxation, on the one hand, reduces time allocated to both legal and criminal activities as leisure time becomes relatively cheaper than market activities, but, on the other hand, it increases time allocated to market activities as long as leisure is a normal good. If offenders exhibit risk neutrality and the utility function is separable, then the income effects essentially disappear and the results become clear. A pure income tax regime and the current U.S. income tax laws then will reduce crime unambiguously, and so will a shift from a deductibility regime to a nondeductibility regime.

The indeterminacy associated with variable leisure time is not surprising. In part, it is similar to indeterminacies obtained in the work of Hillman and Katz (1984) and in the tax evasion literature when the labor-supply decision is endogenous.[16] This indeterminacy, however, strongly suggests the importance of empirical work that would guide policymakers in deciding between different tax regimes and between different levels of monetary sanctions and tax rates.

It is worth emphasizing, lastly, that leisure activities include both legal and criminal non-market activities. Therefore, an increase (decrease) in leisure time does not necessarily mean a decrease (increase) in the level of criminal activities in general, but rather a potential decrease (increase) in the level of income-producing crimes.

APPENDIX A

To derive (13'), insert to (7) the following terms (calculated for risk neutrality and $U_{LW} > 0$):

(A1) $$H_{bb} = U_X(X,L)(1-t)^2 w''(b) - U_{XL}(X,L)(1-t)w'(b)$$

$$-(1-p)U_{XL}(X,L)(1-t)w'(b) - pU_{YL}(Y,L)(1-t)w'(b)$$

$$+(1-p)U_{LL}(X,L) + pU_{LL}(Y,L) < 0$$

[16] See, for example, Andersen (1977), Baldry (1977), Pencavel (1979).

(A2) $$H_{ab} = -U_{XL}(X,L)(1-t)(c'(a)-pf'(a))$$

$$-(1-p)U_{XL}(X,L)(1-t)w'(b) - pU_{LY}(Y,L)(1-t)w'(b)$$

$$+(1-p)U_{LL}(X,L) + pU_{LL}(Y,L) < 0$$

(A3) $$\frac{\partial H_b}{\partial t} = -U_X(X,L)w'(b) + (1-p)U_{XL}(X,L)(w(b)+c(a))$$

$$pU_{YL}(X,L)(w(b)+c(a)-f(a))$$

(A4) $$\frac{\partial H_a}{\partial t} = -U_X(X,L)(c'(a)-pf'(a))$$

$$+(1-p)U_{XL}(X,L)(w(b)+c(a)) + pU_{YL}(Y,L)(w(b)+c(a)-f(a))$$

It is apparent that $\frac{\partial H_a}{\partial t}$ cannot be signed because the first term is negative, the second term is positive, and the third term can be negative, zero, or positive, depending on whether $w(b)+c(a)-f(a) \lesseqgtr 0$.

APPENDIX B

A pure income tax regime will have no effect on the relative time allocation between legal and criminal activities if:

(B1) $$\frac{\partial \frac{a^*}{b^*}}{\partial t} = \frac{\partial \frac{a^*}{t} b^* - \partial \frac{b^*}{t} a^*}{b^{*2}} = 0,$$

which implies that:

(B1') $$\frac{\partial \frac{a^*}{t}}{\partial \frac{b^*}{t}} = \frac{a^*}{b^*}$$

Where:

(13) $$\frac{\partial a^*}{\partial t} = \frac{(U_X(X,L))^2(1-t)^2(c'(a)-pf'(a))w''(b)}{|H|} < 0 \ ,$$

(B2) $$\frac{\partial b^*}{\partial t} = \frac{(U_X(X,L))^2(1-t)^2(c''(a)-pf''(a))w'(b)}{|H|} < 0$$

Inserting these terms back to (B1') we obtain (14).[17]

APPENDIX C

We examine the characteristics of

(7) $$\frac{\partial a^*}{\partial t} = \frac{1}{|H|}\left[H_{ba}\frac{\partial H_b}{\partial t} - H_{bb}\frac{\partial H_a}{\partial t}\right]$$

for the case of risk neutrality and $U_{LW} > 0$, assuming a tax regime with no deductions for fines is in place. Direct calculation of H_{ba}, H_{bb}, $\frac{\partial H_b}{\partial t}$, and $\frac{\partial H_a}{\partial t}$ yields:

