Prison Sentencing and Criminal Activity: A Dynamic Model

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A dynamic model of time allocation between labor and criminal activity is developed, assuming that these activities are substitutable. Our attention specially focuses on the long-term influence of prison sentence on criminal activity. Two extensions are discussed to remove the undetermined impact of an increase in repression: heavier penalty for repeat offenders and "enhanced human capital" sanctions.

Crime – Time allocation – Sanction

Peines d’emprisonnement et criminalité : un modèle dynamique

Un modèle dynamique d’allocation temporelle entre activités légales et illégales est proposé dans cet article, en considérant ces activités comme substituables. L’impact à long terme de l’emprisonnement sur l’activité criminelle est plus particulièrement analysé. Deux prolongements sont discutés : une inflation des sanctions pour les récidivistes et un recours à des sanctions « éducatives ».

Criminalité – Allocation temporelle – Sanction

JEL : J22, K14, K42

1. Introduction

The idea that offenders respond to the costs and benefits of crime dates to the eighteenth century, following Beccaria and Bentham. Becker [1968] provided the first modern and mathematical treatment of the subject, giving a new impetus to the school of thoughts initiated in the 18th century. The main levers of criminal law are the probability of being caught and the severity of the sanction. It is widely accepted that the probability has an influence on crime level (Garoupa [1999]; Polinsky and Shavell [2000]). In this context, an increase in police forces has a negative influence on crime

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level (Marvell and Moody [1996]; Levitt [1997]). The impact of the severity of the sanction appears to be more undetermined.  

In case of imprisonment – the basecase of our paper – an increase in the severity of sanctions produces a decrease in crime level in the short term. Most works have studied the effect of incarceration rates on aggregate crime rates (Levitt [1996]; Levitt [2004]). Prison sentences can prevent crime through incapacitation of criminals behind bars and deterrence of potential offenders (Abrams [2013]). This paper focuses on the deterrent effect. According to the theory of specific deterrence, lighter punishment makes the threat of future sentences less costly, thus promoting crime. But, for this latter effect, several studies have produced mixed empirical evidence.

In a dynamic perspective, the influence of imprisonment is not clear, both empirically and theoretically. Most inmates reoffend after release. Indeed, serving time behind bars have collateral consequences. First, it may reduce post-release labour market prospects, through increased stigma or decreased human capital (Aizer and Doyle [2015]; Mueller-Smith [2014]; Western et al. [2001]). Second, incarceration may increase the expected payoff from future crime by enhancing prisoners' criminal capital, as a “school of crime”, which is supported by recent empirical research on peer-effects in Florida (Bayer et al. [2009]), Denmark (Damm and Gorinas [2013]) and France (Ouss [2011]).

Such collateral consequences are confirmed by empirical evidence: in the five years following release, 77% of ex-prisoners are re-arrested in the U.S. (Durose et al. [2014]), 83% in the 9 years following release (Alper et al. [2018]). 59% are re-convicted in the five years in France (Kensey and Benaouda [2011]). Such average rates may suggest that prisons are ineffective from a deterrence point of view in a dynamic perspective. This context has led to the development of alternative penal sanctions which either avoid incarceration or hasten release from prison. In the United States, after decades of growth, the total prison population has been declining. More generally, a key question for policymakers is the extent to which more punitive criminal justice sanctions can deter criminal behaviour or if a lower level of crime can be attained by an expenditure reallocation of funds from prisons to alternative uses.

Our work adopts a dynamic perspective and is placed theoretically within two important discussions. The first one is the long-term influence of pen-
alty severity, as economists have produced little theoretical evidence on the effectiveness of incarceration in reducing crime by deterrence. More precisely, we take into account changes in perspectives on legal market for past convicted. If the severity of the sanction often seems to prevent crime, we show that both stigma and human capital depletion may change such a result. Secondly, we propose clear economic explanations for two kinds of policies: enhanced penalties for repeat offenders, on the one hand; “enhanced human capital” sanctions, i.e. sanctions allowing to avoid human capital depletion, on the other hand. This article provides answers to three questions: What is the long-term effect on deterrence of an increase in the severity of sanctions? How does this effect change in the event of increasing punishment for repeat offenders? How does it change in the event of adjustments of sentence making it possible to avoid the loss of human capital?

The first input of this paper is an analysis of the influence of penalty severity. The increase in severity of sanction creates a drop in long-term employability due to obsolescence of human capital or social stigma (Rasmussen [1996]). The fact that individuals may face lower wages than if they had not been convicted has been widely recognized. In our model, we introduce stigma and human capital depletion in the dynamic process of time allocation between legal and illegal activities.

In such a context, there is an adverse change in the arbitrage process between legal and illegal activities. Thus, if we analyze several periods, the impact of the severity of the sanction on deterrence and crime levels appears to be complex and little theoretical evidence has been produced on the link between the dynamics of choice and the long-term influence of sanctions. More precisely, one can wonder whether stigma and human capital obsolescence can be considered as part of an efficient policy (Rasmusen [1996]; Furuya [2002]; Funk [2004]). Indeed, the formal punishment that a convicted criminal is confronted with, is only a part of the whole penalty. Stigma and human capital depletion are also part of the sanction. We will take account of two kinds of effects.

The first effect relies on stigma or reputational costs. The second effect of our model relies on the human capital obsolescence due to the time of incarceration itself. The two effects will be distinguished: first a stigmatization / reputational cost effect which is independent from the penalty severity; secondly, a human capital depletion effect due to the time spent behind bars.

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5. Several empirical studies have analyzed such effects. If Waldfogel [1994] find substantial and persistent decline in earnings (around 10%), Gropper [1995] and Kling [1999], on the other hand, find smaller declines.

