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Abstract

The recent increase of offences provoked a call for longer prison terms under the assumption that longer prison terms reduce offences. A critical barrier for examining this assumption is the unavailability of consistent data on offences and the recidivism due to the separation of various agencies in the criminal justice. This paper examines the assumption by proposing a total system model over separated agencies to estimate the figures needed. This model also enables to forecast the caseload of the system and to identify critical factors for the crime control.

Key words : Aging effect ; Feedback model ; Prison term ; Recidivism ; Total criminal justice system ; Stability

1. Introduction

The increase of offences and juvenile delinquency in the recent decades in several countries provoked an opinion to demand longer prison terms for offences and juvenile delinquency. This opinion is based on the assumption that longer prison terms contribute to reducing the rates or the numbers of offences and juvenile delinquency. This assumption has been examined in various ways : the minimization of disutility of offenders (e.g., Ehrlich 1973), the minimization of crimes subject to the limit of prison capacity (Blumstein and Nagin 1978), the selective imprisonment subject to the budget constraint (Chaiken and Rolph 1980) and others. These approaches are based on exquisitely conceptualized modelings with elaborate ideas to solve obstacles of limited availability of data. Though highly interesting and informative, their assumptions are not realistic or their models are too simple to reflect the reality despite their great merits to overcome the limited data availability.

This paper examines this assumption in a different way. A critical barrier for this examination is the unavailability of consistent data on offences and juvenile delinquency and the associated recidivism. The inconsistency of data comes from the complexity that the criminal justice system is composed of independent agencies. Our approach is to propose an overall model to estimate data needed.

The crime problem is complicated in that it lies on the interface among the legislative (lawmaking), administrative (arresting, protecting, correcting and rehabilitating) and judicial (judging) organs each of which has its own principle. The laws were made with an idea of the House while they are executed with another idea of the administrative organ and so on. The administrative organ itself is composed of a variety of agencies (police, relief facilities, prison and so on) corresponding to a variety of functions. These agencies are under various ministries and some of them are only formally under the ministries. In the Japanese system, National Police Agency is under National Public Safety Commission, Public Procurator's Office is only formally under Ministry of Justice with a virtual independence of it, correction facilities are under Correction Bureau of Ministry of Justice, rehabilitation facilities are under Rehabilitation Bureau of Ministry of Justice and so on. The complexity increases by the intervention of the juvenile authorities (e.g., the juvenile court as a part of the Family Court, the juvenile reformatory facilities under Ministry of Justice) in the criminal problem as main actors in the juvenile problem over the judicial police and the criminal court. From another view point, the crime and juvenile delinquency problems lie between the regulation and education(or correction, rehabilitation) problems which are quite different or even conflicting each other. Each agency makes statistics with its own idea. This results in mutually inconsistent statistics, resulting from the difference of definitions which reflects the difference of ideas. This situation requires, for our analysis, an inter-agency model with aid of which consistent figures are to be systematically estimated from statistical data given by each agency.

The total criminal justice system (TCJS) has already been modeled across a variety of agencies (Blumstein and Larson 1969, Belkin, Blumstein and Glass 1973, Blumstein and Graddy 1981). It is classified into two categories : linear models and feedback models (Blumstein and Larson 1969). Linear models handle only the forward flow of offenders along a straight line through the system without loop. These are useful in calculating the incremental cost for increment of offences. Feedback models include the recycle of offenders through the system, i.e., the recidivism. As a critical problem of the offence is the possibility of re-offence in the future (the re-offence accounts for the major portion of the total offences), this paper presents a feedback model to handle the recidivism.

It has long been believed that offence and re-offence significantly depend on ages especially for younger offenders and juvenile delinquents. This belief implies that the re-offence rate significantly depends on the length of prison term especially for younger offenders and juvenile delinquents because a longer prison term makes them older. This is critical because younger offenders and juvenile delinquents account for the majority of offenders. In some criminal justice analyses, the offence and re-offence rates are aggregated over ages presumably for the simplicity or for the data unavailability though ages are considered in interpretation of real data analyses. In the aforementioned TCJS feedback models, the re-arrest probability depends on ages exogenously in a numeric model (Blumstein and the left-half plane in the complex plane. Thus it is asyptotically stable without oscillation. That is, the system asymptotically approaches an equilibrium point instead of exploding to the infinity. This is a desirable property but its acceptability depends on the equilibrium value which might be inacceptable to the public. Thus the effort for reducing the offence rate is still needed.

Assuming the constant input v(t) = c independently of t and applying the Laplace inverse transform (i.e., the Bromwich integral), we obtain a stationary response :

$$m(t) = c\,\{1 - q \exp[-((1-q)/d)\,t]\}/\,(1 - q) = c\,\{1 - q \exp[(q-1)t/d]\}/(1 - q)$$

Equivalently, letting $T = d/(1 - q)$,

$$m(t) = m_0 \exp(-t/T) + m_\infty \{1 - \exp(-t/T)\} \qquad (1)$$

Using (1), a direct electric circuit model analogical to the model in Fig. 1 is depicted by Fig. 3 where the electric current corresponds to the flow of offenders. This system is determined by the time constant T and the values of m at t = 0 and t = ∞. In this circuit system the coile size which corresponds to the average length of time elapsed between the consecutive offences of individual offenders does not affect the stationary state if $q < 1$. Here m(t) asymptotically approaches the upper limit $c / (1 - q)$ from below in a concave manner as t increases. This means that the system has the finite equilibrium for $q < 1$ but that m(t) diverges to the infinity as q approaches 1. An American estimate is $q = 0.875$ (Belkin, Blumstein and Glass 1973). This value may be inacceptable to the public because then m = 8 c, that is, the re-offence accounts for 7/8 of the total offences. This means that reducing the re-offence rate is critically effective for reducing the total offences (Blumstein and Larson1969).

