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The impact of heroin dependence on long-term robbery trends

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This study reports the results of a time series analysis of the relationship between heroin use and robbery over the period 1966 to 2000 in NSW. A statistically significant relationship was found between these two variables, controlling for other potential causes of the increase in robbery, such as rising unemployment rates for males, a decreased likelihood of apprehension by police for robbery crimes, and a reduction in the likelihood of imprisonment for robbery. Using the time series modelling results, the elasticity between dependent heroin use and robbery was estimated; a 10 per cent decrease in the annual number of heroin dependent users resulted in a 6 per cent decrease in robbery. The paper concludes on the basis of this and other evidence that policies designed to encourage more heroin users into methadone treatment or increase the price of heroin are likely to prove helpful in reducing or limiting the growth in robbery.

INTRODUCTION

Between 1973/74 and 1988/89, the recorded robbery rate in Australia more than doubled (Mukherjee & Dagger 1990). There are no national data on robbery between 1990 and 1992. Between 1993 and 2001, however, the recorded rate of robbery in Australia almost doubled again (Australian Bureau of Statistics 2002). In the last two years the rate of robbery in Australia has fallen significantly. Yet by international standards, our robbery rate remains comparatively high. According to the last international crime victim survey, only Poland (among the seventeen countries surveyed) has a higher robbery rate than Australia (van Kesteren, Mayhew & Nieuwbeerta 2000).

There is some evidence that the national increase in recorded rates of robbery is partly due to an increase in public willingness to report the offence to police (Australian Bureau of Statistics 1994, p. 9). But the increase is unlikely to be due just to increased reporting. Crime victim surveys conducted by the Australian Bureau of Statistics in 1983 and 1993 also show a doubling in the national prevalence of robbery victimisation (Australian Bureau of Statistics 1986; 1994).[1]

The increase in robbery has been particularly notable in New South Wales (NSW). Between 1973/74 and 1988/89, the recorded rate of robbery in NSW *more than* doubled (Mukherjee & Dagger 1990). Between 1993 and 2001, the recorded rate of robbery in NSW more than doubled again (Australian Bureau of Statistics 2002). The growth in robbery during the 1990s, however, was not confined to NSW. Between 1993 and 2000, robbery rates rose by about 66 per cent in Victoria, 90 per cent in Western Australia, 62 per cent in Tasmania, 25 per cent in the Northern Territory, 159 per cent in the ACT and six per cent in Queensland. Only South Australia recorded a decrease in robbery over this period.

One possible explanation for the increase in robbery is an increase in the level of heroin. Heroin users are prone to resort to crime to fund their purchases of heroin (Dobinson & Ward 1985, p. 50; Hogg 1987, p. 87; Chaiken & Chaiken 1990). Law et al. (2001) estimate that the number of dependent heroin users in Australia increased from about 670 in 1967 to about 67,000 by 1997. Heroin dependence has been a particularly prominent problem in NSW. This State has about a third of Australia's population but, between 1979 and 1995, accounted for more than half of all those placed on methadone treatment and just under half of all fatal opioid overdoses (Law et al. 2001, p. 437).

Just as NSW accounts for about half of Australia's heroin users, so it also accounts for just over half of all Australia's recorded robberies. This has been true for a considerable length of time (Australian Bureau of Statistics 2002).

The recent drop in heroin consumption in NSW has also coincided with a significant fall in the incidence of robbery (Weatherburn, Donnelly & Chilvers 2003).

Although the rise in Australian robbery rates could be due to increased heroin dependence, there have been no formal studies in Australia designed to test for the existence of such a link. Indeed, aggregate-level studies of the time series relationship between heroin use and property crime are surprisingly rare, even in the international literature. Perhaps the most cited study on the issue is that conducted more than twenty-five years ago by Silverman and Spruill (1977). They found a close relationship between estimated levels of expenditure on heroin and time series trends in robbery and burglary in Detroit in the United States. Subsequent studies seeking to confirm the effect of heroin dependence on crime have generally used individual-level rather than aggregate-level data (Chaiken & Chaiken 1990). These data provide a better basis on which to test conjectures about the causal relationship between drug use and criminal behaviour. However they are of limited use in estimating the overall contribution which heroin dependence makes to aggregate crime rates.