6. In Rasmussen [1996] in case of conviction, the wages become lower as the individuals are perceived to be less productive. Through moral hazard and adverse selection models, the signaling effects are the channels by which the employer chooses a lower wage for someone who has already been convicted. In Iacobucci [2014] a reputational cost weighs on the profit of a given firm in case of past conviction due to a binary reputational cost. If sanction increases, reputational costs increase due to a signaling effect on the type of the firm. Mungan [2016] accommodates both of stigma and reputational costs in a generalized model.

7. Mocan et al. [2005] propose a dynamic model of human capital accumulation which underlines the depreciation of legal human capital behind bars. Aizer and Doyle [2015] show the impact of juvenile incarceration on human capital accumulation and future crime. Our own model also take into account of human capital depletion due to incarceration as the wage-cut increases with the penalty severity.
and which evolves with the penalty severity. The deterrent effect of an increase in penalty severity can be ambiguous as will be shown below: First the wage-cut on labor market creates a negative-incentive effects on crime before the occurrence of any conviction. As shown in Imai and Krishna [2004] the prospect of future reductions in labour market remuneration leads to reduced current period criminal activity. But secondly, changes in legal perspectives for past convicted individuals can reinforce criminal paths.

The second input of this paper is to propose clear explanations for enhanced penalties for repeat offenders as well as enhanced human capital sanctions – development of alternative sanctions to imprisonment, education and paid employment in prison... Indeed, if the first practice is common and rooted in our civil and criminal codes – “three-strikes-and-you’re out” in California, act on minimum sentences in France, it has long been difficult for economists to justify such a distinction and existing economic literature generally offers mixed results regarding punishment of repeat offenders. Most of existing works have not explicitly analyzed the role of changes of perspectives on legal market to justify escalating penalties.

Miceli and Bucci [2005] offer explanation for rising penalties based on the existence of stigma on legal market suffered by convicted criminals. They prove that increasing penalties are part of an optimal enforcement policy. But their model supposes to include irrational people who commit crime regardless of the severity of punishments and apply to a restrictive set of circumstances – crimes that should definitively be deterred. Finally, Funk [2004] also models the impact of stigma on the decision to commit crime or to seek legal employment. But, she focuses on the role of stigma as part of an efficient policy and proposes an explanation for increasing penalties as a solution to guarantee stigma effectiveness. Our work differs from the two precedent papers in three respects.

First, as stated above, if the instant paper also deals with diminished employment opportunities, the main purpose is not to address stigma, but the long-term influence of prison sentencing. Secondly, as a difference with precedent papers, we also take into account human capital obsolescence as a main channel for changes in labour perspectives. This later cause is at the heart of the relation between prison sentencing and legal market perspectives. Thirdly, our alternative schemes include both enhanced penalties for repeat offenders – as in the two precedent papers – but also enhanced human capital sanctions as solutions to manage the ambiguity of penalty severity.

8. Emons [2007] proposes explanations based on the fact that individual’s choice is always history dependent (always or never committing crime). Such assumptions are not included in Emons [2003], so that stronger penalties for repeat offenders are not economically justified. Chu et al. [2000] derive a partial result, by comparing increasing penalty schemes and uniform ones, in case of conviction errors, based on the idea that the probability of erroneously convicting repeat offenders is lower than that of convicting first-time offenders. Polinsky and Shavell [1998] as well as Burnovsky and Safra [1994] do not produce necessarily the empirically verified practice of punishing repeat offenders more severely. Polinsky and Rubinfeld [1991] is based on numerous conditions for justifying increasing penalty scheme in case of fines (whereas we address the case of imprisonment).

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Adopting a dynamic perspective appears to be crucial to address the above questions as a given decision has implications for available choices in later periods and thus future decisions. In a static model, if it is optimal to engage in criminal activity in a given environment before prison it will be optimal after release. But such an environment is endogenous, most notably because of human capital variation across time and depreciation while in prison. The dynamic structure of models allows us to better understand such multi-period behaviour and gives additional insights unavailable from static models.

2. The model

We develop a model of time allocation in which two periods are distinguished: youth, when the individual usually starts working; more mature age when the agent can have already been the subject of consistent indictment sentences. We suppose that the policy-maker is looking for improving deterrence by decreasing total time dedicated to crime. We do not consider in the instant paper a social welfare or a social cost function. Instead, we focus on total time dedicated to illegal activity, \textit{i.e.} on the deterrence effect. As we know, the influence of harder punishment is not clear in a dynamic perspective. Thus, the first purpose is to bring additional insights on dynamic deterrence theory. The second input of this paper is to analyse how the ambiguous impact of sanction severity on deterrence can be removed. Thus, clear explanations for enhanced penalties for repeat offenders as well as enhanced human capital sanctions are proposed.

Such explanations are irrespective of any social cost function as we only focus on deterrence. Two kinds of reasons can motivate the analysis of total time dedicated to crime instead of considering a social cost function. First, the purpose of the instant paper is not to establish an economic optimum, but to bring additional insights about the deterrence issue. Secondly, even if the cost of alternative sanctions proposed in the last sections appears to be difficult to evaluate, one can suppose that they could be considered at low additional cost for the public sanction system. This way, as an approximation, the total time dedicated to crime could be considered as the main objective for policy-makers.