The input of the unit step (Fig. 4) to the system is considered as the cohort input and can be used in analysing the re-offence process of each age

Larson 1969) and the first arrest rate depends on ages again exogenously in analytical models (Belkin, Blumstein and Glass 1973, Blumstein and Graddy 1981). This paper augments a TCJS feedback model explicitly with the aging effect as an endogenous variable and examines the aforementioned assumption with its aid. In association with considerations of ages, our proposed model explicitly discriminate the juveniles from the adults in contrast to their mixture in the existing TCJS feedback models.

2. Prototype model

The existing feedback models may be simplified as in Fig. 1 where v and r denote the number of first (or virgin) offenders and that of re-offenders, respectively, m denotes the total number of offenders ($m = v + r$), q denotes the re-offence rate, and the time elapsed between an offence and the subsequent one of a re-offender follows the exponential distribution with the mean d (Belkin, Blumstein and Glass 1973). Here the re-offence denotes the incident that a former offender who has been released from the crminal justice process offends again no matter how many times he had offended before. This simplified model will be referred to as the prototype model.

r can be expressed by the convolution(Blumstein and Graddy 1981). This eases to apply the Laplace transform (the Laplace transform may be expressed as $F(s) = \int_0^\infty \exp(-st)\, f(t)\, dt$ for real s positive). Now Fig. 2 illustrates the prototype model transformed in the s domain (Belkin, Blumstein and Glass 1973).

This model contains a positive feedback loop. As a positive feedback model sometimes diverges or oscillates, the stability of the system must be examined. It can easily be shown that the poles are negative and located in group arrested at $t = 0$. This analysis will be referred to as the cohort analysis hereafter. (Here the cohort denotes a set of first offenders at age 14 or 20, referred to hereafter as the cohort 14 or cohort 20, respectively). The external input is, for $T = d/(1 - q)$,

$$V(s) = c\{1 - \exp(-T/s)\}/s$$

in the s domain. Then

$$m(t) = c\,[1 - q\exp\{-(1 - q)\,t/d\}]/(1 - q) \qquad 0 \le t < T \qquad (2)$$

$$m(t) = c\,q\,[\exp\{(1 - q)\,T/d\} - 1]\exp\{-(1 - q)\,t/d\}/(1 - q) \qquad T \le t \qquad (3)$$

Rewriting (3),

$$m(t) = C\exp(-t/T) \qquad (3')$$

with a constant C for t after the time constant T. (3') means that the number of re-offenders of this cohort depends on $\exp(-t/T)$ and the number of non re-offenders depends on $1 - \exp(-t/T)$. Thus the length of time from the first offence to the final one of an offender follows the exponential distribution with the mean $d/(1 - q)$. The expected total number of offences of an offender of a cohort is $\int_0^\infty m(t)\,dt$.

From m(t) above which is continuous, the Z transform generates, for j being non-negative integers,

$$m(jT) = c\,d/(d - q) \qquad j = 0$$

$$m(jT) = c\,q\,\{d/(d - q)\}^j \exp(-jT/d)/(d - q) \qquad j = 1$$

The expected total number of offences of an offender of a cohort in question is, under the assumption that an offender is active for n years,

$$c\int_0^T [1 - q\exp\{-(1 - q)\,t/d\}]\,dt/(1 - q)$$

$$+\, c\,q\,[\exp\{(1 - q)\,T/d\} - 1]\int_T^{nT} \exp\{-(1 - q)\,t/d\}\,dt/(1 - q)$$

$$= c[1 + q\,d\exp\{-(1 - q)/d\} - 1\}\exp\{-(1 - q)(n - 1)/d\}/(1 - q)]/(1 - q)$$

This formula does not consider that the rate of re-offence decreases with age.

For analysing the effect of the length of prison terms on the re-offence, the prototype model is extended so as to have the time delay at two places as the prison term and the time elapsed between the release from prison and the re-offence. If not prisoned, the formerly defined time elapsed equals the newly defined time elapsed. Let the prison term and the newly defined time elapsed follow the exponential distributions with the mean π and ∂, respectively. The exponential distribution with the mean π = 1.2 year gives a fairly good fit to the data of prisoners released in 1984 (data source : The Correction Statistics 1985 by the Ministry of Justice of Japan).

The transmission function H of the two delays together along the loop with the branch ignored in the extended prototype model (Fig. 5) is

$$H(s) = \{(s + 1/\partial)(s + 1/\pi)\} / \{s^2 + (1/\partial + 1/\pi)s + (1 - q)\pi/\partial\} \qquad (4)$$

Let u_1 and u_2 denote the roots of the denominator on the right hand side of (4). Then

$$u_1, u_2 = [-(1/\partial + 1/\pi) \pm \{(1/\partial - 1/\pi)^2 + 4q\pi/\partial\}^{1/2}]/2$$

are negative real. Thus the system is again asymptotically stable without oscillation though it contains a positive feedback loop. In the t domain,

$$m(t) = c/(1 - q) + [q\{u_2 \exp(u_1 t) - u_1 \exp(u_2 t)\}]/\{(1 - q)(u_1 - u_2)\}$$

This time m(t) is again monotone increasing in t but first in a convex and then in a concave manner with an infection point in the middle. As far as π is finite, again m(t) asymptotically approaches $c/(1 - q)$ in the stationary state. This is theoretically awkward in that the survivals of former offenders would decrease by death for extremely long π so that it is theoretically possible to make r(t) = 0. Thus the extended prototype model is too insensitive to the aging effect for our purpose. This again requires to consider the aging or the survival rate of arrestees.

3. Feedback model with aging.

Our proposed feedback model with aging effect is depicted by Fig. 6. As our focus is on ages, our model is discrete with the sampling interval of one year. As the juveniles of age less than 14 is not responsible for offences in the Japanese regulation, they are neglected from our model. For the simplicity, persons over age 70 are also neglected for whom the rates of offences and re-offences are quite low. This negligence is safe because offenders or re-offenders over age 70 are usually suspended even if they offend. Thus, our model handles persons from age 14 upto age 69 inclusive. Also for the simplicity of a discrete model, it is handled as if offences take place all at the beginning of each year.