The purpose of this bulletin is to report the results of a study designed to estimate the contribution which rising rates of heroin dependence have made to the increase in robbery in NSW between 1966 and 2000. There is, unfortunately, no generally accepted body of theory about which controls might be appropriate in testing for the effect of heroin dependence on robbery over time. Classical deterrence theory points to the need to control for changes in the risk of apprehension for robbery and the severity of sentence imposed on convicted offenders. Research has provided confirmation of the general importance of risk of apprehension and imprisonment (Nagin 1998; Spelman 2000) to criminal behaviour. And while little research has been conducted on the specific links between deterrence variables and robbery, both Wilson and Borland (1978) and Sampson and Cohen (1988) found strong evidence that police activity is an important determinant of robbery trends, even in the presence of controls for other factors (e.g. unemployment) likely to influence those trends.

Classical deterrence theory also suggests a need to control for factors such as unemployment, which may influence the number of people motivated to offend. While the evidence on this issue is mixed (Chiricos 1987), at least one Australian time series study has found a positive relationship between unemployment and crime (e.g. Kapuscinski, Braithwaite & Chapman 1998). Another factor likely to increase robbery rates is an increase in the price of heroin. Unfortunately the collection of time series data on the price of heroin is too recent a development in Australia to permit formal controls for changes in the price of heroin. There is no evidence to suggest, however, that the price of heroin rose over the period during which the robbery rate in NSW increased. In fact the available data indicate that the price of heroin *declined* substantially between 1996 and 2000 (Topp et al. 2001). Thus although we cannot include a control for changes in heroin prices in our model, there is no reason to believe that rising heroin prices have contributed to the increase in robbery.

There is one other factor that may have influenced trends in robbery in NSW between 1966 and 2000. Robbery offenders, like most offenders, are disproportionately male and young. A change in the proportion of young males in the population could therefore produce an increase in the robbery rate. In this study we have not included controls for the percentage of young males in the population aged 15-24 years. This is because the proportion of young males aged 15-24 in NSW actually *declined* from about 8.6 per cent in 1975 to about 7.1 per cent in 2000 (Australian Bureau of Statistics 1981; 2001).

DATA AND METHODS

The dependent variable in our analysis is the annual rate of robbery (per 100,000 population) recorded by NSW police between 1966 and 2000.[2] In order to describe the relationship between the rate of robbery and heroin use, we require a measure of the level of dependent heroin use in NSW over the same time period. As there is no reliable measure of the actual number of dependent heroin users in NSW over the period of our study, we use a proxy variable in the model. Law et al. (2001) estimated the number of heroin users from opioid overdose deaths recorded each year, using data from longitudinal research on the annual risk of overdose among a large sample of dependent heroin users. The results were consistent with similar estimates obtained from the number of heroin users entering methadone treatment. Figure 1 shows the annual rate of deaths from heroin overdose (per million males aged 15-44) graphed against the robbery rate (per 100,000 population) for the years 1966 to 2000.

Figure 1 shows that both series trend upwards over the time period with a strong linear correlation between the two series (Pearson correlation coefficient, $r = 0.953$). Since the late 1970s, the relative magnitude of the two series has been fairly stable so a multivariate linear relationship between the series, incorporating selected control variables, was modelled.

Figure 2 shows the trend in the annual rate of male unemployment in NSW over the period 1966 to 2000 (scaled on the right-hand axis), graphed against the robbery rate (on the left-hand axis). The rate of unemployment for males, rather than for the general population, has been used because the majority of robbery offenders are male. The data were obtained from official reports published by the Australian Bureau of Statistics. The unemployment series is lagged by one year to account for the delay generally thought to exist between changes in unemployment and changes in crime (Cantor & Land 1985; Greenberg 2001).