A two-period model is used for simplicity\(^9\). We focus on risk neutral individuals seeking to maximize total earnings on two independent markets of employment: one for legal activities and one for illegal activities. We consider as Ehrlich [1973] that legal and illegal activities are substitutable and not complementary\(^10\). The problem facing a potential criminal is how to allocate a fixed amount of working time (normalized to 1) to these different

\(^9\) A more realistic framework would use an overlapping generation framework.
\(^10\) Obviously this assumption is a simplification of reality since illegal earnings may appear outside as inside of a given legal working framework.
sources of income. Returns in either market are assumed to be linearly
dependent on working time as well as wages, but the risks of illegal activity
is increasing with time devoted to this market. We suppose that the wage of
a representative individual is lower if this agent has already been convicted.
Finally, the actualization rate – and its differences among individuals – is not
addressed11.

2.1. A decision model for the potential offender

Let’s see the arbitration process of a given agent between legal and illegal
markets during the two periods. \( t_1 \) and \( t_2 \) correspond to the time allocated to
illegal activity during the two distinct periods. For simplicity the duration of
each period is standardized to one. These times can be zero or one for each
individual, with corner solutions in order to have no negative values.

First Period

During the first period the agent has not been convicted. The legal activity
has constant returns. Illegal activity is remunerated and risky. The expected
monetary value earned in first period can be written as follows for a risk
neutral individual:

\[
V_1 (t_1) = s_0 (1 - t_1) + I t_1 - \pi C t_1^2.
\]  

\( I \) denotes the return of criminal activity, i.e. the income derived per unit of
time dedicated to illegal activity (possibly including psychological costs). \( \pi \)
represents the probability of being caught per unit of time dedicated to illegal
activities (we assume linear relation between time devoted to illegal
activity and the probability of being caught). It is consistent to assume that
the probability of being caught increases with the involvement in crime12.
Here, we assume linearity and such probability can be written \( \pi t_1 \). We sup-
pose, without loss of generality, that the return of illegal activity \( I \) can be
kept even in case of conviction because of instantaneous consumption. If
such a return is only partially consumed, a part of \( I \) would be lost in case of
conviction. This would be equivalent to an increase in the intensity of the
sanction.

\( C \) is the intensity of the penalty imposed on a criminal per unit of time
dedicated to crime (we assume linear relation between time devoted to
illegal activity and the intensity of the sanction) and occurs a marginal cost
of 1 to a convicted offender. Such a sanction is non-monetary and refers to
imprisonment instead of a fine. It is also consistent to assume that punish-

\[11\] For dynamic model with actualization rates and optimal deterrence over several
periods, see Davis [1988].

\[12\] One could assume that their chances of getting caught could decrease marginally with
\( t \) if offenders become better at crime as they spend more time at it, or increase marginally
due to information accumulation by authorities.

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ment will be heavier that involvement in illegal activities is important (even if all the crimes are not known by the court). Here, we also assume linearity so that the intensity of the penalty can be written $C_t$.

Due to the two linearities (for probability and severity), the quadratic form of equation [1] allows inner solutions, consistent with Ehrlich’s [1973] empirical observation that offenders often devote time to both activities. In fact, the two linearities are not crucial for having inner solutions if probability depends on time spent on illegal activities. Other reasonable conviction functions can allow to obtain the main effects. $s_0$ is the wage earned by unit of time dedicated to legal activity. Finally, for each of the two periods, we do not take into account the loss of time spent behind bars. As penalty is a non-monetary sanction, it would be possible to consider an incapacitation effect due to imprisonment, with less time dedicated both to legal and illegal activities. Such an incapacitation effect is not at the heart of the instant paper and we only address the deterrence issue. Thus, such a decrease in total time allocated between legal and illegal activities is not taken into account.

Second period

The first period has an impact on the second one through the following mechanism: as above-mentioned, someone who has been sentenced to a criminal punishment (typically a prison sentence) has a lower wage on legal market. This can be due both to stigma / reputational cost and to human capital depletion. In the instant model, we both take into account of instantaneous stigmatization in case of conviction and of human capital depletion due to incarceration. The second effect on wage-cut increases with the penalty severity. Indeed, the two effects will be distinguished: first a stigmatization / reputational cost effect which is independent from the penalty severity; secondly, a human capital depletion effect due to the time spent behind bars which evolves with the penalty severity.

We will consider, as a simplification to underline stylized facts, that several parameters do not change between the two periods: the return per unit of time dedicated to crime denoted by $I$ (which is totally kept even in case of conviction); the base-case wage per unit of time dedicated to legal activity denoted by $s_0$; finally, in the first part of the paper, the sanction per unit of time dedicated to illegal activity and denoted by $C$ is not supposed to change between the first and second period. Such hypothesis can be considered as limitation of the instant framework. Formally, the wage by unit of time on legal market can be written:

- $s_0$, if the individual has not been convicted
- $s(C, s_0)$, if the individual has already been sentenced. $s(C, s_0)$ is considered as a decreasing function with $C$ as the human capital effect increases with the severity of the sanction per unit of time dedicated to crime. Indeed, we suppose that changes in legal perspectives are due both to stigma and human capital obsolescence associated with time behind bars. If stigma can be a binary process (an employer stigmatizes someone if and only if he has
been convicted), human capital depreciation depends crucially on the length of the sanction per unit of crime, i.e. on $C$.

In case of conviction $s(C, s_0)$ increases with the base-case wage of first period denoted $s_0$. But, in case of conviction, the variation of the wage per unit of time with $s_0$ is lower than the first period variation. It can be expressed mathematically as follows: $0 \leq \frac{\partial s}{\partial s_0} \leq 1$. Hereafter, $s(C, s_0)$ will be denoted as $s$.