(C1) $$H_{ab} = -U_{XL}(X,L)((1-t)c'(a) - pf'(a)) + G < 0$$

(C2) $$H_{bb} = U_X(X,L)(1-t)^2 w''(b) - U_{XL}(X,L)(1-t)w'(b) + G < 0$$

(C3) $$\frac{\partial H_a}{\partial t} = -U_X(X,L)c'(a) + K(w(b)+c(a))$$

(C4) $$\frac{\partial H_b}{\partial t} = -U_X(X,L)w'(b) + K(w(b)+c(a))$$

Where:

$$G = -KW_b + M < 0$$

$$K = (1-p)U_{XL}(X,L) + pU_{YL}(Y,L) > 0$$

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[17] The same will be true if $\frac{\partial a^*}{\partial t}$ and $\frac{\partial b^*}{\partial t}$ were calculated for $U_{LW} > 0$ instead of separability.

$$M = (1-p)U_{LL}(X,L) + pU_{LL}(Y,L) < 0$$

It is apparent that $\frac{\partial H_b}{\partial t}$, and $\frac{\partial H_a}{\partial t}$ cannot be signed (the first term in each is negative while the second term is positive), therefore it is likely that $\frac{\partial a^*}{\partial t}$ will not be signed either. Inserting these terms back to (7) yields (C5):

$$\frac{\partial a^*}{\partial t} = \frac{1}{|H|}[-U_{XL}U_X w'(b)pf'(a) + GU_X(c'(a) - w'(b)) - U_X(1-t)^2 w''(b)\frac{\partial H_a}{\partial t}]$$

The first and second terms in the square brackets are negative. The last term, however, depends on $\frac{\partial H_a}{\partial t}$, which cannot be signed. Therefore, $\frac{\partial a^*}{\partial t}$ is ambiguous.

APPENDIX D

We examine the characteristics of (7) for the case of risk aversion and separability, assuming a tax regime with no deductions for fines is in place. By the second order conditions for a local maximum $|H| > 0$ and $H_{bb} < 0$. Direct calculation of $\frac{\partial H_a}{\partial t}$, $\frac{\partial H_b}{\partial t}$, and H_{ba} reveals, however, that none can be signed.

$$\frac{\partial H_a}{\partial t} = -(1-p)U_{XX}(X,L)(1-t)c'(a)(w(b)+c(a)) - (1-p)U_X(X,L)c'(a)$$
$$- pU_{YY}(Y,L)((1-t)c'(a) - f'(a))(w(b)+c(a)) - pU_Y(Y,L)c'(a)$$

The second, third, and forth terms are negative, but the first term is positive.

$$\frac{\partial H_b}{\partial t} = -(1-p)U_{XX}(X,L)(1-t)w'(a)(w(b)+c(a)) - (1-p)U_X(X,L)w'(a)$$

$$- pU_{YY}(Y,L)(1-t)w'(b)(w(b)+c(a)) - pU_Y(Y,L)w'(a)$$

The first and third terms are positive, but the second and forth terms are negative.

(D3) $H_{ba} = (1-p)U_{XX}(X,L)C_aW_b + pU_{YY}(Y,L)(C_a - F_a)W_b + U_{LL}(X,L)$

The first and third terms are negative, while the second term is positive.

APPENDIX E

We examine the characteristics of (D3). Using the multi-attribute absolute risk aversion function $R_A(W,L) = -\frac{U_{WW}(W,L)}{U_W(W,L)}$, the first and second terms in (D3) can be rewritten as:

(E1) $-W_b((1-p)R_A(X,L)U_X(X,L)C_a + pR_Y(Y,L)U_Y(Y,L)(C_a - F_a))$

From the first order condition (3) it follows that:

(E2) $(1-p)U_X(X,L)C_a + pU_Y(Y,L)(C_a - F_a) > 0$

where the first term is positive and the second term is negative.

It follows then that for $R_A(X,L) \geq R_A(Y,L)$, that is, for constant or increasing absolute risk aversion, the terms in the brackets in (E1) are positive, so that $H_{ba} < 0$. However, if $R_A(X,L) < R_A(Y,L)$, that is, if absolute risk aversion is decreasing, then (E1) cannot be signed, so H_{ba} cannot be signed either.

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