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A Dynamic Model of Differential Human Capital and Criminal Activity

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This paper presents a dynamic model of criminal activity. Individuals are endowed with legal and criminal human capital. Potential incomes in legal and criminal sectors depend on the level of the relevant human capital, the rate of return and random shocks. Human capital can be enhanced by participating in both sectors. Legal human capital can also be enhanced through investment. Human capital is subject to depreciation. Individuals maximize expected discounted lifetime utility, which depends on consumption. The model allows analyses of the effects of recessions, imprisonment/rehabilitation scenarios, sanctions and returns to human capital. New insights, such as hysteresis in criminal behaviour, are obtained.

Introduction

Becker's seminal paper (1968) created the foundation for the economic analysis of criminal behaviour. His model, extended by Ehrlich (1973), postulates that participation in criminal activity is the result of an optimizing individual's response to incentives such as legal and illegal market opportunities. Rational economic agents decide to engage in criminal activity after comparing the financial rewards from crime with those obtained from legal work, taking into account the probabilities of apprehension and conviction and the severity of punishment. More precisely, in the Becker–Ehrlich model the individual maximizes a von Neumann–Morgenstern expected utility function, with arguments about the amount of time devoted to non-market activity (which is fixed) and the consumption of a composite market good. The individual can spend time in both the legal and illegal markets, and the real return (in terms of income or the consumption good) in each market is a monotonically increasing function of time spent in that market. With a subjective probability p, the individual is apprehended and punished, which reduces the level of income. With probability $(1-p)$, the individual escapes apprehension and keeps the income generated in both markets. Maximization of expected utility in this framework generates a first-order condition, the analysis of which leads to a number of behavioural implications. For example, an increase in the probability of apprehension and the severity of punishment reduces the incentive to participate in criminal activity, and these effects are increasing in the agent's degree of risk aversion. Similarly, a decrease in legal real wages increases the likelihood of criminal activity.

More recent models that proposed slight modifications to the Becker–Ehrlich model produce ambiguous comparative-static results. For example, Block and Heineke (1975) pointed out that, if time spent in legal and illegal activities enters the utility function directly, comparative-static analyses cease to yield definitive results under traditional preference restrictions. Schmidt and Witte (1984) showed that, in a model consisting of eight possible outcomes (e.g.

employed and not apprehended, unemployed and not apprehended, unemployed, arrested but not convicted, etc.), one cannot determine the relationship between criminal participation and the variables of interest without (in some cases) fairly strong assumptions.[1]

Witte (1980) proposed a model where both the time spent in legal and illegal markets and legal and illegal consumption are arguments of the utility function. Her model too generates ambiguous comparative-static results. Thus, both Block and Heineke (1975) and Witte (1980) conclude that, to inform policy decisions adequately, the guidance of empirical analysis is needed.

Empirical investigations have generally confirmed the predictions of the original Becker–Ehrlich model, uncovering negative impacts on crime of deterrence variables and improved economic conditions[2] (Corman and Mocan 2005; Mocan and Gittings 2003; Corman and Mocan 2000; Freeman and Rodgers 2000; Mocan and Rees 2005; Grogger 1998; Levitt 1998; Tauchen *et al*. 1994).

Although the economic models of crime have revolutionized the analysis of criminal behaviour, they have some other potential shortcomings in addition to the ones described above. For example, they do not recognize the possibility of a bi-directional causality between criminal activity and its determinants. Although the impact of potential legal earnings (legal wages) on crime is part of the traditional economic modelling of crime, previous theoretical work fails to take into account the possible influence of criminal activity on future labour market opportunities.

In addition, recently some social scientists have questioned the power and applicability of the economic paradigm to analyse criminal behaviour. Some of the explicit or implicit criticisms include the failure to incorporate individual heterogeneity into the model in a satisfactory manner. For example, Wilson (1994) stated that '[we need to understand] ... that people facing the same incentives often behave in characteristically different ways because they have been habituated to do so', while 'changing incentives will not alter the behaviour of poorly habituated people as much as we would like, at least in the near term'.[3] In other words, differences in individuals' backgrounds, especially with respect to past participation in criminal activity, necessarily affect their response to incentives. It seems important to address such heterogeneity explicitly.

In this paper we propose a new economic model of criminal behaviour, which addresses these and some other important issues in a coherent framework. The differences between our model and the existing crime models are described in the next section. Section II presents the formal model and its solution. Section III displays the investment and criminal activity policy of the individual whose behaviour is analysed. Section IV presents the dynamic optimal behaviour of the individual and responses to various scenarios. Section V concludes.

I. Improvements over Previous Models

The present model differs substantially from earlier models cited above and their more recent variants. In static crime models individuals make choices at a

particular point in time without regard for the impact of today's decision on future opportunities. Our model is dynamic, and a particular decision (e.g. participation in the criminal sector) has implications both for future decisions and for the choices available to the individual in later periods.

Flinn (1986) and Lochner (2004) also introduce dynamics in some fashion, but they formulate vastly different frameworks from the model developed in this paper. Other examples of departure from standard crime models are Zakharova (2000), who develops a two-period overlapping-generations model of gang activity; Burdett *et al*. (1999), who develop a dynamic labour market model where workers have the option to steal from another worker; Leung (1995), who formulates the recidivism behaviour of a risk-neutral wealth-maximizing agent; O'Flaherty (1998), who analyses individuals' repeated criminal decisions when facing probability of apprehension as well as wrongful punishment in an infinite horizon setting; and Imrohoroğlu *et al*. (2001) and Platania and Schlagenhauf (2000), who construct dynamic general equilibrium models that are capable of explaining the time-series behaviour of the crime rates in the United States.

In our model individuals possess two types of human capital: legal human capital, which determines expected earnings in the legal sector, and criminal human capital, which determines expected illegal earnings. The notion of investment in human capital is standard (Ben-Porath 1967; Grossman 1972; Becker 1993). On the other hand, the concept of allowing the individual to hold two types of human capital *simultaneously* within the context of a dynamic crime model has not been explored before.[4] Both types of human capital can be enhanced by participating in legal and criminal sectors, and legal capital can also be increased through investment. Thus, as the decision to allocate time to each sector depends on the level of both types of human capital, the level of human capital also depends on the extent of sector participation. This notion is similar to those developed in the labour economics literature pertaining to the simultaneity of wages and labour supply (e.g. Blinder and Weiss 1976). In this setting the endogenous relationship between differentiated human capital and participation in differentiated labour markets (legal and criminal) is analysed.

Second, in the model the individual's earnings (legal as well as illegal) depend on his human capital (legal and illegal) and on the rate of return to both types of human capital. In other words, we adopt a standard human capital earnings model, where an exogenous rate of return and endogenous human capital determine the realized earnings (along with stochastic shocks). In this framework we analyse criminal behaviour and its evolution in various scenarios, such as the impact of certainty and the severity of punishment on the acquisition of legal and illegal human capital.

Third, the model not only allows us to analyse the impact of deterrence and legal market opportunities on current criminal activity, but also permits analyses of the nature of the incarceration experience on future behaviour. This therefore is the first paper to propose an analytical approach to the effect of various treatment/punishment regimes on the post-incarceration response of optimizing individuals. In traditional crime models, recidivism (repeated criminal behaviour) is a rational response to unchanging opportunities faced by the criminal. If it is optimal for the individual to engage in criminal activity, given his environment (the return to legal and illegal activities, the cost of

punishment and the probability of apprehension), before he went to prison, it will be optimal again after he leaves prison, since the relevant constraints remain unchanged. In our model the individual may or may not engage in criminal activity after leaving prison. This is because part of the environment that affects behaviour is endogenous and is a function of human capital appreciation or depreciation while in prison.

Fourth, the dynamic structure of the model enables us to observe the multi-period behaviour of the individual, which provides additional insights unavailable from static models. For example, first-generation Becker–Ehrlich type crime models predict that an increase in the probability of unemployment in the legal sector, proxied for by an increase in the unemployment rate, increases the likelihood of entry into the illegal sector. These models postulate that this relationship between unemployment and criminal participation is symmetrical; in other words, a decrease in unemployment decreases criminal participation. However, the model we propose generates a different and novel prediction. In our model the potential exists for the individual to participate in the illegal sector during the recession, as predicted by standard theory; but, contrary to the symmetry implied by the standard model, the individual may tend to remain in the criminal sector after the recession ends. This hysteresis, or recession–crime trap, is due to simultaneous depreciation of legal human capital and the appreciation of criminal human capital during the recession: in terms of labour market opportunities, *he may not be the same person post-recession*.

Fifth, our model is capable of explaining a regularity in criminal activity. As stated by Grogger (1998),

> [t]he likelihood of committing crime typically increases with age until the late teens and then declines. This relationship is quite robust, and seems to hold up across countries, at different points in time, and largely irrespective of the way crime is measured. Although criminologists have studied this phenomenon extensively, they have yet to explain it.
>
> (Gottfredson and Hirschi 1986)

Grogger says that,

> if criminal behaviour responds to wages, then the age distribution of crime may well be a labour market phenomenon. Wages represent the opportunity cost of committing crime, and they rise steeply with age during the early part of one's career.
> (Grogger 1998, p. 757)[5]

Although the rising age–earnings profile of an individual is a reasonable explanation of the decreased propensity to engage in criminal activity as one ages, the actual mechanism and dynamics of this relationship remain unclear. The aforementioned age–earnings profile pertains to legal workers, and not to criminals. The increased age–earnings profile of an individual who has been working in the legal sector is due primarily to the marketable skills acquired through participation in this sector. Therefore, an individual who has participated exclusively in the criminal sector has not accumulated the marketable legal human capital that would provide higher legal wages later in life. An individual who has been participating jointly in both sectors can

conceivably increase his human capital over the course of his life-cycle to the level where exclusive participation in the legal sector is optimal. However, it is unrealistic to believe that such an individual, who is presumably employed in a low-skilled/low-wage legal-sector job, would have a steep age–earnings profile. Put differently, even though higher wages are expected to impact criminal participation negatively, as predicted by standard theory, it is not obvious why someone who was a criminal at a younger age, and faced a given (presumably lower) wage level, should command higher wages in the legal sector when he gets older.

Our benchmark model (explained below) provides a mechanism by which even high rates of participation in the criminal sector throughout an individual's youth can still lead to his switching to the legal sector later in life. The mechanism by which this is accomplished is the efficiency with which savings/investment are translated into legal human capital. If a participant in the illegal sector perceives that investment in legal human capital promises a sufficiently high rate of return once he switches to the legal sector, then it may be optimal for him to limit current consumption and invest in legal human capital via education; and increased legal human capital generates the switch to the legal sector.

II. The Benchmark Model

The individual maximizes expected discounted lifetime utility, which depends on consumption. There are two possible income sources, one from participation in the legal sector and the other from participation in the illegal sector. The individual is endowed with given stocks of legal and illegal human capital. Both types of human capital can be enhanced through experience in both sectors, and legal human capital can be increased by investment. Both types of human capital are subject to depreciation. Incomes from both legal and illegal sources are functions of the relevant human capitals and their respective rates of return. They are also subject to random shocks. The individual can divide his time at a given time period between legal and criminal sectors; that is, he can jointly participate in criminal and legal markets.