For $t$ dedicated to illegal activity, the expected monetary value earned by a risk neutral individual can be written as follows

$$V_2(t_2, s_0) = s_0 (1 - t_2) + l t_2 - \pi C t_2^2.$$  

[2]

If the individual has not been convicted and:

$$V_2(t_2, s) = s (1 - t_2) + l t_2 - \pi C t_2^2$$  

[3]

with $s = s(C, s_0)$ if the individual has already been sentenced. We suppose here $0 \leq s \leq s_0 \leq I$.

### 2.2. Resolution

In case of a rational and risk neutral agent maximizing the expected monetary value over the two periods, the optimization program consists to choose the durations $t_1$ and $t_2$.

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13. If we assume that human capital depreciation is linear with time spent behind bars, one should consider that the legal wage per unit of time on legal market depends on total sanction, i.e. $s = s(C t_1, s_0)$. In such a framework, human capital and wage would depend both on penalty severity and time dedicated to crime in the first period which would induce the analysis to be more complex. Consistently with this approach, it would be interesting to consider both legal and illegal human capital, with accumulation and depreciation processes. Thus, one should consider both $s = s(C t_1, s_0)$ and $l = l(t_1)$. The first function is supposed to be a decreasing one, whereas the second one is supposed to be an increasing one. Such a dual human capital framework is at the heart of our present research. But, in the instant paper, we only take into account the severity per unit of time $C$ for human capital obsolescence, instead of $C t_1$. The first reason of this choice is due to technical considerations. The second one is that it is possible to assume that human capital evolution is partly due to the choice of a public policy as well as conditions behind bars and does not necessarily decrease linearly with time behind bars. Such a choice constitutes a limitation of the instant framework.

14. Marginal probability of conviction in the second period is supposed to be the same for all individuals. We do not account for the possibility that previously convicted criminals might be caught with a higher probability due to supervision, neither for the possibility of an increase in criminal ability and a lower probability to be caught. More generally, avoidance abilities and detection probabilities are not supposed to be heterogeneous among individuals so that the sanction per unit of time dedicated to crime does not take such parameters into account as in Bebchuk and Kaplow [1993] or Frieh [2008].
Second period

If the agent has not been sentenced during the first period, the first order condition gives us a unique interior solution:\(^{15}\)

\[
  t^*_2 = t^*_2(s_0) = \frac{I - s_0}{2\pi C}.
\]  

[4]

As \(\frac{\partial^2 V_2(t^*_2, s_0)}{\partial t^*_2} = -2\pi C < 0\) the interior solution is a maximum for individual value in second period for someone who has not been convicted.

In case of interior solution, we can write the expected monetary value earned after maximizing revenue:

\[
  V_2(t^*_2, s_0) = \frac{(I - s_0)^2}{4\pi C} + s_0.
\]

If the individual has been sentenced, we have also a unique interior solution (the same corner solutions apply):

\[
  t^*_c = t^*_c(s) = \frac{I - s}{2\pi C} \geq t^*_2.
\]  

[5]

As \(\frac{\partial^2 V_2(t^*_c, s_0)}{\partial t^*_c} = -2\pi C < 0\) the interior solution is a maximum for individual value in second period for someone who has been convicted.

Then, we can write the expected monetary value earned after maximizing revenue:

\[
  V_2(t^*_c, s) = \frac{(I - s)^2}{4\pi C} + s.
\]

As earnings on legal market is inferior in case of past conviction, we can calculate the difference in earnings:

\[
  V_2(t^*_c, s) - V_2(t^*_2, s_0) = \frac{(s - s_0)(4\pi C - 2I + s + s_0)}{4\pi C}.
\]  

[6]

As, in case of interior solutions, we suppose \(0 \leq I - s_0 \leq I - s \leq 2\pi C\), we have necessarily \(V_2(t^*_c, s) - V_2(t^*_2, s_0) \leq 0\), i.e. \(V_2(t^*_c, s) \leq V_2(t^*_2, s_0)\).

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15. The corner solutions are \(t^*_2 = 0\) or \(t^*_2 = 1\). In case of interior solutions, we have \(0 \leq I - s_0 \leq I - s \leq 2\pi C\). First, \(I \geq s_0\) so that the return of illegal activity is superior to the return of legal activity. Otherwise, as legal activity is risk-free, the individual would not allocate time to crime. Secondly, \(\pi C \geq (I - s)^2\), so that the expected sanction is above a threshold in order to avoid specialization in crime. This double condition will be supposed to be verified in what follows. The two polar cases correspond to limit cases in which the agent dedicates time exclusively to legal or illegal markets.
Comparing the two situations, it is obvious that conviction changes behaviors, with more time dedicated to illegal activities in case of conviction. This is consistent, since the expected gain on legal market is weaker for convicted individuals, making illegal market more attractive. Thus, changes in legal perspectives for past convicted individuals can reinforce criminal paths. Criminal decisions and conviction in the first period has implications for available choices and arbitration process in later periods. In a dynamic perspective, the environment of such an arbitration is endogenous because of stigma and human capital depletion behind bars. Secondly, the total expected value (on legal and illegal market) earned during the second period is lower in case of conviction. Furthermore, the more the decrease of earnings on legal market, the more the difference between expected value in the convicted and not convicted cases. We analyze later the key influence played by the severity of the penalty on crime levels.