The offence is defined in our analysis as the arrest by police as in the aforementioned TCJS feedback models for a couple of reasons. The incident of offence itself is difficult to detect or to define while the exact number of arrests and ages of arrestees are readily known. Although the exact data of detected offences is available, offenders and naturally their ages are not identified for many of detected offences. The arrest is not the same as the identified offence, the prosecution or the guilty because many identified offenders may not be arrested, arrests may be false or cases may be dismissed, suspended or acquitted. But the rate of arrest is quite high for serious offences and the rates of false arrests and acquittals are quite low in Japan. The suspension and the dismissal are usually decided for minor offences. Therefore the number of arrest can be considered as the closest to the number of serious offences among available official data and is relevant enough to the aim of our analysis because threats to the social life with which we are concerned are due to serious offences. It is also relevant to our analysis because our final purpose is to deter offences and the arrest is observed to have a strong deterrent effect (Montmarquette and Nerlove1985). It should be mentioned that little demographic bias is observed for arrests (Hindelang, Hirschi and Weis 1979) and that the arrest data is relatively free from the selection bias because the arrest is the first stage in the flow prior to selections (Maltz and Pollock 1980, Tierney 1983, Zatz and Hagan 1985). For the juveniles under age 14 who can not be arrested but guided or protected as a matter of terminology, the guidance and the protection are considered as equivalent to the arrest when data for juvenile of age less than 14 are needed. To be precise, the occupational failures most of which are the traffic offences are omitted from the arrest because they are usually not considered as criminal acts with which we are concerned. Now the re-offence denotes the incident that a former arrestee (a person who has been arrested at least once) is arrested again for another suspicion in our model.

The arrest data by National Police Agency, Japan describes the number of arrestees by age every year, but ages are not known by offence type or by category of first arrest or re-arrest.

As the age is handled discretely, the exponential distribution which is continuous is replaced with the geometric distribution which is discrete. In statistical terms, a former arrestee tries every year the two possibilities : re-arrest or no-arrest with the probabilities p and 1 - p, respectively. In reality p depends on age but in this paper, by the limit of data, p depends only on whether a former arrestee is juvenile or adult. The average time delay from the arrest to the imprisonment is safely assumed to be less than one year in Japan because it is usually less than one year for the minor offence and the minor offences account for the overwhelming majority cases. That is, its mean and its median are less than the unit of time. Hence the variation of the delay is neglected and the delay is assumed as constant in that the prisonment of an arrestee starts in the same year as his offending. In a US study (Belkin, Blumstein and Glass 1973), the delay is included in the time elapsed between arrests.

In this model depicted by Fig. 6, X_i (i = 1, ..., 17) denotes a vector with 56 components each denoting the number of arrestees from age 14 to 69 denoted by $x_{i,1}$ to $x_{i,56}$, respectively. X_1 denotes a vector of numbers of the first (or virgin) arrestees of each age. X_2 denotes a vector of the number of the total arrestees of each age. X_3 denotes a vector of the number of adult arrestees of each age with X_4 denotes a vector of adult prisoners of each age. X_5 denotes a vector of the number of released prisoners of each age. X_6 denotes a vector of the number of released prisoners to resume offending activities. X_7 denotes a vector of the number of released prisoners desisting the offending activities. X_8 denotes the number of adult arrestees not imprisoned. X_9 denotes a vector of the number of adult released arrestees not imprisoned who resume the offending activities. X_{10} denotes a vector of the number of adult arrestees who desist offending activities. X_{16} denotes the adult recidivists of each age. Note that $x_{i,j} = 0$ for i = 3, ... , 10 and 16 and $j \leq 7$ which denotes age ≤ 20. X_{11} denotes a vector of the number of juvenile arrestees of each age. X_{12} denotes a vector of the number of juvenile arrestees to resume offending activities of each age. X_{13} denotes a vector of the number of juvenile arrestees to desist offending activities of each age. Note that $x_{i,j} = 0$ for i = 11, ... , 13 and $j \geq 8$ which denotes age $\geq$ 21. X_{14} denotes a vector of released arrestees to resume offending activities of each age. X_{15} denotes the number of recidivists not imprisoned previously of each age. X_{17} denotes a vector of the number of the total recidivists of each age. A_1 denotes a discriminator which discriminates the juveniles from the adults. A_2 denotes a transmission function to judge and to send the convicted to the prison. B_j (j = 1, 2, 3) denotes orthogonal matrices with the rate of recidivism for each age on the principal diagonal. The average length of prison terms is denoted by μ which is treated here as a constant parameter. p_1 and p_2 denote vectors of the probability of recidivism in a year for each age. For the simplicity all the juveniles are assumed to be released without staying in juvenile facilities because the numbers of juveniles in such facilities and their re-delinquency are quite limited and the average length of their stay therein is shorter than our time unit.

To our discrete model with one year as the unit time the aging operation is applied via the aging matrix D. Now the following relations are easily obtained from Fig. 6. The current year is denoted by n.

$$X_2(n) = X_1(n) + X_{17}(n)$$

$$X_3(n) = A_1 * X_2(n)$$

$$X_4(n) = A_2 * X_3(n) = A_2 * A_1 * X_2(n)$$

$$X_{11}(n) = (I - A_1) * X_2(n)$$

$$X_8(n) = (I - A_2) * X_3(n) = (I - A_2) * A_1 * X_2(n)$$

$$X_5(n) = D^{\mu} * X_4(n - \mu) = D^{\mu} * A_2 * A_1 * X_2(n - \mu)$$

$$X_6(n) = B_1 * X_5(n) = B_1 * D^{\mu} * A_2 * A_1 * X_2(n - \mu) \equiv C_2 * X_2(n - \mu)$$

$$X7(n) = X5(n) - X6(n) = D^{\mu} * A_2 * A_1 * X_2(n-\mu) - C_2 * X_2(n - \mu)$$