In each period the individual solves a two-stage dynamic stochastic optimization problem. In each period he first decides on the proportion of time to be allocated to the criminal sector (and therefore to the legal sector). Then, after the realization of income from that particular decision in that period, he decides on the optimal amount of consumption. These ideas are formalized as follows.

At each time point the individual maximizes

$$(1) \qquad E\sum_{t=0}^{\infty}\beta^t U(c_t),$$

where β is the time discount ($0<\beta<1$), c_t stands for consumption at time t, and E is the expectations operator. The utility function $U(c_t)$ depicted in (1) takes on the form depicted in equation (2), where $\sigma>1$ combines risk aversion and intertemporal elasticity of substitution:

$$U(c_t) = \frac{c_t^{1-\sigma}}{1-\sigma}. \tag{2}$$

The following holds between consumption (c_t), income (y_t) and investment in legal human capital (I_t):

$$0 \leqslant c_t \leqslant y_t, \quad I_t = y_t - c_t. \tag{3}$$

Income is determined by $y_t = \max(y_t^*, y_{\min})$ and

$$y_t^* = f_t^{cr} y_t^{cr} + (1 - f_t^{cr}) y_t^{lg}, \tag{4}$$

$$y_t^{cr} = r^{cr} h_t^{cr} + \xi_t, \tag{5}$$

$$y_t^{lg} = r^{lg} h_t^{lg} + \mu_t, \tag{6}$$

where $y_{min} > 0$ represents a lower bound on income, suggesting that welfare programmes and other types of social networks provide a positive amount of income to the individual; y_t^* stands for earned income at time t; and f^{cr} represents the fraction of time the individual spends in the criminal sector ($0 \leqslant f^{cr} \leqslant 1$). Put differently, the individual can participate in both legal and criminal sectors simultaneously, and the fraction of his time that will be allocated to each sector is a choice parameter. Income from criminal activity at time t is represented by y_t^{cr}, and $y_t{}^{lg}$ is income from legal activity; h_t^{cr}, and h_t^{lg} represent criminal and legal human capitals, respectively; r^{cr} and r^{lg} stand for the returns to criminal and legal human capitals; and ξ_t and μ_t are shocks to income with $E[\xi_t] = E[\mu_t] = 0$. We also postulate that $E[\xi_t \mu_t] = 0$, which implies that unexpected shocks to legal income are not correlated with perturbations in illegal income.

$$E[\xi_{t-i}\xi_{t-j}] = E[\mu_{t-i}\mu_{t-j}] = 0 \quad \text{for } i \neq j;$$

that is, the shocks are serially uncorrelated. They have normal distributions with standard deviations of one.

Criminal human capital evolves according to the following difference equation:

$$h_{t+1}^{cr} = f^{cr}\Psi^{cr} + (1 - f^{cr})\Psi^{lg} + (1 - \delta^{cr}) h_t^{cr}, \tag{7}$$

where Ψ^{cr} and Ψ^{lg} represent the amounts by which criminal capital is enhanced from participation in the criminal sector and legal sector, respectively, although exclusive participation in one sector is permissible. The extent of the impact on criminal capital also depends on the time spent in each sector (f^{cr} and $(1 - f^{cr})$). This means that individuals become more skilled criminals through learning-by-doing, and experience gained in the legal sector also helps them enhance their criminal capital. Criminal human capital is subject to depreciation (δ^{cr}). Note that positive Ψ^{lg} implies a lower bound on criminal capital: $h_{\min}^{cr} = \Psi^{lg}/\delta^{cr}$, which can be added to and subtracted from (7) to give another formulation for criminal capital's behaviour in (8):

$$h_{t+1}^{cr} = h_{\min}^{cr} + f^{cr}(\Psi^{cr} - \Psi^{lg}) + (1 - \delta^{cr})(h_t^{cr} - h_{\min}^{cr}). \tag{8}$$

Legal human capital evolves according to the following difference equation:

$$h^{lg}_{t+1} = f^{cr}\Omega^{cr} + (1 - f^{cr})\Omega^{lg} + (1 - \delta^{lg})h^{lg}_{t} + \lambda(I_t), \tag{9}$$

where Ω^{cr} and Ω^{lg} represent the amounts by which legal human is enhanced by participation in the criminal sector and legal sector, respectively; δ^{lg} is the rate of depreciation of legal human capital and λ is a monotone-increasing function representing the increase in legal capital due to investment.

The term $\lambda(I_t)$ in (9) provides a mechanism whereby individuals can increase their legal human capital by investment in schooling and training. The amount of legal human capital that can be acquired through investment has an upper bound of $\lambda_{\max}$, and

$$\lambda(I) = \lambda_{\max}(1 - \mathrm{e}^{-\alpha I}).$$

The parameter α determines the speed at which $\lambda(I)$ approaches $\lambda_{\max}$. Specifically, the slope of $\lambda(I)$ at $I = 0$ is given by α. The behaviour of legal human capital enhancement as a function of investment for the benchmark model is depicted in Figure A1 in the Appendix.

Note that, if an individual participates only in the legal sector but does not invest (so that $\lambda(I_t) = 0$), his legal capital will eventually grow to an upper bound of $h^{lg}_{*} = \Omega^{lg}/\delta^{lg}$. Similarly, lowest possible legal capital is $h^{lg}_{\min} = \Omega^{cr}/\delta^{lg}$.

When the individual participates in the criminal sector, he faces the likelihood of getting caught and incarcerated. The probability of incarceration depends on the skill level of the criminal, represented by his criminal capital, as well as on the extent of his criminal activity. A higher level of criminal capital makes incarceration less likely as the criminal possesses the know-how about avoiding arrest. On the other hand, if the proportion of time spent in the criminal sector (f^{cr}) rises, this increases the likelihood of getting caught. Specifically,

$$p(h^{cr}, f^{cr}) = 1 - \exp[-\eta f^{cr}/(v + h^{cr})], \tag{10}$$

where p is the probability of incarceration, η is a parameter that represents the effectiveness of the criminal justice system (larger values of η imply higher likelihood of incarceration) and v captures the impact of the individual's criminal capital on his ability to avoid incarceration. (A larger v is associated with a smaller difference in the probability of incarceration among individuals with high versus low criminal capital.) The specific shape of p for the benchmark model is displayed in Figure 1.

If the individual is incarcerated, he spends time in prison. This represents both a loss of income and a loss of utility, where the latter can be monetized. Although prison time may involve multiple periods of incarceration, there are no decisions to be made (about sector participation or investment) while in prison. Therefore, to evaluate the expected value of a decision, prison time can be compressed into a single step. More specifically, to account for the loss of income and utility resulting from being in prison, we postulate that income while in prison is represented as $y_t = y_{pris}$.

In addition, the individual may face a loss of human capital while in prison. Criminal capital may deteriorate because of a depreciation in criminal skills. Legal capital may decrease both because of depreciation of skill and because of loss of reputation resulting from a criminal record (Lott 1992b). It is possible

that time in prison will increase, rather than decrease, the level of criminal capital. This could happen if the prison culture helps the individual gain new criminal skills. To account for the change in criminal and legal human capital arising from imprisonment, we postulate that if the individual gets incarcerated, then upon leaving prison his legal human capital will be equal to

$$h_t^{lg} = \tau^{lg}(h_t^{lg} - h_{\min}^{lg}) + h_{\min}^{lg}, \tag{11}$$

where τ^{lg} captures the extent of the decrease in legal human capital resulting from incarceration ($0 \leqslant \tau^{lg} \leqslant 1$). Similarly, his criminal human capital will be

$$h_t^{cr} = \tau^{cr}(h_t^{cr} - h_{\min}^{cr}) + h_{\min}^{cr}. \tag{12}$$

Note that the loss of human capital is greater for white-collar crimes following incarceration (Lott 1992a, b); thus, we postulate that $\tau^{lg} \leqslant \tau^{cr}$. Furthermore, although in the benchmark model we take $\tau^{cr} < 1$, it could be the case that $\tau^{cr} > 1$ if the criminal culture in prison allows the individual to acquire a net gain in his criminal capital. In this case the individual would come out of prison with a higher level of criminal capital than he possessed when he entered (see Bayer *et al.* 2003 for empirical evidence). This issue is addressed below. Equation (1) is maximized over c_t and f_t^{cr} subject to all the constraints depicted in (3)–(12).

The stochastic dynamic programme described above leads to the following Bellman equation:

$$EV_t(h_t^{cr}, h_t^{lg}) = \max_{0 \leqslant f \leqslant 1} E\{\max_{0 \leqslant c \leqslant y} [U(c_t) + \beta EV_{t+1}(h_{t+1}^{cr}, h_{t+1}^{lg})]\}, \tag{13}$$

where y is a stochastic variable that depends on f^{cr} according to (4)–(6). Equation (13) describes the expected value at the present time of a given combination of human capital stock in terms of optimal participation, consumption and investment decisions plus the discounted expected value of the resultant human capital combination next period. It is well known that (13) is equivalent to the maximized value of (1), subject to the appropriate constraints. The problem is too complicated to yield a closed-form analytic solution. However, the Bellman equation in (13) can be used as the basis for accurate numerical approximations of policy (optimal allocation of time between legal and criminal sectors and consumption) for the individual for any period. A steady-state solution is found by working backward in time until a stationary solution is achieved, (i.e. until $E[V_{t+1}(h^{cr}, h^{lg})] \approx E[V_t(h^{cr}, h^{lg})] \forall h^{cr}, h^{lg}$), which permits effective time-series analysis. Once the optimal policy is found, we are able to study the behaviour of the individual under various regimes, including income, incarceration, punishment and rehabilitation. Using time-series graphs, we explore the dynamic response of the individual to changes in the relevant parameters.

We normalize the model by setting $r^{lg} = 1$. It has been shown that the hourly income from crime is higher than the comparable income from legal work (Freeman 1996, p. 31). Given that crime is intermittent (Freeman 1999), and that criminals consume a disproportionate amount of leisure in comparison to legal workers, we choose $r^{cr} = 4$ in the benchmark model. As we discuss below, results are robust to variations in these parameter values. Following the empirical evidence provided by Cox (1984) and Mincer and

Polachek (1974), we choose $\delta^{lg} = 0.03$. With respect to the discussion following equation (9), we choose $\Omega^{lg} = 5\delta^{lg} = 0.15$, so that $h^{lg}_{*}/h^{lg}_{\min} = 5$. We set $h^{lg}_{\min} = 1$, and because $h^{cr}_{\min} = \Psi^{lg}/\delta^{cr}$, this implies that $\Psi^{lg} = \delta^{cr}$. It is meaningful that the rate of depreciation in criminal capital is less than the depreciation rate of the legal capital; therefore we set $\delta^{cr} = 0.02$. This in turn implies that $\Psi^{lg} = 0.02$. We set the upper limit of human criminal human capital at 15. As $h^{cr}_{\max} = \Psi^{cr}/\delta^{cr}$, this implies that the impact on criminal human capital of participation in criminal sector (Ψ^{cr}) is 0.3. The impact on legal human capital of participation in criminal sector (Ω^{cr}) is chosen to be 0.03. This suggests that participating in crime has an impact on criminal human capital that is ten times higher than the impact on legal capital.