**First period**

In the first period, the agent maximizes the expected monetary value earned over the two periods:

$$V(t_1) = V_1(t_1) + (1 - \pi t_1) V_2(t_{2n}^*, s_0) + \pi t_1 V_2(t_{2c}^*, s).$$  \[7\]

Thus, if the conditions are verified, we have an inner solution which can be written:

$$t_1^* = \frac{I - s_0 + \pi (V_2(t_{2c}^*, s) - V_2(t_{2n}^*, s_0))}{2\pi C} \leq t_{2n}^*.$$  \[8\]

We can write it as follows:

$$t_1^* = \frac{I - s_0}{2\pi C} + \frac{(s - s_0) (4\pi C - 2I + s + s_0)}{8\pi C^2}.$$  \[8\]

So that:

$$t_1^* = t_{2n}^* + \frac{(s - s_0) (4\pi C - 2I + s + s_0)}{8\pi C^2} \leq t_{2n}^*.$$  \[8\]

As $\frac{\partial^2 V(t_1^*)}{\partial t_1^2} = -2\pi C < 0$ the interior solution is a maximum for individual value in first period.

**3. Results and discussion**

If the two periods are of equal importance, total time allocated to crime by a representative agent is proportional to $T^*$, which can be written as follows:
\( T^* = t_1^* + \pi t_1^* t_{2c}^* + (1 - \pi t_1^*) t_{2n}^* \) \[9\]

It is necessary to examine how this value depends on the different parameters. Broadly speaking, the agent allocate time to crime up to the point where marginal gain of crime equals marginal loss. The later is both due to the expected sanction and opportunity loss on legal market. In what follows, we will separately analyse the impact of several parameters on \( t_1^* \), \( t_{2n}^* \) and \( t_{2c}^* \). Indeed, a numerical calculus of the total effect on \( T^* \) would imply to take account of combined effects. But, a qualitative discussion of the respective impacts of each parameter does not need such a calculus. Mathematically, for a given parameter denoted \( X \), the variation \( \frac{dT^*}{dX} \) is a combination of the variations during several periods, all of the coefficients being positives:

\[
\frac{dT^*}{dX} = \frac{\partial t_1^*}{\partial X} + \pi t_{2c}^* \frac{\partial t_1^*}{\partial X} + \pi t_1^* \frac{\partial t_{2c}^*}{\partial X} + (1 - \pi t_1^*) \frac{\partial t_{2n}^*}{\partial X} - \pi t_{2n}^* \frac{\partial t_1^*}{\partial X}
\]

so that:

\[
\frac{dT^*}{dX} = (1 + \pi (t_{2c}^* - t_{2n}^*)) \frac{\partial t_1^*}{\partial X} + \pi t_1^* \frac{\partial t_{2c}^*}{\partial X} + (1 - \pi t_1^*) \frac{\partial t_{2n}^*}{\partial X}.
\]

As \( t_{2c}^* \geq t_{2n}^* \), each of these coefficients appear to be positive. Thus, an unambiguous effect of a given parameter for each period is enough to demonstrate an unambiguous effect on aggregate time \( T^* \).

In this context, the influence of several parameters is not ambiguous. Obviously, the return \( I \) of criminal activity, has a positive impact on crime levels. Secondly, marginal loss due to crime increases with the probability of being apprehended and convicted by unit of time devoted to crime. Thirdly, the influence of the basic legal wage \( s_0 \) must be clarified.

**Proposition 1:** An increase in basic legal wage \( s_0 \) has a negative impact on time dedicated to crime, for each period.

**Proof:**

Impact on \( t_{2n}^* \). As \( t_{2n}^* = \frac{I - s_0}{2\pi C} \), the influence in second period is clearly negative for someone who has not been convicted.

Impact on \( t_{2c}^* \). As \( t_{2c}^* = \frac{I - s}{2\pi C} \) and because we have supposed – intuitively – that \( 0 \leq \frac{\partial s}{\partial s_0} \leq 1 \), the influence in second period is also negative for someone who has already been convicted.

Impact on \( t_1^* \). The influence of legal wage during first period can be calculated:

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\[
\frac{\partial t_1^*}{\partial s_0} = -1 \frac{\partial s}{\partial s_0} \frac{4\pi C - 2I + 2s}{8\pi C^2} = -1 \frac{1}{2\pi C} + \frac{\left(\frac{\partial s}{\partial s_0} - 1\right)(4\pi C - 2I + 2s)}{8\pi C^2}.
\]

We have supposed that: \(0 \leq \frac{\partial s}{\partial s_0} \leq 1\). What is more \(0 \leq I - s \leq 2\pi C\) so that

\[
\frac{\partial t_1^*}{\partial s_0} \leq 0.
\]

As \(\frac{\partial t_1^*}{\partial s_0} \leq 0\), \(\frac{\partial t_{2n}^*}{\partial s_0} \leq 0\) and \(\frac{\partial t_{2r}^*}{\partial s_0} \leq 0\) we have unambiguously \(\frac{\partial T^*}{\partial s_0} \leq 0\).

QED

Thus, an increase in basic legal wage has a negative impact, both for total time dedicated to crime and for each period, which is consistent with the idea that opportunity cost increases with the basic legal wage. The impact of the severity of punishment is more complex.

3.1. The undetermined impact of an increase in sanctions

Two effects can be distinguished. The first one is classic and due to deterrence. The second one is due to a change in perspective on the legal market for someone who has already been convicted — we have \(s(C, s_0)\) as a decreasing function with \(C\). To understand the combination of these two effects, we must analyze how it impacts each period.

**Proposition 2:** An increase in the penalty severity per unit of time dedicated to crime has unambiguously a deterrent impact in first period and for someone who has not been convicted. In case of past conviction, there is a deterrent impact for the second period if and only if \(-C \frac{\partial s}{\partial C} \leq I - s\).