$$X_9(n) = B_2 * X_8(n) = B_2 * (I - A_2) * A_1 * X_2(n)$$

$$X_{10}(n) = X_8(n) - X_9(n) = (I - B_2) * (I - A_2) * A_1 * X_2(n)$$

$$X_{12}(n) = B_3 * X_{11}(n) = B_3 * (I - A_1) * X_2(n)$$

$$X_{13}(n) = X_{11}(n) - X_{12}(n) = (I - B_3) * (I - A_1) * X_2(n)$$

$$X_{14}(n) = X_9(n) + X_{12}(n) = \{B_2 * (I - A_2) * A_1 + B_3 * (I - A_1)\} * X_2(n)$$

$$\equiv C_1 * X_2(n)$$

$$X_{15}(n) = p_1 * \Sigma_{i=0}^{n} D_1^{\,i} * X_{14}(n - i)$$

$$= p_1 * \Sigma_{i=0}^{n} D_1^{\,i} * C_1 * X_2(n - i)$$

$$X_{16}(n) = p_2 * \Sigma_{i=0}^{n} D_2^{\,i} * X_{16}(n - i)$$

$$= p_2 * \Sigma_{i=0}^{n-\mu} D_2^{\,i} * C_2 * X_2(n - \mu - i)$$

$$X_{17}(n) = X_{15}(n) + X_{16}(n)$$

$$= p_1 * \Sigma_{i=0}^{n} D_1^{\,i} * C_1 * X_2(n - i)$$

$$+ p_2 * \Sigma_{i=0}^{n-\mu} D_2^{\,i} * C_2 * X_2(n - \mu - i)$$

$$D = \begin{matrix} 0, 0 \ldots\ldots\ldots\ldots 0, 0 \\ 1, 0 \ldots\ldots\ldots\ldots 0, 0 \\ 0, 1 \ldots\ldots\ldots\ldots 0, 0 \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ 0, 0 \ldots\ldots\ldots\ldots 1, 0 \end{matrix}$$

$$D_j = (1 - p_j) * D \qquad j = 1, 2$$

Thus, for all $i = 3, 4, \ldots, 17$, X_i are expressed by X_2 which is known as the arrest statistics for every year.

Formally, X_1 can also be expressed by X_2 as

$$X_1(n) = X_2(n) - X_{17}(n)$$

and

$$X_{17}(n) = p_1 * \Sigma_{i=0}^{n} D_1^{\,i} * C_1 * X_2(n - i)$$
$$+ p_2 * \Sigma_{i=0}^{n-\mu} D_2^{\,i} * C_2 * X_2(n - \mu - i).$$

But X_1 will be treated as an independent input and denoted by V for the purpose of clearness. Note that $X_{17}(0) > 0$ because some offenders pass through CJS within a year.

Using the above formulas,

$$X_2(n) = X_1(n) + X_{17}(n)$$
$$= V(n) + p_1 * \Sigma_{i=0}^{n} D_1^{\,i} * C_1 * X_2(n - i)$$
$$+ p_2 * \Sigma_{i=0}^{n-\mu} D_2^{\,i} * C_2 * X_2(n - \mu - i)$$
$$= V(n) + p_1 * \{C_1 * X_2(n) + D_1 * C_1 * X_2(n-1) + \dots + D_1^{\,n} * C_1 * X_2(0)\}$$
$$+ p_2 * \{C_2 * X_2(n-\mu) + \dots + D_2 * C_2 * X_2(0)\}$$

Then,

$$X_2(n) = F * V(n) + E_1 * X_2(n-1) + \dots + E_i * X_2(n-i) + \dots + E_n * X_2(0) \qquad (5)$$

where F is defined for C_1 and C_2 which were defined above with X_{14} and X_6,

$$F = (I - p_1 * C_1)^{-1} \qquad \mu \geq 1$$
$$F = (I - p_1 * C_1 - p_2 * C_2)^{-1} \qquad \mu = 0$$

and E's are defined for $\mu \geq 1$,

$$E_i = p_2 * F * D_1^{\,i} * C_1 \qquad i = 1, 2, \dots, \mu - 1$$
$$E_i = p_1 * F * D_1^{\,i} * C_1 + p_2 * F * D_2^{\,i-\mu} * C_2 \qquad i = \mu, \dots, n$$

and for $\mu = 0$,

$$E_i = p_1 * F * D_1^{\,i} * C_1 + p_2 * F * D_2^{\,i} * C_2 \qquad i = 1, 2, \dots, n$$

The equation (5) means that the number of arrestees at n depends on the numbers of vergin arrestees at n and the numbers of arrestees in the past.

Alternatively, X_2 of every year is expressed by V of every year.

$$
\begin{pmatrix}
1, -E_1, -E_2, \dots, -E_i, \dots\dots, -E_n \\
0, 1, -E_1, \dots, -E_{i-1}, \dots, -E_{n-1} \\
\dots\dots \\
0, 0, 0, \dots, 1, \dots\dots, -E_{n-i+1} \\
\dots\dots \\
0, 0, 0, \dots\dots, 0, \dots, 1, -E_1 \\
0, 0, 0, \dots\dots, 0, \dots, 0, 1
\end{pmatrix}
\begin{pmatrix}
X_2(n) \\ X_2(n-1) \\ \dots \\ X_2(n-i-1) \\ \dots \\ X_2(1) \\ X_2(0)
\end{pmatrix}
= F
\begin{pmatrix}
V(n) \\ V(n-1) \\ \dots \\ V(n-i-1) \\ \dots \\ V(1) \\ V(0)
\end{pmatrix}
\quad (6)
$$

Using (5) or (6) provides the number of arrestees for each age.

4. Parameter estimation

In view that the assumption on the stationarity of parameter values was found reasonable in US studies(Belkin, Blumstein and Glass 1973, Blumstein and Cohen 1979), the situation of the Japanese society which is more stable than the US society with respect to crimes in these decades may allow to assume that parameter values are almost stationary. Thus parameter values are taken from the 1983 statistics unless otherwise stated.