Following the evidence provided by Lott (1992b), we assume that going to jail depreciates legal human capital by 30% owing to reputation effects; that is, $\tau^{lg} = 0.7$ in equation (11). The depreciation in criminal human capital resulting from incapacitation is assumed lower at $\tau^{cr} = 0.95$ in (12). We set $\eta = 1.5$ and $v = 1$, which generate the apprehension probabilities shown in Figure 1 as a function of the rate of participation in the criminal sector (f^{cr}) and the level of criminal human capital. The behaviour of p is consistent with empirical apprehension probabilities. We set $\alpha = 0.6$ and $\lambda_{\max} = 0.3$, which provide the relationship between investment and legal human capital growth as depicted in Figure A1 in the Appendix. The level of the severity of punishment is captured by the level of income in prison (y_{pris}), which is set to 0.6.

The estimates of constant relative risk aversion obtained from property/liability insurance and equity pricing analyses range from 1.2 (Szpiro 1986) to 4.0 (Pindyck 1988). In the benchmark model we set σ to 1.5. Finally, we set $\beta = 0.95$. We acknowledge that there is no empirical counterpart to some of the parameters. However, it should be noted that the results are robust with respect to variation in these parameter values. Furthermore, the contribution of this paper is in the depiction of the *direction* of the movement of variables of interest, rather than their magnitudes. To the extent that this is a theoretical paper and not an empirical one, this is not a handicap. For example, we are interested in the analysis of an individual's decision to participate in criminal activity during a recession. While the timing of this decision depends on the parameter values, its direction does not.

III. Investment and Criminal Participation Policy

Figures 1, 1(a), 1(b) and 1(c) provide a general introduction to the nature of policy generated by the model with benchmark parameters. Figure 1 displays the probability of incarceration as a function of criminal capital and the fraction of time spent in the criminal sector (f^{cr}), based on equation (10). The right-most axis measures the fraction of time allocated to the criminal sector (f^{cr}), which implies that the fraction of time spent in the legal sector is $(1 - f^{cr})$. As can be seen, the probability of incarceration rises as criminal know-how, or criminal capital, declines and as the time spent in the criminal sector increases. Figure 1(a) presents the expected investment policy, where the proportion of income that is saved and invested is displayed as a function of legal and criminal human capitals. Figure 1(b) displays the decision of the individual

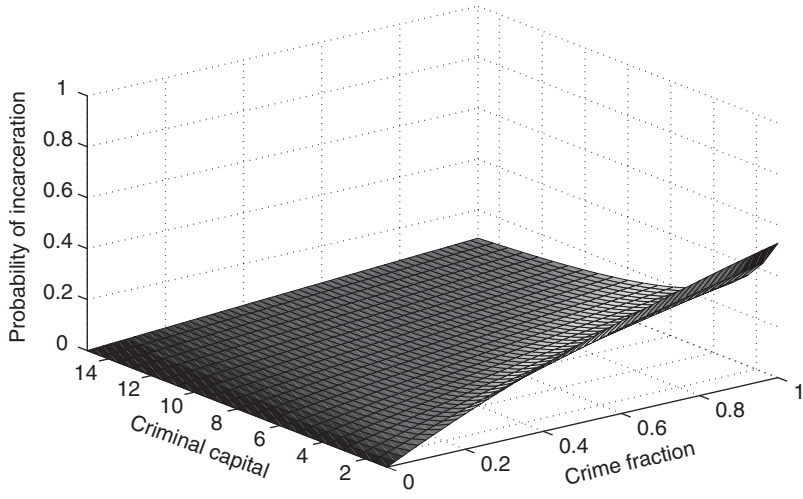

FIGURE 1. Probability of incarceration

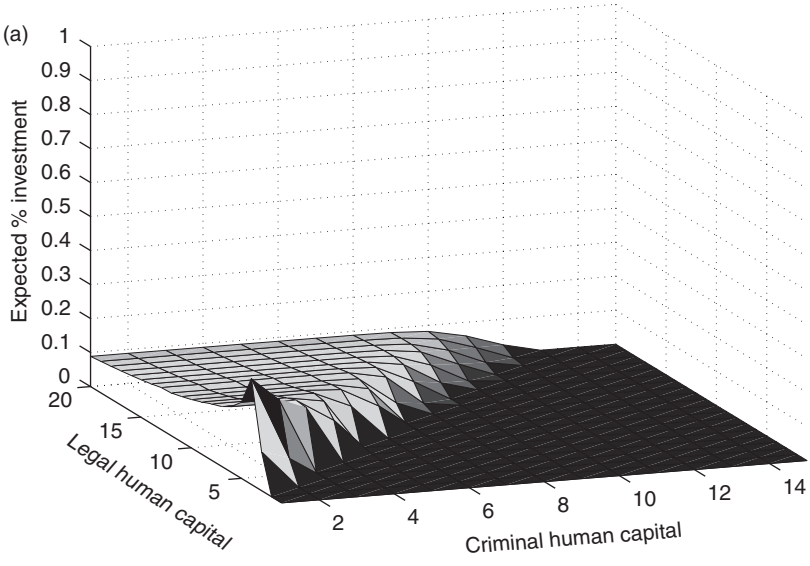

FIGURE 1(a). Investment policy

regarding his allocation of time between legal and criminal sectors. As can be seen, the fraction of time spent in the criminal sector rises as legal human capital decreases and as criminal human capital increases.

Figure 1(c) depicts the dynamic behaviour of legal and criminal human capital. The arrows demonstrate the direction towards which the human capital combination of the individual moves. As can be seen, there is a bifurcation, which generates two steady states. Specifically, one steady state occurs where legal human capital is about 11 and criminal human capital is 1; here, the individual fully participates in the legal sector. The second outcome is where criminal human capital is about 14.5 and legal human capital is 1; here the individual participates fully in the criminal sector.

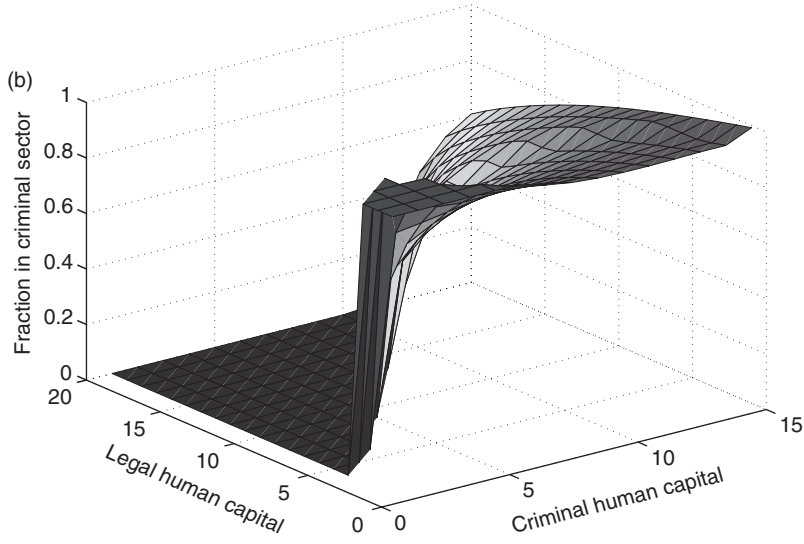

FIGURE 1(b). Proportion of time in crime

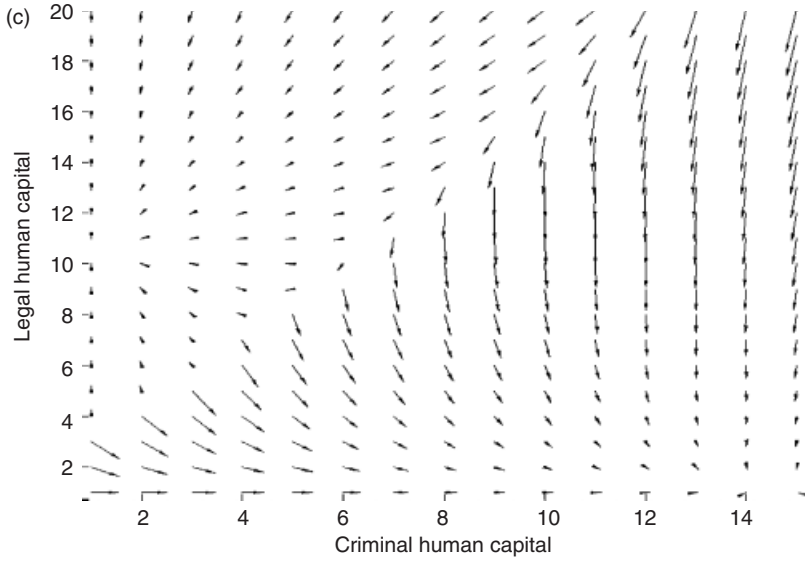

FIGURE 1(c). Human capital evolution

Increase in the probability of incarceration

Figure 2 depicts the scenario where the probability of incarceration is increased. More specifically, all benchmark parameters were kept constant, but η was increased to 5. This has lifted up the surface of incarceration probability, especially for those individuals who have low criminal capital but spend a lot of time in the criminal sector. Figures 2(a)–2(c) display the expected investment, the optimal fraction of time spent in the criminal sector and the evolution of legal and criminal human capitals of the individual, respectively, when he faces more strict law enforcement as depicted in Figure 2.