**Proof:**

Impact on \(t_{2n}^*\). There is a pure deterrence effect and, unambiguously:

\[
\frac{\partial t_{2n}^*}{\partial C} = -\frac{I - s_0}{2\pi C^2} \leq 0.
\]

Impact on \(t_1^*\). During the first period, we observe that the time devoted to crime is inferior to the second period one, whatever the conviction profile of the agent. Indeed, the perspective of future changes on the legal market is anticipated and increases the deterrence effect.
As \( t_1^* = \frac{I - s_0 + \pi (V_2(t_{2c}^*, s) - V_2(t_{2n}^*, s_0))}{2\pi C} \) we can calculate the following derivative:

\[
\frac{\partial}{\partial C} \left( \frac{V_2(t_{2c}^*, s) - V_2(t_{2n}^*, s_0)}{4\pi C} + s - s_0 \right) = \frac{- (I - s)^2 + (I - s_0)^2 + 2C \frac{\partial s}{\partial C} (2\pi C - (I - s))}{4\pi C^2}
\]

As \( 0 \leq I - s_0 \leq I - s \leq 2\pi C \), \( \frac{\partial}{\partial C} \left( V_2(t_{2c}^*, s) - V_2(t_{2n}^*, s_0) \right) \leq 0 \), so that when the sanction per unit of time increases, the numerator of \( t_1^* \) decreases and the denominator increases. Thus, we can write:

\[
\frac{\partial t_1^*}{\partial C} < 0.
\]

An increase in \( C \) has two kinds of deterrence effect on the first period: the first one is a classical one, due to sanction itself; the second one is due to the fear of changes in the legal market perspectives and reinforces the role of sanction.

Impact on \( t_{2c}^* \). For the second period, in case of past conviction, time devoted to crime is superior to the non-convicted case. An increase in \( C \) has two opposite effects: the first one is a classical one, due to sanction itself; the second one is due to changes in the legal market perspectives and contradicts the basic role of sanction. The total effect between these two contradicting effects appears to be undetermined if we do not know the values of the parameters:

\[
\frac{\partial t_{2c}^*}{\partial C} = \frac{1}{2\pi C^2} \left[ -C \frac{\partial s}{\partial C} (I - s) \right].
\]

Thus, \( \frac{\partial t_{2c}^*}{\partial C} \leq 0 \) if and only if:

\[
-C \frac{\partial s}{\partial C} \leq I - s.
\]

In this latter case, as \( \frac{\partial t_1^*}{\partial C} \leq 0 \), \( \frac{\partial t_{2n}^*}{\partial C} \leq 0 \) and \( \frac{\partial t_{2c}^*}{\partial C} \leq 0 \) we have unambiguously:

\[
\frac{\partial T^*}{\partial C} \leq 0.
\]
QED

The condition given above consists in a comparison between:

- The net benefits of illegal activities, \( I - s \)
- The local change in legal market perspectives due to stigma or human capital depletion

If the effect of \( C \) on \( s \) is strong enough, compared to the net benefits provided by criminal activity, an increase of the sanction per unit of time dedicated to crime is going to increase the time allocation to criminal activities in the second period.

The deterrence condition can also be written as follows:

\[
- \frac{\partial s}{\partial C} \leq \frac{I - s}{C} = 2\pi t_{2c}^*.
\]

If crime level for convicted agents is already high, an increase in sanction through imprisonment for example is globally dissuasive (first effect dominates). But, if the time dedicated to crime is low enough, an increase in sanction induces globally an increase in crime for convicted agents, due to changes of perspectives on legal market (second effect dominates). Such a result can appear to be quite intuitive: if the fear of loss on legal market is clearly part of the sanction during the first period, the same mechanism can reinforce the convicted offenders in a criminal path. In this latter case, the impact on \( T^* \) for a representative agent is also undetermined as long as we do not know the numerical parameters of the model.

The ambiguity of penalty severity partially contradicts literature on deterrence by severity (Ehrlich [1973]; Block and Heineke [1975]; Stigler [1970]). Nevertheless, these findings are consistent with empirical evidence found in part of the literature, especially for young offenders (Lipsey [1995]; Prior and Paris [2005]). More generally, the effect of conviction and prison on legal opportunities is widely discussed (Waldfogel [1994]; Grogger [1995]; Kling [1999]), and the total impact of an increase in sanctions is difficult to determine.

But, average penalty is only one of the key issues. The modulation and application of the sanction, most notably by taking into account the criminal career, appears very important. Thus, it is necessary to analyze more carefully how to remove the undetermined impact of an increase in sanctions. Two kinds of proposal are more specifically examined and modeled. The first one relies on the possibility to differentiate the sanction between recidivists and first time offenders. The second one supposes to break the correlation between the sanction severity and changes in perspectives on legal market (education programs, paid employment in prison, alternative sentences...). We call this latter kind of alternatives “enhanced human capital” sanctions.
3.2. Increasing penalties for repeat offenders: an economic explanation

In this section, we assume a differentiated penalty between first time and repeat offenders. As seen above, this practice is common, rooted in our civil and criminal codes, but the existing works have not explicitly analyzed the potential role of changes of perspectives on legal market. From our point of view, it is indeed a key explanatory factor. Formally, call $C_1$ and $C_2$ the penalties respectively applied to first time and repeat offenders per unit of time dedicated to crime. The wage per unit of time is $s_0$ if the individual has not been convicted and is written $s(C_1, s_0)$ in case of conviction, later denoted as $s$.

**Proposition 3:** Let us differentiate the sanctions per unit of time between first time and repeat offenders, according to the class of rules:

$$C_2 = AC_1 \left( \frac{I - s}{I - s_0} \right).$$  

with $1 \leq A \leq \left( \frac{I - s}{I - s_0} \right)$ so that:

$$C_1 \left( \frac{I - s}{I - s_0} \right) \leq C_2 \leq C_1 \left( \frac{I - s}{I - s_0} \right)^2.$$  

According to this proposed scheme, total time dedicated to crime is unambiguously decreasing with the penalty severity per unit of time $C_1$.