The Crime Statistics by the Ministry of Justice of Japan does not describe the ages of first arrestees and re-arrestees. Thus it is needed to estimate $x_{1,j}$ for age index j (which denotes age j + 13). The Statistics show that the ratio of first arrestees to re-arrestees is almost equal for the juveniles (70.2 : 29.8) and adults (68.3 : 31.7). This indicates the stability of the ratio for ages. In the Statistics the re-arrestee includes the juvenile arrestee with former guidance and the protection experiences due to illegal acts prior to their age 14. Using the ratios for the juveniles and adults, the number of arrestees the data of which is available for each age as $x_{2,j}$ is partitioned into first arrestees and re-arrestees for each age separately of juveniles and adults as $x_{1,j}$ and $x_{17,j}$ for j = 1 (age 14), ... , 56 (age 69) for each year.

The probabilities of recidivism in a year, p_1 and p_2 for the non-prisoned (juveniles and adults) and the prisoned (adults), respectively, are estimated by the least square method using the geometric distribution function as was stated above. The Data by Justice Research Institute and the Correction Statistics by Division of Justice Studies, Justice Ministers Office, both under the Ministry of Justice provide data on the frequency of years after the release. The associated density can be formally expressed below for j = 1 or 2, respectively, where i denotes the years after the release.

$\text{Prob}_j\{\text{re-arrested i year after the release}\} = p_j\,(1 - p_j)^i \qquad i = 0, 1, 2, \ldots$

This yields $p_1 = 0.268$ and $p_2 = 0.327$, respectively, with good fittings despite slight under-estimation for $i \le 1$ and slight over-estimation for $i \ge 4$. This deviation may be interpreted that the recidivists population consists in two groups with one mainly for $i \le 1$ and the other mainly for $i \ge 4$. The estimated values of p_1 and p_2 imply the average periods between arrests is 2.80 years and 2.07 years for the non-prisoned and the prisoned, respectively. p1 and p2 are treated as independent of ages due to the data unavailability.

The rates of recidivism denoted by B_i, i = 1,2 and 3, are estimated for ages by using the same Data and the Statistics as p_1 and p_2. The recidivism ratios for ages denoted by $b_{i,j}$ are formulated (see Fig. 6) as

$b_{1,j} = \Sigma_{k=-K}^{0} s_{1,j+k} / x_{5,j}$

$b_{i,j} = \Sigma_{k=0}^{K} s_{i,j+k} / x_{i',j}$ $\quad$ i' = 8, 11 for i = 2, 3, respectively

where $s_{i,j+k}$ denotes the numbers of recidivists of age index j + k (i.e., age j + k + 13) among $X_{i'}$ of age index j (i.e., age j + 13) where i' = 5 for i = 1. The assumption underlying this formulation is that the ratio $s_{i,j} : s_{i,j-1}$ (for i = 1) or $s_{i,j+1}$ (for i = 2,3) : ... : $s_{i,j+K}$ remains unchanged for K + 1 years. This assumption is valid for $K \leq 2$. Thus K = 2 in our estimation. B_1 which is only for adults nearly monotonically decreases in ages with a minor oscillation in ages 37 - 49. B_2 increases nearly monotonically in the ages of 20s and hits the maximum at age 29. The result that B_2 is not high for the ages of lower 20s is interpreted that young adults who joined offending activities desist the activities with a high rate. B_2 decreases almost monotonically for higher ages with little oscillation. B_3 decreases in a convex manner for ages 14 to 16 and then increases again in a convex manner after age 16 with the lowest rate for freshmen (age 16) in high schools.

A_1 is known by official statistics but A_2 must be calculated. By definition,

$a_{2,j}$= the number of incoming prisoners for age j+13 / $x_{2,j}$

The nominator is known by the Correction Statistics and the denominator is known by the Crime Statistics. Ages are grouped 20 - 24, 25 - 29, 30 - 39, 40 - 49, 50 - 59, 60 - 69. A_2 ranges from 4.27% (age 60s) and 4.80% (age lower 20s) to 9.47 % (age 30s) as Table 1 shows. This indtes that aged and young prisoners are of relatively minor offence types while the prisoners of age 30s are of relatively serious offfence types. This fact together with the former fact that the recidivism rate is highest around 30 are interpreted that arrestees around age 30 or of ages 30s tend to have offended seriously and/or to re-offend as compared to younger and older arrestees.

5. Analyses

For verifying the model, the real numbers of first arrestees by ages in 1983 are substituted constantly for $x_{1,j}(n)$, or $v_j(n)$ for every n. The outputs of X_2 reach the steady value for $n > 20$. Assuming $\mu = 1$ and using the estimated parameter values above, a good fitting is obtained between the output of $x_{2,j}$ and the real numbers of total arrestees by ages in 1983 with the correlation coefficient 0.99 with the 1% significance. Thus it can be claimed that the model is valid.

As the number of cases to be handled is the load to each agency in the criminal justice system (e.g., X_3, X_4 and X_{11} are the load to the Court, the prison and the juvenile court, respectively), the caseload of the system can be forecasted in a similar way for appropriate values of parameters.

The cohort input (Fig. 4) to the model yields forecasts of the recidivism by ages. Assuming that the number of first arrestees of age i at year j is given (e.g.,10,000), the number of re-arrestees among those 10,000 at year j + k at which they are i + k years old is forecasted. The forecasted numbers of re-arrestees are lower on the model with aging effect than on the prototype model without aging effect for every paprameter value tried. This result is interpreted that the recidivism decreases with aging. As to the expected times of re-arrest, 0.30, 0.37, 0.53, 0.36 and 0.27 times are expected in addition to the first arrest for i = 14, 20, 30, 40 and 50. These figures are interpreted that the juveniles and the aged desist offending activities with higher rates while persons of age around 30 desist the least.