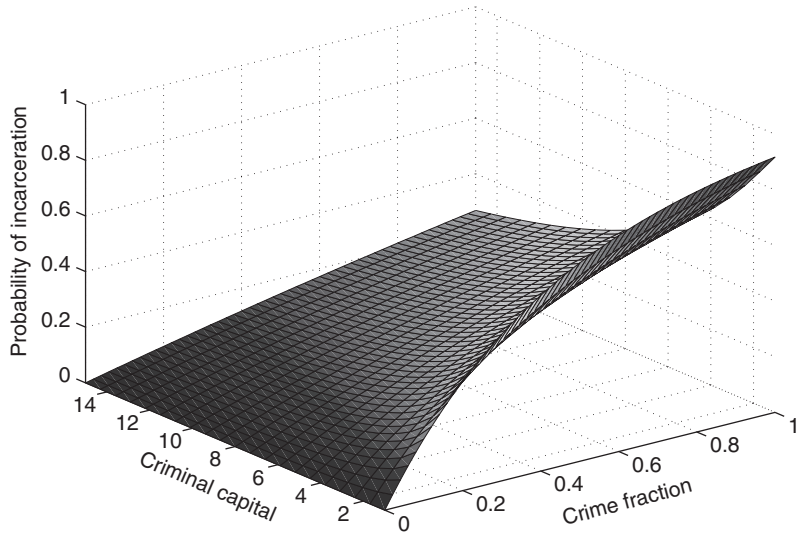

FIGURE 2. Probability of incarceration (stricter law enforcement)

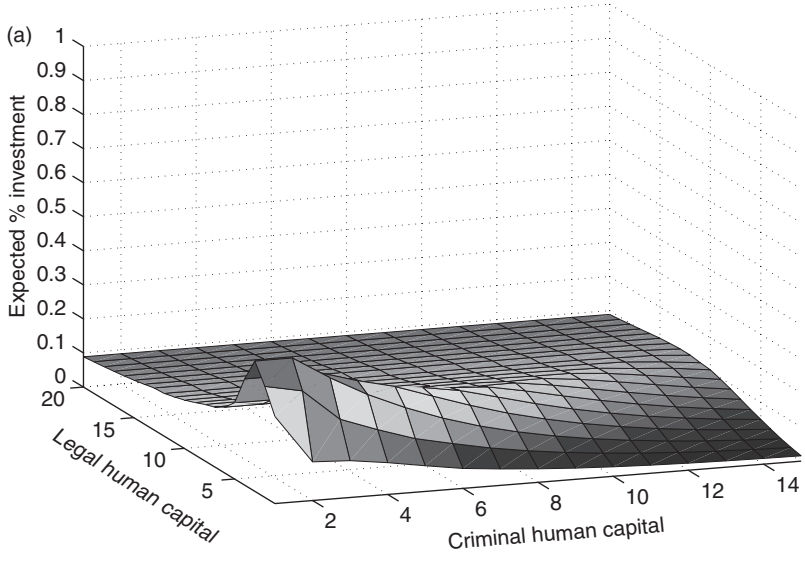

FIGURE 2(a). Investment policy (stricter law enforcement)

The contrast between Figures 1(a) and 2(a) is interesting. In Figure 2(a), even the individuals possessing large amounts of criminal capital (who did not invest in their legal capital when the probability of incarceration was low in Figure 1(a)) decide to invest in their legal human capital as insurance against the relatively high likelihood of apprehension and therefore loss of income. For example, in Figure 1(a) an individual with 5 units of legal human capital and 8 units of criminal human capital does not invest in legal capital; however, when the probability of incarceration is increased, he decides to save part of his income and invest it to enhance his legal human capital (Figure 2(a)).

Figure 2(b) shows the fraction of time spent in the criminal sector when the probability of incarceration is higher. This is the counterpart of Figure 1(b),

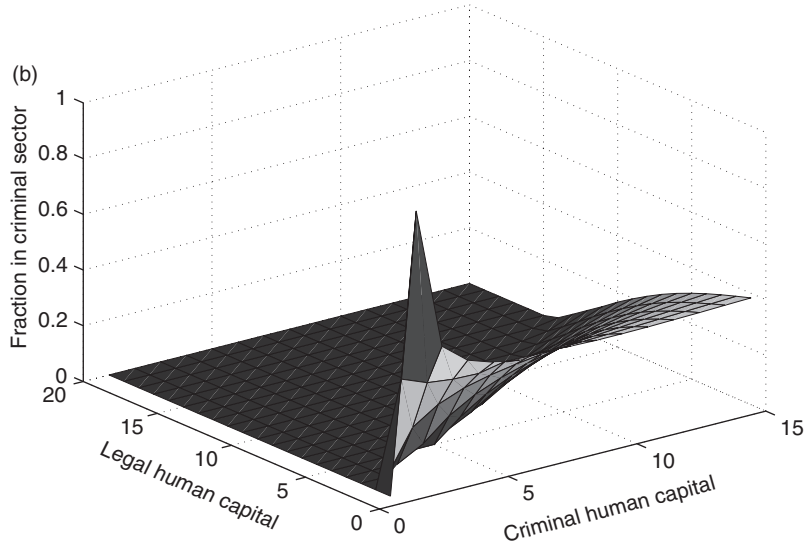

FIGURE 2(b). Proportion of time in crime (stricter law enforcement)

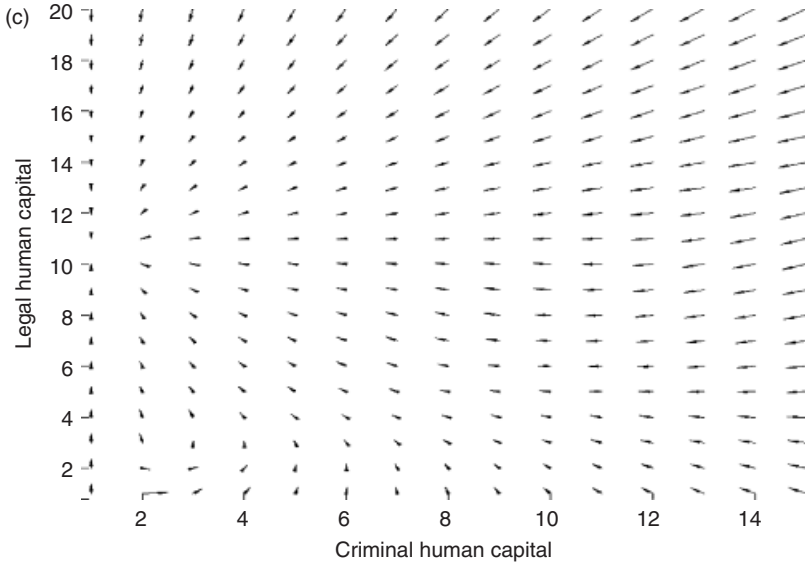

FIGURE 2(c). Human capital evolution (stricter law enforcement)

which presents the same information with a lower probability of incarceration. As can be seen, the enhanced incarceration probability reduces the propensity to participate in the criminal sector. Specifically, the entire surface representing the fraction of time spent in the criminal sector is lower in Figure 2(b). For example, an individual with 10 units of legal human capital and 10 units of criminal human capital spends about 60% of his time in the criminal sector when the probability of incarceration is low (Figure 1(b)), but no time in the criminal sector when the incarceration probability goes up (Figure 2(b)).

Figure 2(c) presents the dynamics of human capital formation when the incarceration probability is increased. In this scenario even individuals with high

levels of criminal human capital tend to increase their legal human capital and reduce their criminal human capital over time. This generates an outcome whereby, with the passage of time, the relative abundance of legal capital increases; and even if the individual starts off as a criminal (e.g. with criminal capital = 5, legal capital = 2 in Figure 2(c)), he eventually switches to the legal sector.

Increase in the return to legal capital

Figures 3(a)–3(c) provide information about an individual's expected investment, proportion of time spent in the criminal sector and human capital evolution when the return to legal capital is increased. In this scenario everything is the same as in the benchmark case except for the return to legal capital, which is increased to 3. Figure 3(a) can be contrasted with Figure 1(a), and Figure 3(b) is the counterpart of Figure 1(b). When the return to legal human capital is higher, investment in legal human capital is higher. More specifically, Figure 3(a) shows that investment in legal human capital is positive everywhere, even in cases where criminal human capital is high. As a result, we see in Figure 3(b) that criminal participation is reduced substantially (see Figure 1(b) in comparison). Consequently, the steady state in Figure 3(c) occurs where legal human capital is positive (about 13.5) and criminal human capital is 0. Put differently, even individuals with relatively high levels of criminal human capital, who find it initially optimal to participate in the criminal sector (e.g. an individual with criminal human capital = 10, legal human capital = 5 in Figure 3(b)), decide to save part of their income (see Figure 3(a) for the saving behaviour of the same individual), and move to the legal sector over time (see dynamic behaviour of both types of human capital in Figure 3(c)).

The fact that the criminal saves part of his income and invests it to increase his legal human capital captures the essence of the model, and explains how

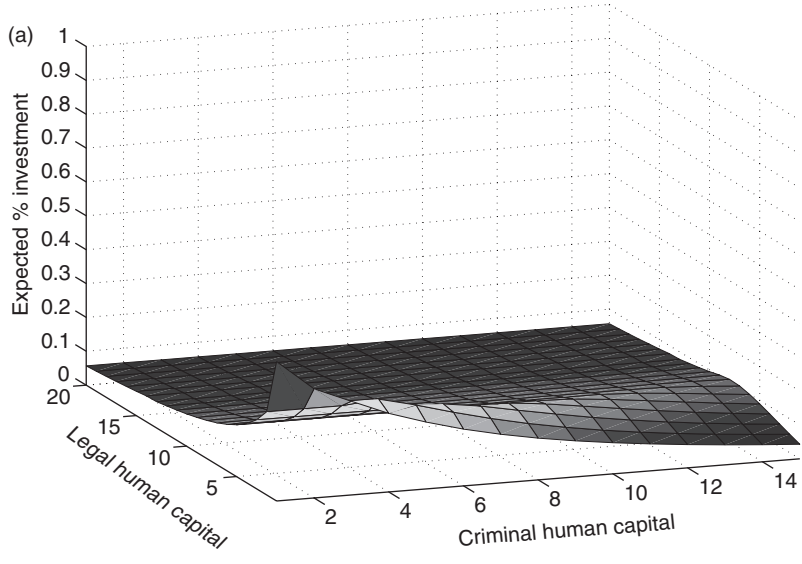

FIGURE 3(a). Investment policy (higher return to legal capital)

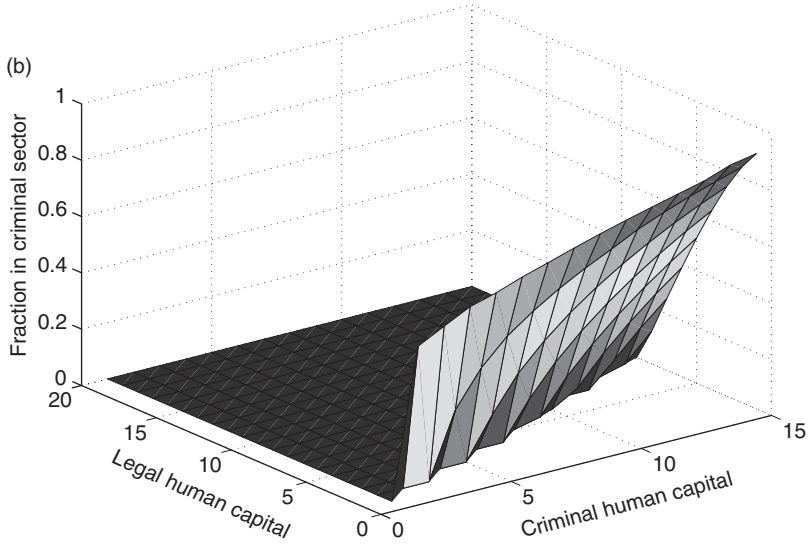

FIGURE 3(b). Proportion of time in crime (higher return to legal capital)

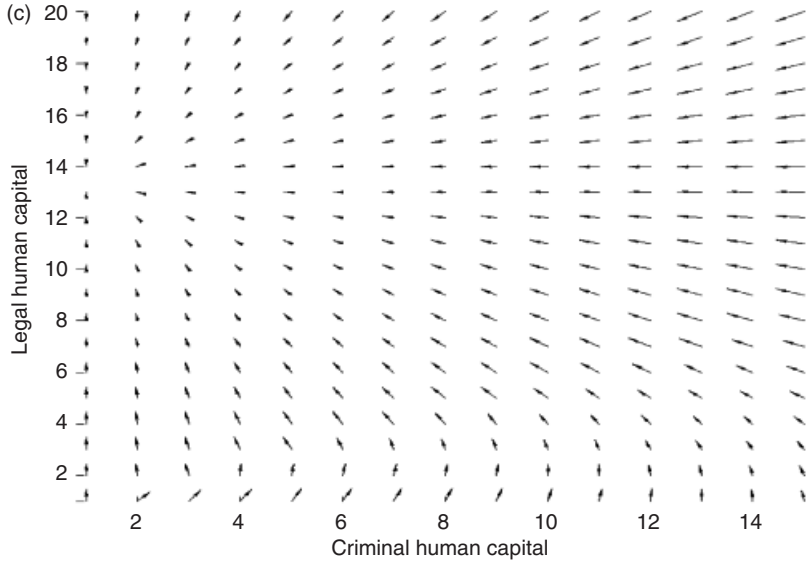

FIGURE 3(c). Human capital evolution (higher return to legal capital)

individuals who are participating in the criminal sector early in their lives are switching to the legal sector later.