Figure 2 shows that there has been significant variation in the male unemployment rate since the mid-1970s, with highest rates experienced in the early-80s and early-90s. In common with the robbery rate, the unemployment rate shows an upward trend over the

Figure 1: Rates of robbery and heroin overdose, NSW, 1966-2000

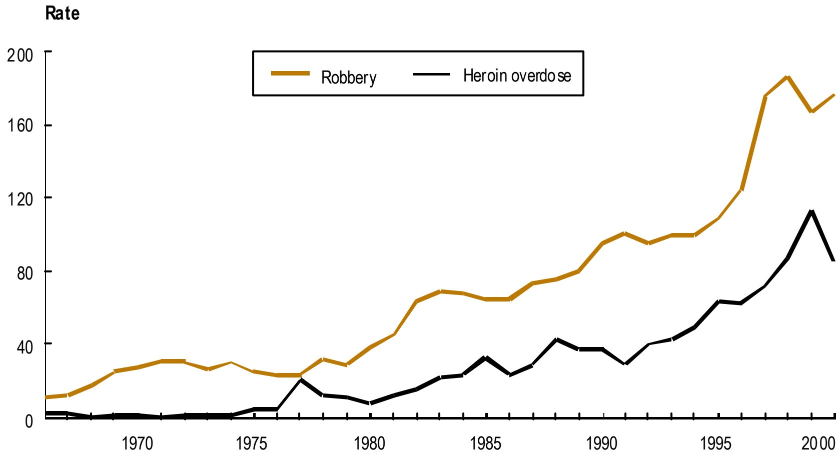
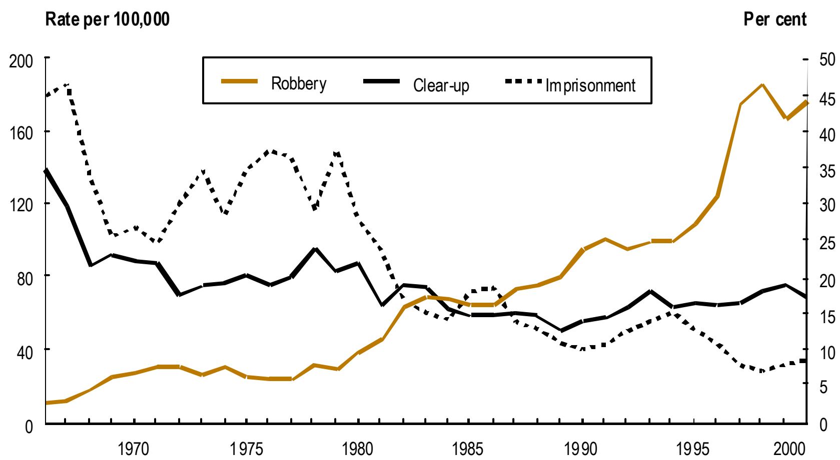


Figure 2: Rates of robbery and male unemployment, NSW, 1966-2000

Figure 3: Robbery rate, percentage of robberies cleared by police, and percentage of robbery offenders imprisoned, NSW, 1966-2000



time period. There is a positive bivariate correlation between the lagged unemployment series and robbery (r = 0.641), confirming the need to control for changes in rates of male unemployment in our analysis.

The risk of apprehension for a robbery offence is measured by the rate of police 'clear-up' for this offence. Clear-up rates are calculated as the percentage of recorded criminal incidents of robbery that are considered dealt with, or 'cleared', by police within the same year.[3] The severity of punishment for a robbery offence is measured by an imprisonment rate for robbery offenders. The annual imprisonment rate for robbery is calculated as the number of persons who are serving a prison sentence for robbery, as a percentage of the total number of recorded robbery offences in the same year.[4] Figure 3 shows the clear-up rate and the imprisonment rate for robbery, both lagged by one year, for the time period 1966 to 2000 (both scaled on the right-hand axis), graphed against the robbery rate (on the left axis). The clear-up and imprisonment rates have been lagged by one year to allow for the delay in awareness, by offenders, of changes in the risk of apprehension and in punishment severity.