As to the length of offending activities, the offenders of age 14 are expected to desist after 4.5 years (at age 18 or 19). For the cohort of age 14, the expected times of re-arrest is 0.30 as was stated above. If the rate of re-offence for the non-prisoned adults is reduced half, i.e., $B_2/2$ is substituted for B_2, then it is reduced to 0.29. If the rate of re-offence for the juveniles is reduced half, i.e., $B_3/2$ is substituted for B_3, then it is reduced to 0.14. The effect of reducing B_2 is insignificant (0.30 -> 0.29) because many juvenile delinquents desist delinquent or offending activities before or shortly after age 20. The effect of reducing B_3 is quite significant (0.30 -> 0.14) for the opposite reason.

The above results of cohort analyses indicate a possible effect of taking a special care of young adults shortly after age 20 on reducing the recidivism. Indded, Fig. 7 shows that the share of young adults in the total arrestees decreases in ages till age 22 more rapidly than after age 23. The number of protected juveniles (denoted by arrestees here for simplicity) decreases monotonically in ages till age 19 with a increasing speed. The number of arrestees at age 20 is higher than that of age 19 because of the separation line at age 20 between juveniles and adults. After age 20, the number of arrestees decreases again monotonically in ages but with its decreasing speed is diminishing monotonically in ages. The young adults till age 22 are similar to the senior juveniles of age 18 or 19 in the manner of decreasing in offendings in ages. A recent trend is to try to reduce the separation age between the juveniles and the adults (now 20 in Japan) to a younger age (e.g.,18). But the above discussion oppositely suggests to raise the separation age to 22.

The deterrent effect of imprisonment is multiple : threat for expected imprisonment; contrition, correction or rehabilitation in prisons; the separation of possible re-offenders from possible victims for a certain length of time and so on. The former two are psychological and are difficult to quantify from official statistics. The separation effect that possible re-offenders can not re-offend in prison is easily handled in our model by varying the value of μ. The replacement effect by new recruit which keeps the number of offenders constant (Blumstein and Nagin 1978) is limited to certain offence types like drug distribution and hence the number of replaced offenders is negligible at least in Japan. A side-effect of imprisonment is the aging effect that prisoners get older and their recidivism rate decreases while in prison. The aging effect is also easily handled in combination with the separation effect in our model. This paper considers the separation effect and the aging effect.

Let S_μ denote the deterrent effect of imprisonment of the average length μ and let X_2^μ denote the value of X_2 (the number of arrestees) for the parameter value μ. S_μ may be measured by the decrease of X_2^μ in μ.

$$S_\mu = X_2^0(n) - X_2^\mu(n)$$

and

$$\Delta S_\mu = S_{\mu+1} - S_\mu$$

Fig. 8 shows that the number of arrestees denoted by X_2^μ is decreasing and convex in μ. That is, the deterrrent effect of longer prison term is positive but diminishes as the prison term is longer. The gradient of diminishing is the steepest between prison terms one year and two years. This leads to suggesting that $\mu \leq 2$ is reasonable. The current value $\mu = 1.2$ lies in this range and may be judged as reasonable.

6. Conclusion

A feedback model with aging effect was proposed for the total criminal justice system which ranges from juvenile delinquents and first arrestees to prisoners and crinical re-offenders. The aging effect had been neglected in models thus far proposed though empirically known to have significant effects on the recidivism. Our proposed model allowed to estimate many unknown factors from simple official statistics, especially to forecast the number of offenders (or arrestees) from simple official statistics under the steady state assumption. Varying the parameter values on the model allowed to evaluate effects of changes in parameter values on other factors such as the number of offenders. Especially, taking the aging effect into the model led to a quantitative evaluation of the rate of the juvenile recidivism as having the greatest effect on the total number of offenders. Similarly it led to suggesting to take a special care of younger adults less than age 22 in contrast to the recent opinion to reduce the separation between the juveniles and the adults from age 20 to 18. It also led to a quantitative evaluation of deterrent effect of the length of prison terms, suggesting an ineffectiveness of longer prison terms in contrast to a recent demand of longer prison terms as a deterrent measure.

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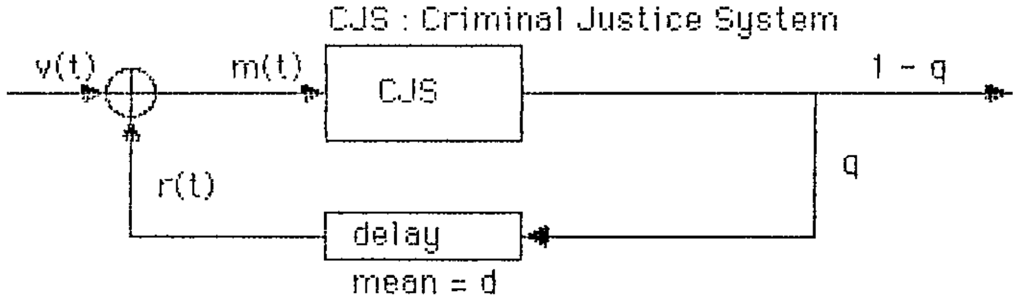

Fig. 1 Feedback model of criminal justice system (prototype model)