The set of figures from 2(a) to 3(c) demonstrate the impact of 'carrots and sticks'. A high probability of apprehension can be attributed to effective law enforcement, and a high return to legal capital can be representative of a strong labour market. When apprehension probability or returns to legal capital go up, individuals even with substantial amounts of criminal human capital have much larger propensity to invest in their legal human capital. This indicates that changes in the returns to legal and criminal human capital can be effective means of influencing criminal activity through their influence on investment in

legal capital. This aspect of the model will be further demonstrated in the next section.

IV. The Dynamic Optimal Behaviour

Figures 4(a)–6(c) depict the individual's optimal decision path under various scenarios. The figures include the time path of both legal and criminal human capital, and the fraction of time spent in the criminal sector. Because the fraction of time spent in the criminal sector is between 0 and 1, it is multiplied by 10 in Figures 4(a)–6(c) so that it can easily be presented on the same scale in the graphs.

The impact of a recession

Figure 4(a) displays the optimal dynamic behaviour of the individual before, during and after a recession. The individual has four units of legal human capital and one unit of criminal human capital in period 1, and he is fully participating in the legal sector. (The fraction of time spent in the criminal sector is zero.) The recession takes place in period 3, simulated by a 30% reduction in legal income. During the recession, the individual finds it optimal to participate in the criminal sector. Specifically, he allocates more than 90% of his time to crime in period 3 (see Figure 4(a)). After this one-period recession, he reduces the proportion of his time allocated to crime: this falls to about 15% in period 4, continues to decline steadily, and becomes zero in period 8. In other words, the person switches back to the legal sector after the recession. Note that participation in criminal activity increases the criminal human capital of the individual. However, his legal human capital also rises, primarily

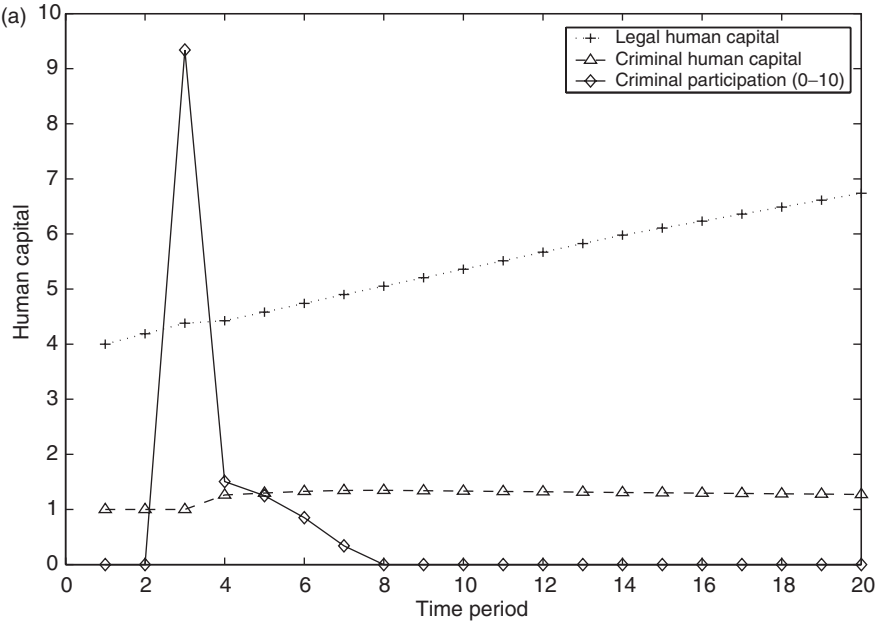

Figure 4(a). Short recession

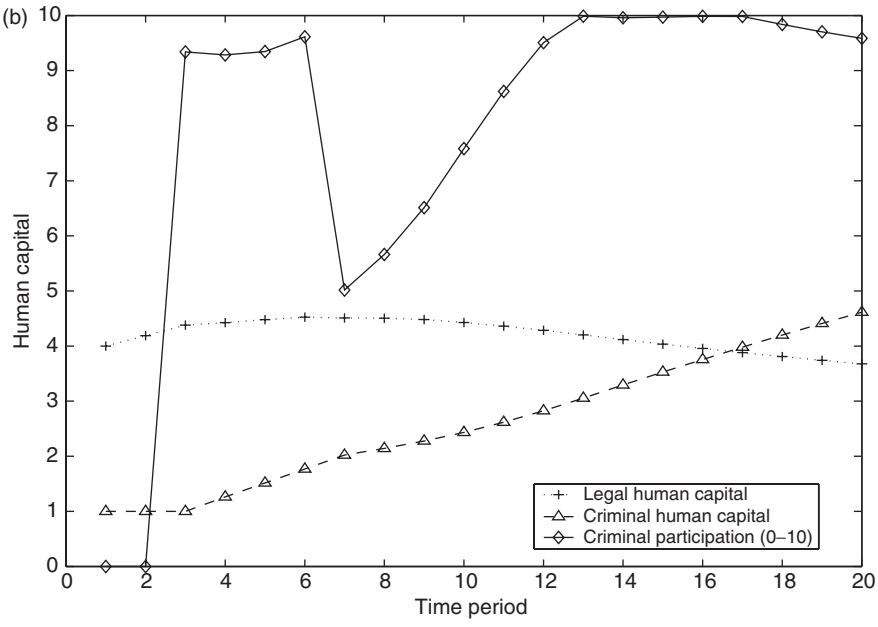

FIGURE 4(b). Long recession

because of investment in legal capital. As the fraction of time spent in crime declines in periods 4–8, the rate of increase in criminal capital diminishes, which makes it possible to switch fully to the legal sector.

Figure 4(b) presents the same scenario with one difference: the recession lasts longer. In this case it lasts four periods, starting with period 3. As before, the individual finds it optimal to increase the proportion of his time spent in the criminal sector during the recession. However, because the recession lasts longer, his criminal human capital appreciates steadily during this period. When the recession is over, he reduces his time allocation to crime to about 50%, but then increases it continuously afterwards.

The novelty of our dynamic model can be seen in this analysis of human capital and the participation decision after the recession. Participation in the criminal sector during the recession increases the individual's criminal human capital and depreciates his legal human capital. (See the time-path of the legal human capital in Figure 4(b), depicted by a + sign.) This decrease in his legal human capital, coupled with the increase in criminal human capital that took place during the recession, makes it difficult for him to switch back to the legal sector after the recession is over. Figure 4(b) demonstrates that, although the fraction of time allocated to crime drops immediately after the recession, the individual finds it optimal to increase this steadily thereafter, and he finds it optimal to stay in the criminal sector.

The criminal trap, or hysteresis in criminal activity, that emerges in our model is in sharp contrast to the predictions of other models. The current crime models posit a symmetry in the pre- and post-recession behaviour of the individual: a decrease in legal earnings potential during the recession pulls the individual to crime, and an increase in potential legal earnings after the recession brings him back to the legal sector. By contrast, in our model, as seen

in Figure 4(b), the individual does not switch back to the legal sector after the recession is over: he is not the same person after the recession.

This result provides a testable hypothesis. In a recession, where the unemployment rate rises, the property crime rate is expected to increase; but after the recession is over and the unemployment rate declines, the crime rate will not revert back to its original level. Put differently, property crime is predicted to exhibit asymmetric behaviour over the business cycle. This prediction of the model is supported by the US data (Mocan and Bali 2005).

Certainty and severity of punishment

Equation (10) depicts the probability of incarceration. Variations in η provide a convenient means by which to model the effects of the certainty of punishment, as higher values of η represent higher probability of incarceration. Figure 5(a) displays the dynamic behaviour of an individual who possesses 2 units of legal human capital and 4 units of criminal human capital. The individual's optimal decision is to participate heavily in the criminal sector. Note that, although criminal human capital increases and legal human capital decreases, criminal participation declines slightly. This is because at higher income levels the relative cost of incarceration becomes greater. Therefore the individual reduces his participation in the criminal sector in order to reduce the risk of incarceration. In Figure 5(b) the same individual goes to jail in period 3, and his legal and criminal human capitals depreciate while he is in prison. (The rate of depreciation is higher in case of legal human capital in accordance with benchmark parameters; i.e. $\tau^{cr} = 0.95$ and $\tau^{lg} = 0.7$.) In this case the person finds it optimal to remain a criminal upon leaving prison, because his legal human capital is reduced more than his criminal human capital.