**Proof:**

1) A differentiation without specification rule.

In the differentiated framework, it is possible to find for the second period:

$$t_{2n}^* = \frac{I - s_0}{2\pi C_1}$$  

$$t_{2c}^* = \frac{I - s_{2c}}{2\pi C_2}$$  

And, for the first period:

$$t_1^* = \frac{I - s_0 + \pi \left( \frac{(I - s)^2}{4\pi C_2} + s - \frac{(I - s_0)^2}{4\pi C_1} - s_0 \right)}{2\pi C_1}.$$  

Impact on $t_{2n}^*$. For someone who has not been convicted, there is a pure deterrence effect, and unambiguously:

$$\frac{\partial t_{2n}^*}{\partial C_1} = -\frac{I - s_0}{2\pi C_1^2} \leq 0.$$  

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Impact on \( t_{2c}^* \). For a convicted individual:

\[
\frac{\partial t_{2c}^*}{\partial C_1} = -\frac{\partial s}{2\pi C_2} \geq 0
\]

Impact on \( t_1^* \).

\[
\frac{\partial t_1^*}{\partial C_1} = 2\pi C_1 \left( \frac{2C_1 \frac{\partial s}{\partial C_1} (I-s)}{4\pi C_2} + \frac{\partial s}{\partial C_1} + \frac{(I-s_0)^2}{4\pi C_2^2} \right)
\]

It is not possible to conclude about the sign of this derivative without specifying the evolution of \( C_2 \) with the evolution of \( C_1 \). What is more, \( \frac{\partial t_{2c}^*}{\partial C_1} \geq 0 \).

Thus, it is not possible to conclude about the sign of \( \frac{\partial T^*}{\partial C_1} \geq 0 \). For this reason, we propose the following class of rules in increasing penalties:

\[
C_2 = AC_1 \left( \frac{I-s}{I-s_0} \right).
\]

We suppose \( A \geq 1 \) so that \( C_2 \geq C_1 \left( \frac{I-s}{I-s_0} \right) \geq C_1 \)

And the conditions for interior solutions: \( 0 \leq I-s_0 \leq 2\pi C_1 \) which implies \( 0 \leq I-s \leq 2\pi C_2 \).

2) A differentiation with a specification rule.

In this new framework, we can write:

\[
t_{2n}^* = \frac{I-s_0}{2\pi C_1}
\]

\[
t_{2c}^* = \frac{I-s}{2\pi C_2} = \frac{I-s_0}{2\pi AC_1} \leq t_{2n}^*
\]

\[
V_2 \left( t_{2n}^*, s_0 \right) = \frac{(I-s_0)^2}{4\pi C_1} + s_0 \text{ and }
\]

\[
V_2 \left( t_{2c}^*, s \right) = s(1-t_{2c}^* + lt_{2c}^* - \pi C_2 (t_{2c}^*)^2 = \frac{(I-s)(I-s_0)}{4\pi AC_1} + s
\]

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And the time dedicated to crime in the first period can be written:

$$t_1^* = \frac{I - s_0 + \pi (V_2 (t_{2c}^*, s) - V_2 (t_{2n}^*, s_0))}{2\pi C_1}$$

and:

$$t_1^* = \frac{I - s_0 + \pi \left[ (s - s_0) + \frac{I - s_0}{4\pi C_1} \left( \frac{I - s}{A} - (I - s_0) \right) \right]}{2\pi C_1}$$

Impact on $t_{2n}^*$. In this new framework, it is obvious that:

$$\frac{\partial t_{2n}^*}{\partial C_1} = - \frac{I - s_0}{2\pi C_1^2} \leq 0$$

Impact on $t_{2c}^*$. 

$$\frac{\partial t_{2c}^*}{\partial C_1} = - \frac{I - s_0}{2\pi AC_1^2} \leq 0$$

Impact on $t_1^*$. For the first period:

$$\frac{\partial}{\partial C_1} (V_2 (t_{2c}^*, s) - V_2 (t_{2n}^*, s_0)) = \frac{\partial}{\partial C_1} \left( (s - s_0) + \frac{I - s_0}{4\pi C_1} \left( \frac{I - s}{A} - (I - s_0) \right) \right), \text{i.e.}$$

$$\frac{\partial}{\partial C_1} (V(t_{2c}^*, s) - V(t_{2n}^*, s_0)) = \frac{\partial s}{\partial C_1} \left( 1 - \frac{I - s_0}{4\pi C_1} \right) + \frac{(I - s_0) \left( I - s_0 - \frac{I - s}{A} \right)}{4\pi C_1^2}$$

As $0 \leq I - s_0 \leq 2\pi C_1$, $I - s_0 \leq 4\pi AC_1$ and the first term of this derivative is negative. The second part is also negative if $A = 1$. Otherwise, the negativity is verified as long as $A \leq \left( \frac{I - s}{I - s_0} \right)$.