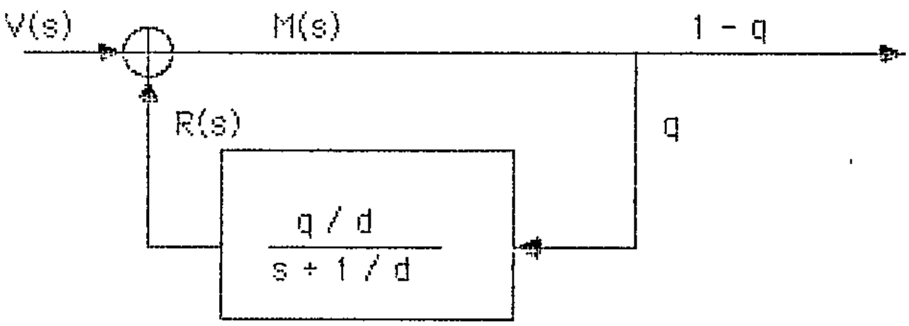

Fig. 2 Laplace transform of prototype model

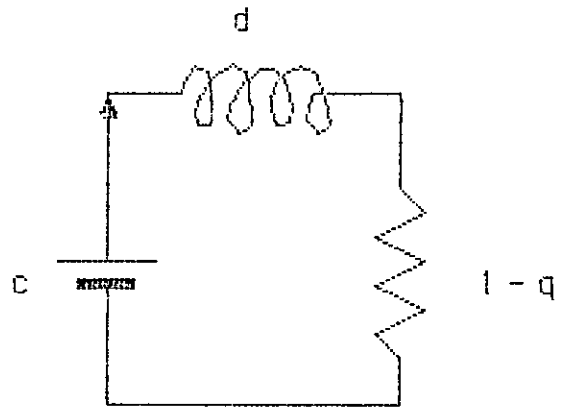

Fig. 3 Analogical electric circuit

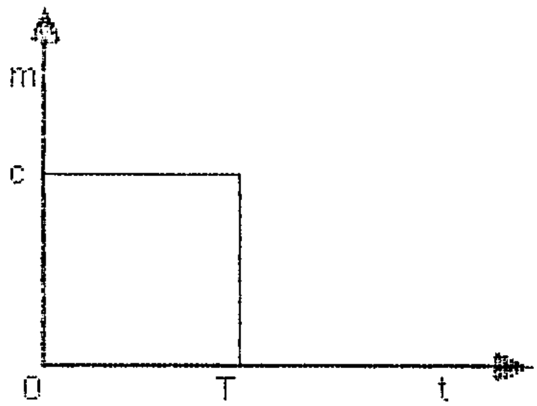

Fig. 4 Unit step input

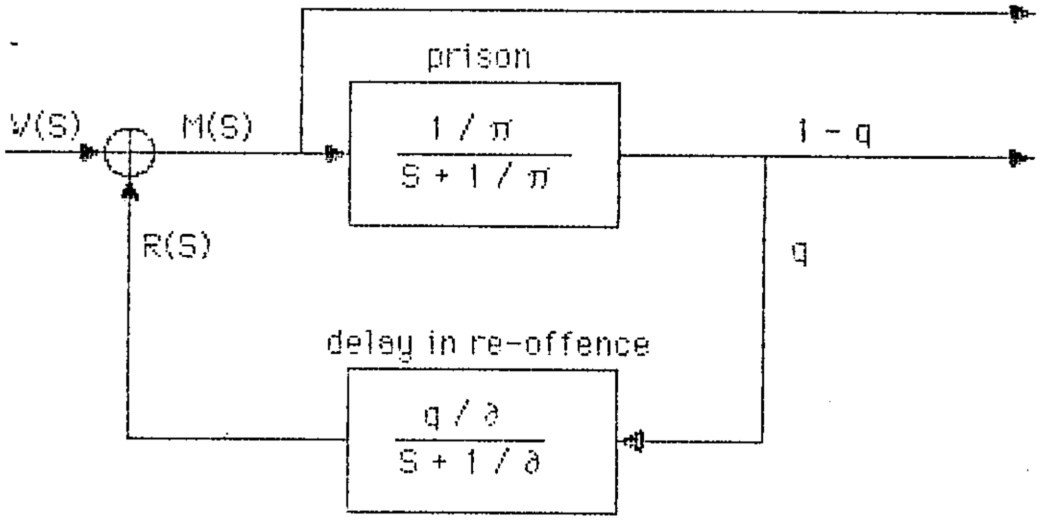

Fig. 5 Laplace transform of extended prototype model under the exponentiality assumption