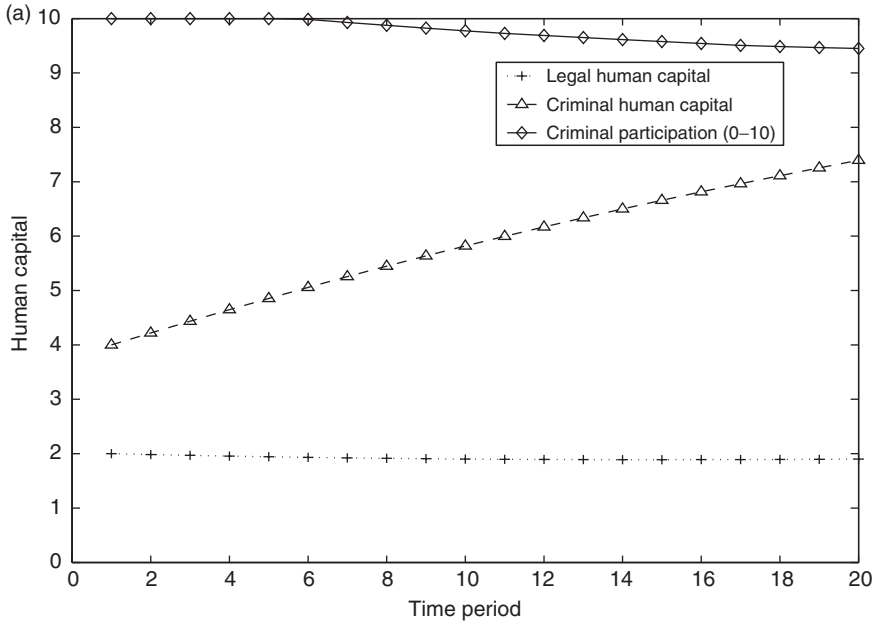

FIGURE 5(a). No imprisonment

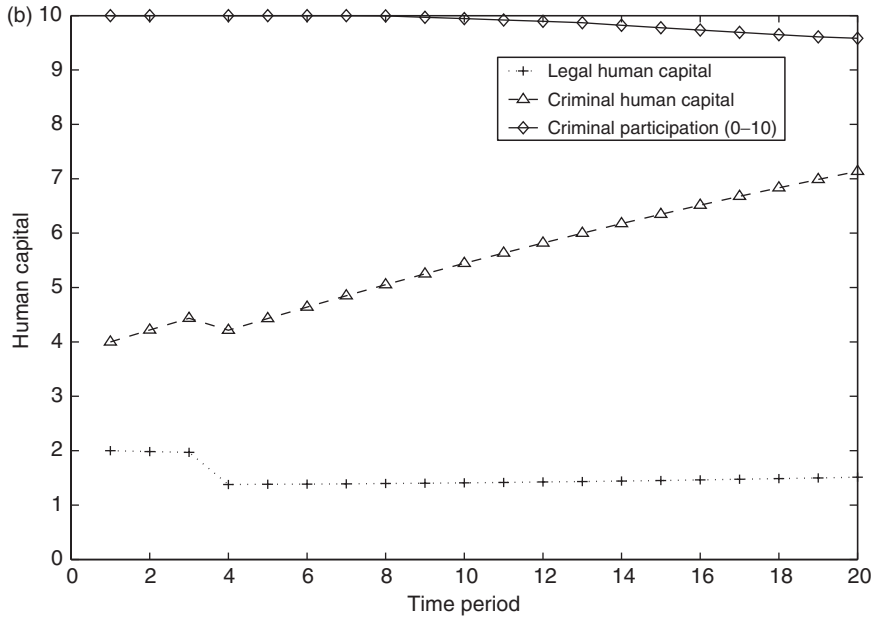

FIGURE 5(b). Imprisonment

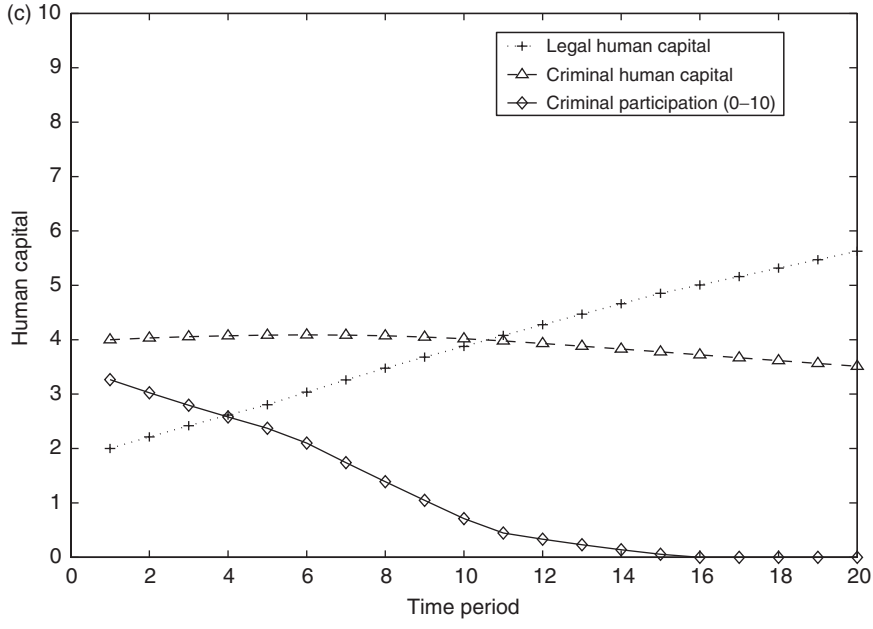

FIGURE 5(c). High certainty of punishment

Figure 5(c) presents the dynamic optimal behaviour of the individual under the benchmark parameters, with one exception: the certainty of punishment is increased. This is captured by an increase in η to 5. (Figure 1 displays the incarceration probability for $\eta = 1.5$, which is the benchmark case, and Figure 2 displays the incarceration probability when $\eta = 5$.) The landscape generated by the enhanced probability of apprehension generates a dramatic change in

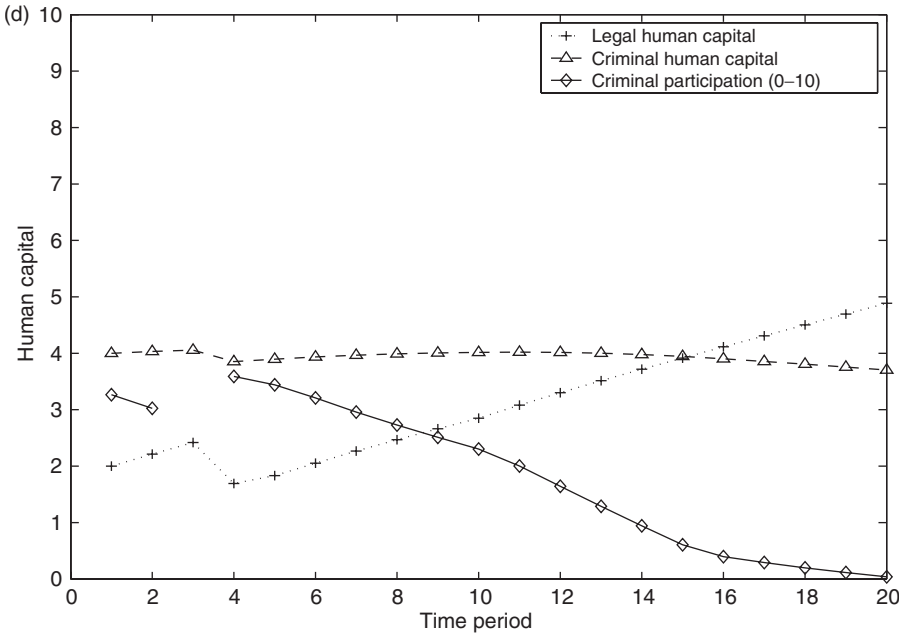

FIGURE 5(d). Imprisonment with high certainty of punishment

behaviour. The individual finds it optimal to spend less time in the criminal sector, and over time he reduces the fraction of time spent in crime to zero. (In contrast see Figure 5(a), where the only difference is a lower probability of apprehension).

Figure 5(d) demonstrates the evolution of human capital as well as sector choice of the individual facing a high probability of apprehension who ends up in jail. Put differently, this is the same environment as Figure 5(c), except for incarceration in period 3. Consistent with the incarceration scenario depicted in Figure 5(b), the individual's criminal human capital becomes relatively more abundant upon leaving prison. Consequently, he increases the fraction of his time devoted to crime in period 4, but over time he reduces his allocation of time to the criminal sector.

The extent of the loss of income and utility while in prison is captured by the magnitude of y_{pris}. Figure 5(e) displays the optimal behaviour of the individual when facing the benchmark parameters, with one difference: the severity of punishment is increased, represented by a reduction in y_{pris} to 0.2. Thus, the behaviour in Figure 5(e) can be compared to that in Figure 5(a). As can be seen in Figure 5(e), in this landscape, where the severity of punishment is higher, the individual initially spends about 50% of his time in crime, but he gradually switches to the legal sector when facing a higher cost of going to prison.

Rehabilitation and prison culture

The potential importance of rehabilitation on post-prison behaviour is acknowledged by researchers as well as members of the criminal justice system. Administrators of the California and US federal prison systems indicated that 'rehabilitation programming was being made available . . . to provide the opportunities and experiences to enable individuals in less

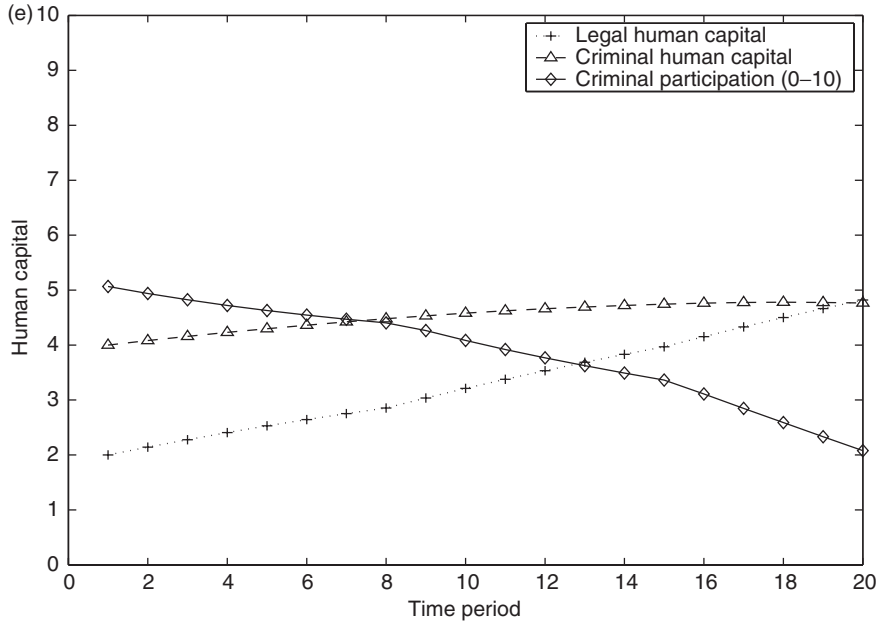

FIGURE 5(e). High severity of punishment

destructive, more socially acceptable ways' (California Department of Corrections 1978, vol. II, p. 8; cited by Witte 1980). Unlike previous economic models of crime, our model allows the investigation of the impact of various imprisonment scenarios on post-incarceration behaviour. The impact of the prison term on post-period criminal activity is analysed by investigating the influence of rehabilitation and prison culture. In equations (11) and (12) we postulated that time in prison would depreciate legal as well as criminal human capital. If prison culture enhances criminal human capital because the inmates learn from each other, then $\tau^{lg} \leqslant 1$, but $\tau^{cr} > 1$. That is, the inmate leaves the prison with a depreciated legal human capital, but with a criminal human capital that has appreciated. On the other hand, if prison provides rehabilitation in the form of education, job training and other legal human capital-enhancing skills, and if the transfer of criminal human capital across inmates is not prevalent, then $\tau^{cr} \leqslant 1$, and $\tau^{lg} > 1$.