If $1 \leq A \leq \left( \frac{I - s}{I - s_0} \right)$, we have $\frac{\partial}{\partial C_1} (V(t_{2c}^*, s) - V(t_{2n}^*, s_0)) \leq 0$. Thus, when the sanction per unit of time increases, the numerator of $t_1^*$ decreases and the denominator increases. We can write:

$$\frac{\partial t_1^*}{\partial C_1} \leq 0.$$  

Unambiguously, if $C_2 = AC_1 \left( \frac{I - s}{I - s_0} \right)$, with $1 \leq A \leq \left( \frac{I - s}{I - s_0} \right)$ as $\frac{\partial t_1^*}{\partial C_1} \leq 0$, $\frac{\partial t_{2n}^*}{\partial C_1} \leq 0$ and $\frac{\partial t_{2c}^*}{\partial C_1} \leq 0$ we have unambiguously:

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\[
\frac{\partial T^*}{\partial C_1} \leq 0. 
\]

QED

Thus, an increase in \( C_1 \) would have two kinds of deterrence effect on total crime devoted to crime:

- The first one is a classical one, due to sanction itself;
- The second one, due to changes in the legal market perspectives, reinforces the deterrence effect of sanction if the proposed scheme is adopted for repeat offenders. The maximum threshold condition weighing on the parameter \( A \) signifies that such an influence of \( C_1 \) on legal perspectives implies to have \( C_2 \) under this threshold.

Therefore, the threat of strong enough punishment for repeat offenders is able to prevent the effect of stigma and human capital depletion on criminal paths. Thus, the impact of severity in first period seems no longer ambiguous as far as the severity in second period follows a given scheme. This constitutes a clear explanation for enhanced penalties for repeat offenders. One can object that this kind of solution is highly questionable since it raises the issue of the subsistence of former detainees (remaining stigmatized on legal market). That is why we examine and model below another kind of solution to remove the undetermined impact of an increase in sanction severity.

3.3. Enhanced human capital sanctions: an economic explanation

As we know, the depletion of legal opportunities due to past conviction depends on the severity of the sanction per unit of time dedicated to crime. More precisely, two effects are distinguished: first a stigmatization / reputational cost effect which is independent from the penalty severity; secondly, a human capital depletion effect due to the time spent behind bars and which evolves with the penalty severity. The stigma or reputational costs, conceived as in Rasmusen [1996], Iacobucci [2014] or Mungan [2016] occur as long as a given individual has been convicted. Human capital obsolescence due to prison itself increases with the penalty severity as shown in Mocan et al. [2005] or Aizer and Doyle [2015]. That is why \( s ( C, s_0 ) \) has been considered in the instant paper as a decreasing function with \( C \). Most of time, changes in legal perspectives are due both to stigma and human capital obsolescence associated with time behind bars. If stigma can be a binary process (an employer stigmatizes someone if and only if he has been convicted), human capital depreciation depends crucially on the length of the sanction per unit of time, \( ie \) on \( C \).

One option to alleviate the ambiguous effect of severity is to break the correlation between the severity of the sanction per unit of time and the depletion of legal opportunities: developing education or paid employment
in prison; developing alternative sanctions... A simple formalization of this process is proposed below.

**Proposition 4:** If \( s(C, s_0) = \alpha s_0 \) with \( \alpha \in [0, 1] \), so that human capital and second period wages do not decrease with \( C \), there is unambiguously a deterrent effect of penalty severity.

**Proof:**

In such a context:

\[
\frac{\partial s}{\partial C} = 0.
\]

And the condition stated in the proof of Proposition 2 is unambiguously verified:

\[
-C \frac{\partial s}{\partial C} \leq I - s = I - \alpha s_0
\]

QED

Even if stigma induces an instantaneous fall in legal opportunities, education or paid employment can compensate human capital depreciation. Thus, legal wage does not depend on \( C \) and an increase in \( C \) has globally a deterrence effect, both for convicted and non-convicted individuals. As Pyne [2010] showed, the juvenile justice system characteristics – more lenient than the adult one and with higher expenditures by inmate – are efficient responses to the fact that incarceration reduces human capital acquisition by juveniles. In the instant paper, we argue that imprisonment has also an influence on the evolution of human capital for adults and we give a rationale for enhanced human capital penalties.

Unlike the first solution to remove the undetermined impact of penalty severity, the second one allows to provide a decent standard of living for former convicted. Little empirical evidence has been produced to measure the efficiency of alternative or enhanced human capital sanctions. The few empirical evaluations include prison conditions, probation, parole systems or electronic monitoring as underlined in introduction. Another example of enhanced human capital sanction is Community Services, which are implemented in several European countries. In such kind of sanctions, both stigma and human capital depletion do not increase with the length of the sanction as the penalty itself is based on time dedicated to legal activity. Therefore, there is a change in arbitration process between legal and illegal activities. Restorative Justice – *Referral orders* in Great Britain or *Halt Scheme* in Netherlands – aims at bringing stakeholders together in order to reach an agreement, which also modify stigma or human capital depletion. If such kind of enhanced human capital sanctions seem to be encouraging (Van Hees [1999]; Maxwell and Morris [2006]), future research is needed to understand how these alternatives compare in terms of human capital and stigma with regard to future incentives to commit crime.
Conclusion

The optimal design of the law enforcement policy supposes an understanding of criminal behavior over time. The purpose of this article is to propose theoretical keys based on a dynamic model of time allocation between legal work and criminal activity. Thanks to this model, the undetermined impact of an increase in penalty severity is highlighted. In this context, stigma and human capital depletion are not necessary part of a deterrence policy. Two extensions are discussed: heavier penalty for repeat offenders and enhanced human capital sanctions. Several extensions to this work would deserve to be conducted. First, more works need to be done to understand the role of sanctions and changes in perspectives on legal market when legal and illegal activities can be substitutes as well as complementary. Our assumption is indeed a simplification as illegal earnings may appear outside as inside a legal working framework. Then, the individual relation to time could be considered in a model including several periods, as actualization rates appear to be crucial in dynamic criminal choice. Finally, it would be really interesting to test whether such theoretical work – and most notably the two kinds of methods which are presented – can be verified on a country panel with different penalty schemes.

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