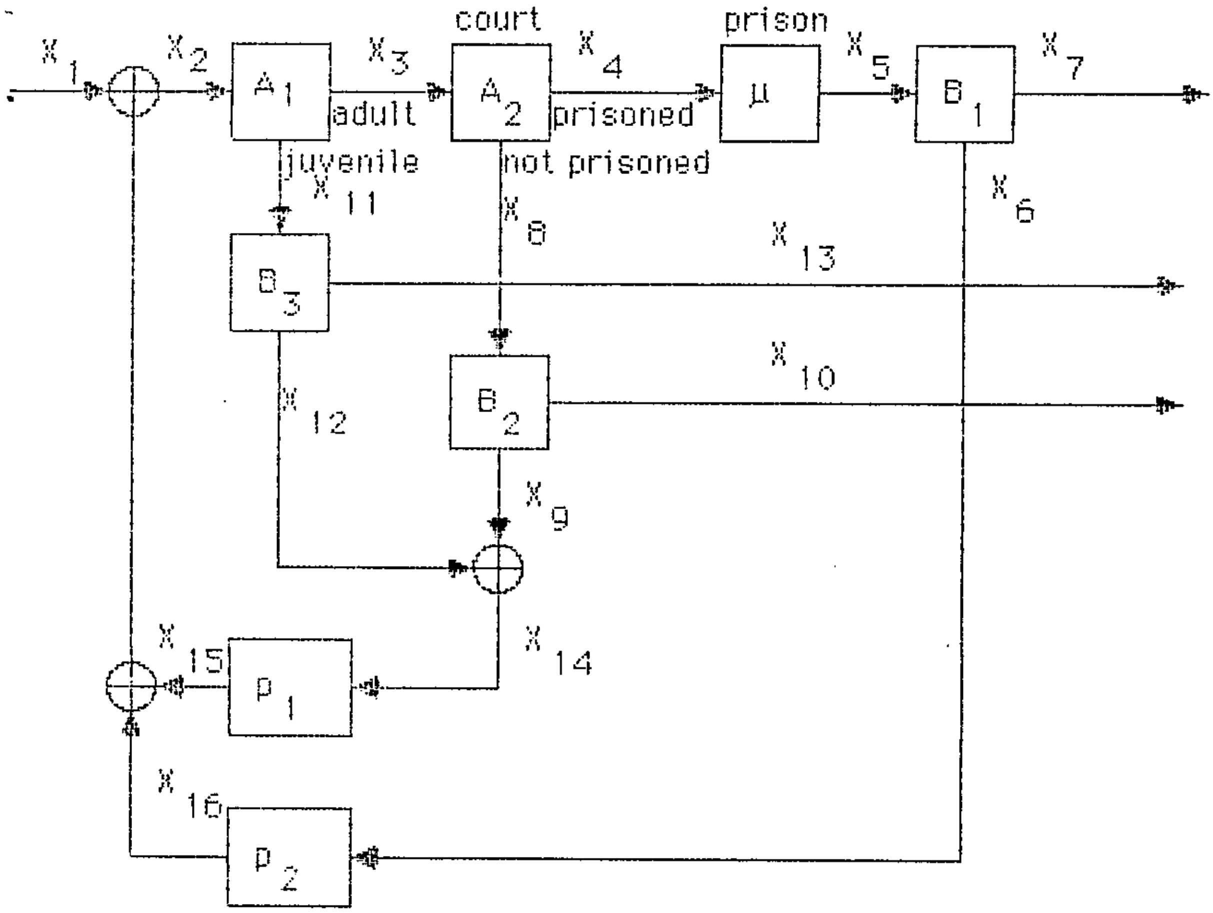

Fig. 6 Total criminal justice system with length of prison terms

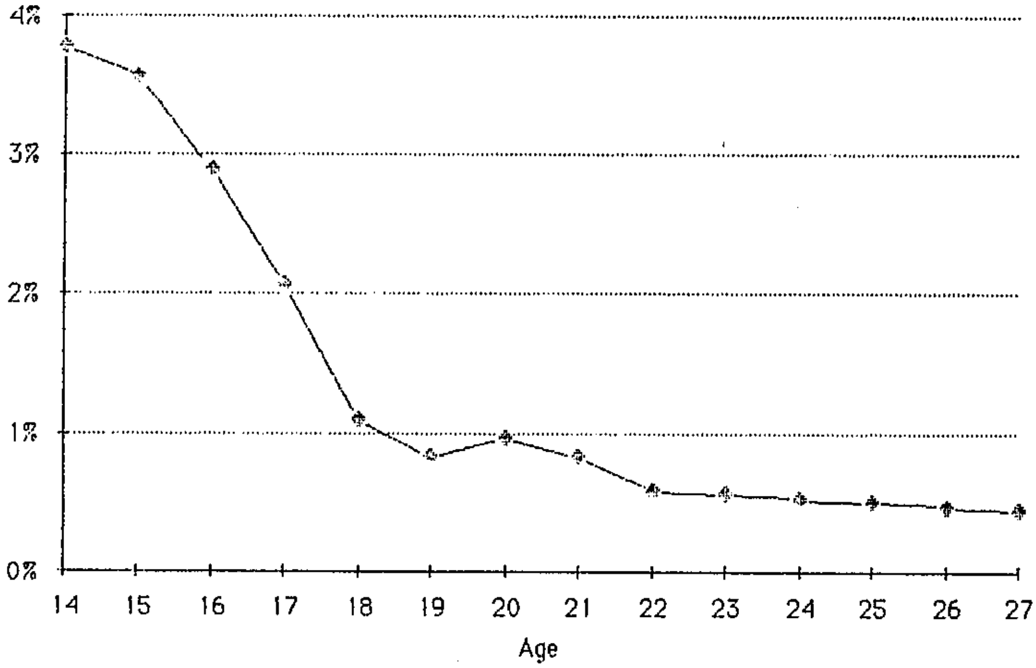

Fig. 7 Composition ratio of arrestees

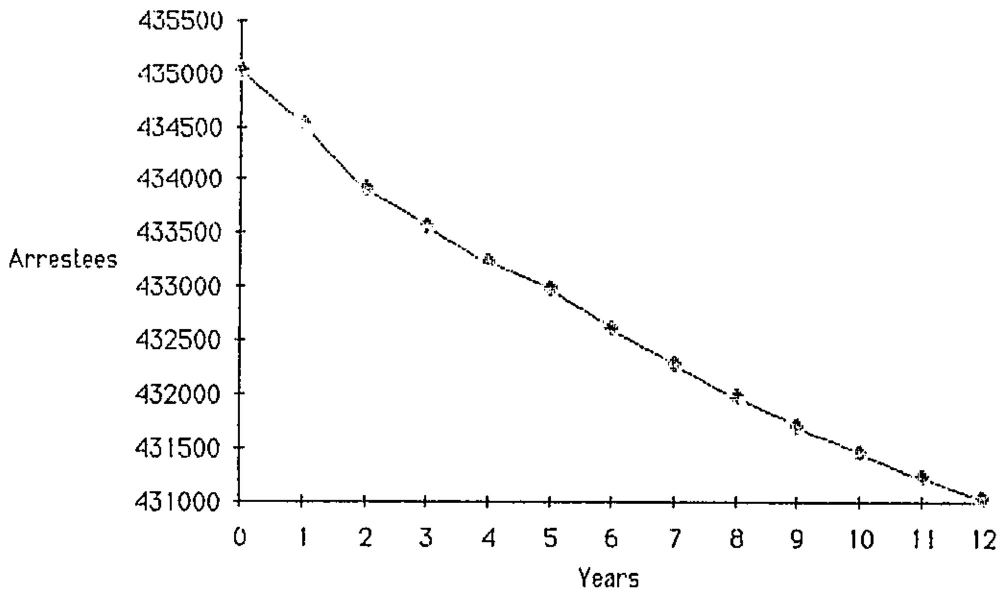

Fig. 8 Effect of prison terms

Table 1 Transmission parameter A_2

Ages (j)	14-19	20-24	25-29	30-39	40-49	50-59	60-69
A_2 (%)	0*	4.80	8.00	9.47	9.07	7.20	4.27

* : juveniles are not prisoned by definition as in Fig. 6.

$A_2(j)$=Number of incoming prisoners of age j/number of arrestees of age j