Figure 6(a) is the benchmark case, where the time-series behaviours of both legal and criminal human capital are displayed, as well as sector choice. Under the benchmark parameters the individual finds it optimal to spend about 25% of his time in the criminal sector in period 1 and 20% in period 2. In period 3 he goes to prison. In Figure 6(a) there is no rehabilitation or prison culture ($\tau^{lg} = 0.7$, $\tau^{cr} = 0.95$); that is, both types of human capital depreciate, but the depreciation in legal capital is larger because of the loss of reputation. As a result, upon leaving prison in period 4 the individual finds it optimal to increase his time in crime.

Note that substantial depreciation in legal human capital (as depicted in Figure 6(a), and consistent with Lott 1992b) increases the criminal propensity to recidivate upon leaving prison. This applies to white-collar crimes as well, because, as shown in Lott (1992b), white-collar criminals suffer a loss in reputation because of conviction, and this loss can be thought of as a reduction

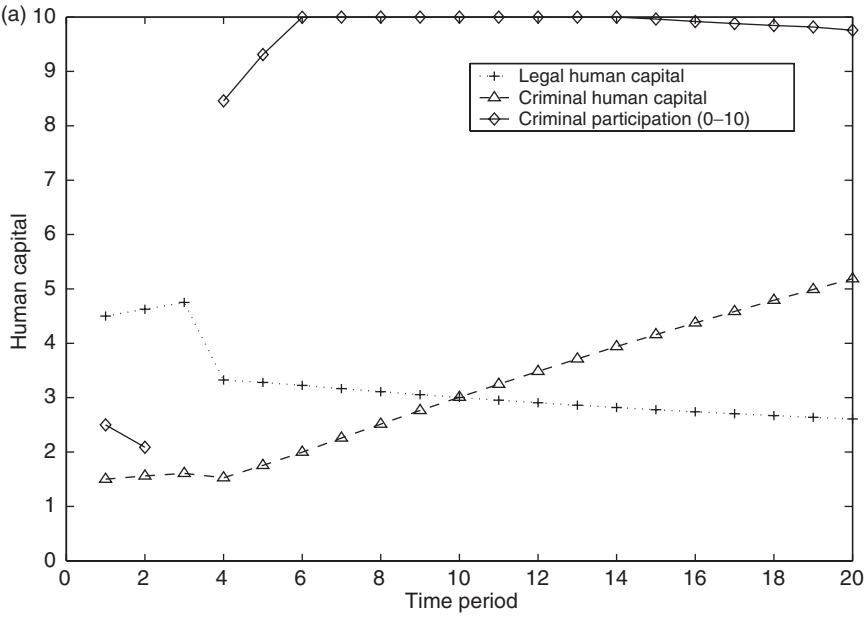

FIGURE 6(a). Imprisonment with no rehabilitation and no prison culture

in legal human capital. No data exist to identify the extent of recidivism of white-collar criminals. The closest available data pertain to individuals convicted of fraud: 66% of prisoners who were convicted of fraud and were released from state prisons in 1994 were re-arrested again within three years; 19% were re-arrested again for fraud (Langan and Levin 2002).

Figures 6(b) and 6(c) display the simulations based on two imprisonment regimes for the same individual depicted in Figure 6(a). In Figure 6(b) the individual's environment is the same as in Figure 6(a). However, this time the individual is exposed to a strong prison culture, which enhances his criminal human capital ($\tau^{cr} = 1.2$) by what he learns from the other inmates. In the simulation that generated Figure 6(b) it is also assumed that the prison does not provide an enhancement of the legal capital ($\tau^{lg} = 0.7$, as in the benchmark). These parameters are known to the individual at the outset. In this scenario, while in prison, the criminal human capital of the inmate appreciates and his legal human capital depreciates; and when he leaves the prison in period 4 he is a better criminal than before (possessing more criminal human capital). Thus, he finds it optimal to participate almost fully in the criminal sector right after leaving prison, and he stays in the criminal sector thereafter.

Figure 6(c) displays the impact of a strong rehabilitation regime while in prison. In particular, the impact of the prison culture is eliminated ($\tau^{cr} = 0.95$ as in the benchmark, signifying some depreciation in criminal capital due to imprisonment), but it is assumed that legal human capital appreciates through rehabilitation and training in prison ($\tau^{lg} = 1.2$). Under these conditions, and with the same starting values of human capital, the criminal human capital of the person declines while in prison, while his legal human capital increases. As a result, when he leaves the prison in period 4 he finds it optimal to participate in the legal sector, as depicted in Figure 6(c).[6]

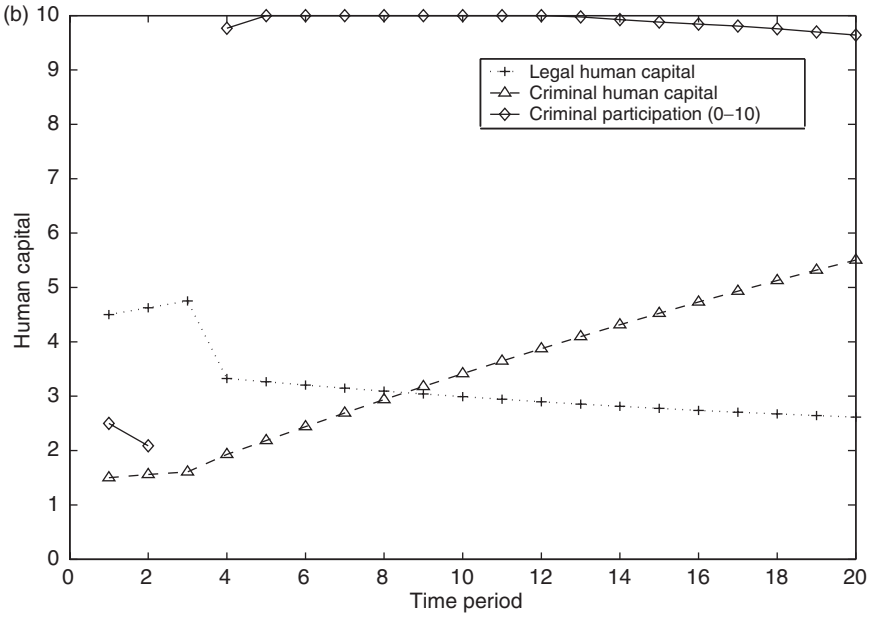

FIGURE 6(b). Imprisonment with prison culture

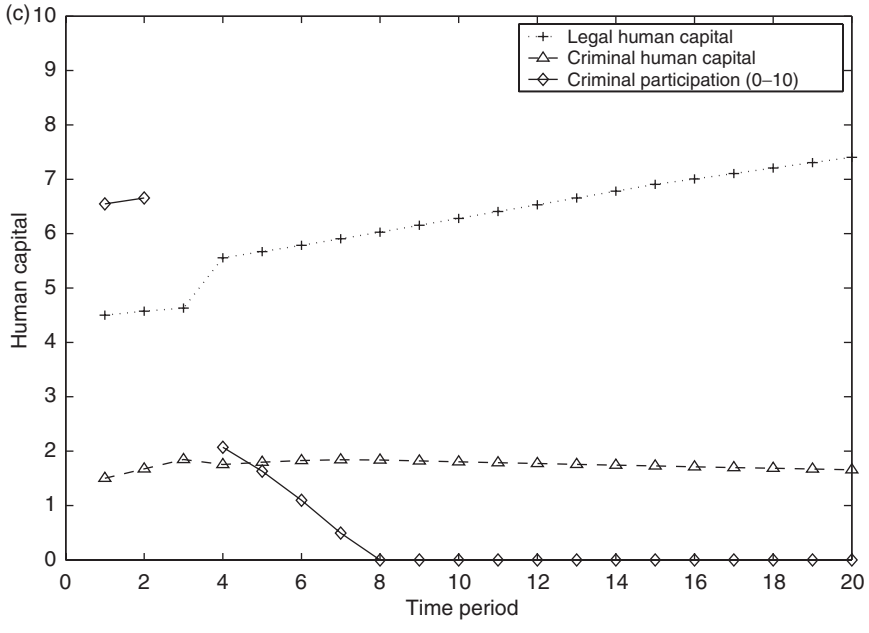

FIGURE 6(c). Imprisonment with rehabilitation

V. CONCLUSION

This paper presents a new economic model of criminal activity. Individuals possess two types of human capital: legal and criminal. Both types of human capital can be enhanced by participating in the legal and criminal sectors, and

legal capital can also be enhanced by investment. Each type of human capital is subject to depreciation. Potential income in each sector depends on the level of the human capital, the relevant rate of return and random shocks. In this two-stage dynamic stochastic model, in each period the individual determines the optimal fraction of time to be allocated in each sector (legal or illegal); then, after the realization of income in that period from legal and/or illegal sources, he decides on the optimal amount of consumption. The extent of criminal activity and the level of criminal human capital determine the probability of incarceration. If incarcerated, the person goes to prison, where the extent of the punishment is represented by a loss of income. Everything about this landscape is known to the individual when he makes his decision. In the benchmark model both types of human capital depreciate in prison, but legal human capital depreciates more owing to a loss-of-reputation effect. We entertain the scenario in which rehabilitation in prison appreciates legal human capital, and the scenario in which prison culture appreciates criminal human capital.

The endogenous relationship between differentiated human capital and differentiated labour markets (legal and criminal) renders the individual's labour market opportunities endogenous. The choices made in each period influence the opportunities available in future periods. The model provides a framework in which the interplay between criminal participation, legal market earnings and deterrence can be analysed. Thus, in a consistent intertemporal framework the analysis of the effects of recessions, the variations in the certainty and severity of punishment and various imprisonment/rehabilitation scenarios is possible.

Several critically important issues in the analysis of criminal behaviour remain unresolved owing to the time-dependant nature of the problems, but are effectively addressed here. For example, the model provides an analytical approach to the effect of various treatment/punishment regimes on the post-incarceration response of optimizing individuals. In traditional crime models, recidivism is a rational response to unchanging opportunities faced by the criminal. If it is optimal for the individual to engage in criminal activity before he goes to prison, it will still be optimal after he leaves prison if the environment remains unchanged. In this model the individual may or may not engage in criminal activity after leaving prison. This is because part of the environment that affects behaviour is endogenous and is a function of the appreciation/depreciation of human capital while in prison.

The model generates some new insights, which are different from those provided by static models. For example, Becker–Ehrlich type crime models predict that an increase in the probability of unemployment in the legal sector, represented by an increase in the unemployment rate, increases the likelihood of entry into the illegal sector. These models postulate that this relationship between unemployment and criminal participation is symmetrical; that is, a decrease in unemployment decreases criminal participation. In our model the potential exists for the individual to find it optimal to participate in the illegal sector during the recession, as predicted by standard theory; but, contrary to the symmetry implied by the standard model, he may tend to remain in the criminal sector after the recession ends. This hysteresis is due to the simultaneous depreciation of legal human capital and the appreciation of criminal human capital during the recession.

The model is capable of explaining a regularity in criminal activity, which is the reduced propensity of an individual to engage in criminal activity as he/she

ages. A switch from the criminal sector to the legal sector can be optimal in a number of ways. First, criminals may find it optimal to acquire legal human capital as a hedge against the uncertainty surrounding criminal income. A criminal's investment in legal human capital is a primary endogenous mechanism that makes the decision to switch to the legal sector optimal. Other channels that may create the same behaviour include changes in the certainty and severity of punishment and changes in the relative returns to legal and criminal human capitals.

The change in the level of human capital while in prison influences the post-prison behaviour of the individual. Whereas rehabilitation in prison decreases the tendency of criminal activity after the release from prison, if prison culture enhances criminal human capital, the tendency to engage in crime after prison goes up.

APPENDIX

TABLE A1
BENCHMARK PARAMETER VALUES

Parameter	Benchmark value	Parameter	Benchmark value
r^{lg}	1	τ^{lg}	0.70
r^{cr}	4	τ^{cr}	0.95
δ^{lg}	0.03	η	1.5
δ^{cr}	0.02	v	1
Ω^{lg}	0.15	α	0.6
Ω^{cr}	0.03	$\lambda_{\max}$	0.3
Ψ^{lg}	0.02	y_{pris}	0.6
Ψ^{cr}	0.3	σ	1.5
$h^{lg}_{\min}$	1	β	0.95
$h^{cr}_{\min}$	1		

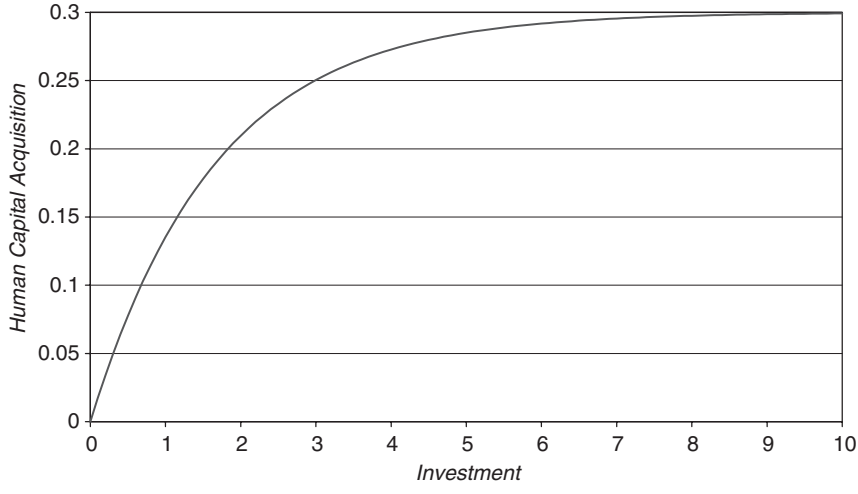

FIGURE A1. Human capital acquisition through investment

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NOTES

1. For example, a negative relationship between time spent in illegal activity, and policing, prosecution and judicial policies requires the assumption of risk neutrality or decreasing absolute risk aversion with income. The same assumptions are required to establish that the impact of a marginal increase in the gains resulting from criminal activity on time spent in illegal activity is positive. The assumption of diminishing absolute risk aversion, which is necessary for meaningful comparative-static results in the above cases (and several others), generates counterintuitive results in the case of the impact of unemployment on criminal participation. The standard assumption that the individual is risk averse, and that his risk aversion decreases with increasing income, yields the result that an increase in the unemployment rate decreases the time devoted to crime. This counterfactual result emerges in the Schmidt–Witte (1984) and similar models, because increased unemployment reduces income, which in turn reduces crime via the decreasing absolute risk aversion assumption that is needed to make other results plausible (Schmidt and Witte 1984, p. 162).
2. For a summary of the problems encountered in empirical analyses, see Corman and Mocan (2000).
3. Wilson (1994, p. 6), cited by DiIulio (1996).
4. The two-sector, two-capital framework has been utilized in different contexts, such as endogenous growth models with physical and human capital (Mulligan and Sala-i-Martin, 1993).
5. In a different framework, Leung (1994) shows that, in a model with no recidivism, the falling segment of the age–crime profile is obtained because a large percentage of offenders are arrested at younger ages, and once arrested they stop committing crimes.
6. It is interesting to note that initially criminal participation is higher under the scenario with rehabilitation (Figure 6(c)) than for the baseline case (Figure 6(a)) or the case with prison culture (Figure 6(b)). Specifically, in Figure 6(c) we observe that, although legal human capital is greater than criminal human capital, the person spends about 65% of his time in crime before going to prison. This is because, under prison rehabilitation, going to prison allows the criminal to elevate legal capital faster than by participating in the legal sector, and this is known in advance. In essence, the rational behaviour is to participate in the criminal sector in hopes of being caught.

REFERENCES

Bayer, P., Pintoff, R. and Pozen, D. E. (2003). *Building Criminal Capital Behind Bars: Social Learning in Juvenile Correction*. Yale University Working Paper.

Becker, G. S. (1968). Crime and punishment: an economic approach. *Journal of Political Economy*, **76**, 169–217.

——— (1993). *Human Capital: A Theoretical and Empirical Analysis with Special Reference to Education*, 3rd edn. Chicago: University of Chicago Press.

Ben-Porath, Y. (1967). The production of human capital and the life cycle of earnings. *Journal of Political Economy*, **75**, 352–65.

Blinder, A. S. and Weiss, Y. (1976). Human capital and labor supply: a synthesis. *Journal of Political Economy*, **84**, 449–72.

Block, M. and Heineke, M. (1975). A labor theoretic analysis of the criminal choice. *American Economic Review*, 314–25.

Burdett, K., Lagos, R. and Wright, R. (1999). *Inequality, Unemployment and Crime*. University of Pennsylvania Working Paper.

California Department of Corrections (1978). *Program Planning for the 1978–1979 Fiscal Year*. Sacramento: CDC.

Corman, H. and Mocan, N. (2000). A time-series analysis of crime, deterrence and drug abuse in New York City. *American Economic Review*, **90**, 584–604.

——— and ——— (2005). Carrots, sticks, and broken windows. *Journal of Law and Economics*, **48**, 235–66.

Cox, D. (1984). Panel estimates of the effects of career interruptions on the earnings of women. *Economic Inquiry*, **22**, 386–403.

DiIulio, J. J. (1996). Help wanted: economists, crime and public policy. *Journal of Economic Perspectives*, **10**, 3–24.

EHRLICH, I. (1973). Participation in illegitimate activities: a theoretical and empirical investigation. *Journal of Political Economy*, **81**, 521–65.

FLINN, C. (1986). Dynamic models of criminal careers. In A. Blumstein *et al* (eds.), *Criminal Careers and 'Career Criminals'*. Washington DC: National Academy Press.

FREEMAN, R. B. (1996). Why do so many young American men commit crimes and what might we do about it? *Journal of Economic Perspectives*, **10**, 25–42.

——— (1999). The economics of crime. In O. Ashenfelter and D. Card (eds.), *Handbook of Labor Economics*. Amsterdam: North-Holland.

——— and RODGERS, W. III (2000). Area economic conditions and the labor market outcomes of young men in the 1990s expansion. In R. Cherry and W. M. Rodgers (eds.), *Prosperity for All? The Economic Boom and African Americans*. NY: Russell Sage Foundation.

GOTTFREDSON, M. R. and HIRSCHI, T. (1986). The true value of lambda would appear to be zero: an essay on career criminals, criminal careers, selective incapacitation, cohort studies, and related topics. *Criminology*, **24**, 213–34.

GROGGER, J. (1998). Market wages and youth crime. *Journal of Labor Economics*, **16**, 756–91.

GROSSMAN, M. (1972). On the concept of health capital and the demand for health. *Journal of Political Economy*, **80**, 223–55.

IMROHOROĞLU, A., MERLO, A. and RUPERT, P. (2001). *What Accounts for the Decline in Crime?* University of Southern California Working Paper no. 01-15.

LANGAN, P. A. and LEVIN, D. J. (2002). Recidivism of prisoners released in 1994. *Bureau of Justice Statistics Special Report*, June.

LEUNG, S. F. (1994). An economic analysis of the age–crime profile. *Journal of Economic Dynamics and Control*, **18**, 481–97.

——— (1995). Dynamic deterrence theory. *Economica*, **62**, 65–87.

LEVITT, S. (1998). Juvenile crime and punishment. *Journal of Political Economy*, **106**, 1156–85.

LOCHNER, L. (2004). Education, work, and crime: a human capital approach. *International Economic Review*, **45**, 811–43.

LOTT, J. R. (1992a). An attempt at measuring the total monetary penalty from drug convictions: the importance of and individual's reputation. *Journal of Legal Studies*, **21**, 159–187.

——— (1992b). Do we punish high income criminals too heavily? *Economic Inquiry*, **30**, 583–608.

MINCER, J. and POLACHEK, W. P. (1974). Family investments in human capital: earnings of women. *Journal of Political Economy*, **82**, S76–S108.

MOCAN and BALI, T. (2005). *Asymmetric Crime Cycles*. NBER Working Paper no.11210.

——— and GITTINGS, R. K. (2003). Getting off death row: commuted sentences and the deterrent effect of capital punishment. *Journal of Law and Economics*, **46**, 453–78.

——— and REES, D. I. (2005). Economic conditions, deterrence and juvenile crime: evidence from micro data. *American Law and Economics Review*, In Press.

MULLIGAN, C. B. and SALA-I-MARTIN, X. (1993). Transitional dynamics in two-sector models of endogenous growth. *Quarterly Journal of Economics*, **108**, 739–73.

O'FLAHERTY, B. (1998). Why repeated criminal opportunities matter: dynamic stochastic analysis of criminal decision making. *Journal of Law, Economics and Organization*, **14**, 232–55.

PINDYCK, R. S. (1988). Risk aversion and determinants of stock market behavior. *Review of Economics and Statistics*, **70**, 183–90.

PLATANIA, J. and SCHLAGENHAUF, D. E. (2000). *The Falling Crime Rate in the United States: A Dynamic General Equilibrium Approach*. Florida State University Working Paper, February.

SCHMIDT, P. and WITTE, A. D. (1984). *An Economic Analysis of Crime and Justice: Theory, Methods and Applications*. Orlando, Fla: Academic Press.

SZPIRO, G. G. (1986). Measuring risk aversion: an alternative approach. *Review of Economics and Statistics*, **68**, 156–9.

TAUCHEN, H., WITTE, A. D. and GRIESINGER, H. (1994). Criminal deterrence: revisiting the issue with a birth cohort. *Review of Economics and Statistic*, **76**, 399–412.

WILSON, J. Q. (1994). Culture, incentives, and the underclass. In H. J. Arron, J. Henry, E. M. Thomas and T. Timothy (eds.), *Values and Public Policy*. Washington, DC: Brookings Institution, pp. 54–80.

WITTE, A. D. (1980). Estimating the economic model for crime with individual data. *Quarterly Journal of Economics*, **94**, 57–84.

ZAKHAROVA, D. (2000). *How to Fight Criminal Gangs*. University of Minnesota Working Paper.