Figure 3 shows that the bivariate relationship between the robbery and clear-up series is negative (r= -0.527); that is, clear-up rates declined over the period during which robbery rates were rising. Similarly, the bivariate relationship between the robbery and imprisonment rate series is negative (r = -0.835). The likelihood of imprisonment for a robbery offence, therefore, also declined over the period during which robbery rates were rising. There is no way of knowing what caused this fall in clear-up and imprisonment rates for robbery. The rapid growth in robbery itself could have reduced the quantity of police resources able to be devoted to robbery investigation. This would have impacted adversely on robbery clear-up and imprisonment rates. The salient point for our purposes, however, is that the fall in rates of clear-up and imprisonment for robbery could have contributed to the growth in robbery.

It is well known that the application of traditional statistical estimation procedures such as ordinary least squares (OLS) regression to non-stationary time series can lead to spurious results (Granger & Newbold 1974; Banerjee *et al.* 1993; Britt 2001). The results of such simple, but robust, statistical procedures may still be valid, however, if they are applied to non-stationary time series that exhibit similar time series characteristics and form a long-run cointegrating relationship. This is because, when a cointegrating relationship exists between the series, the residuals from the regression model are stationary. If the usual assumptions of the OLS regression model are also met, then the parameters estimated by the model are said to define the long-term relationship between the series.

Examination of the autocorrelation function (ACF) and partial autocorrelation function (PACF) for the five time series described above suggests that the series are not stationary but that each is integrated of order one (see Tables A1 to A5 in the Appendix). In order to take account of the non-stationarity of each time series, therefore, the analysis of the linear relationship between the rate of robbery and the rates of heroin overdose, unemployment, clear-ups and imprisonment for robbery offences in NSW between 1966 and 2000 will proceed as follows. Firstly, the series are tested for the existence of a cointegrating (long-term) relationship between them. Secondly, the statistical relationship between the robbery rate and the rate of heroin overdose in NSW is analysed using a multivariate regression model, controlling for the covariates of unemployment, police apprehension and punishment severity. And finally, the magnitude of the long-term relationship between the robbery rate and the rate of dependent heroin use in NSW is estimated.

TESTING FOR COINTEGRATION

As noted above, in order to model the linear relationship between robbery and heroin use, controlling for unemployment and the risk of apprehension and punishment severity, we require confirmation that the series are cointegrated. A necessary condition for cointegration is that each series exhibit 'weak' (or unit root) stationarity. The results of Augmented Dickey-Fuller (ADF) tests for unit root stationarity of the robbery, heroin overdose, unemployment, clear-up and imprisonment rate series are shown in Table A6 in the Appendix. From the results in Table A6, we conclude that, for each of the time series: (1) for the undifferenced series (i.e. the series 'in levels'), the null hypothesis of a unit root cannot be rejected, and (2) for the differenced series, the null hypothesis of a unit root is rejected. We conclude that each series is integrated of order one and that the procedures described below which test for, and describe, a cointegrating relationship between the series are valid.

Having established that each of the time series in our study has a unit root, we test for the existence of a long-run cointegrating relationship between them by applying the Johansen Cointegration test. Assuming a linear deterministic trend in each case, we performed the test for a cointegrating relationship between the following combinations of series: (1) robbery and heroin overdose, (2) robbery, heroin overdose and clear-ups, (3) robbery, heroin overdose, clear-ups and unemployment, (4) robbery, heroin overdose and imprisonment, and (5) robbery, heroin overdose, imprisonment and unemployment. Note that the clear-up rate and the imprisonment rate are not modelled in the same equation because of problems of collinearity between the two measures ($r = 0.752$).

In each of the five tests conducted, the results indicate the presence of one cointegrating equation between the modelled series at the five per cent level of significance. The estimated cointegrating coefficients and standard errors for each combination of variables are shown in Table A7 in the Appendix. In summary, the cointegration test results all show that a long-run stationary relationship exists between the rate of robbery and the rate of dependent heroin use (represented by the proxy measure of heroin overdose death rates) in NSW over the period 1966 to 2000. Moreover, this relationship is shown to exist both in the simple bivariate case, and in combination with the measures of unemployment and the risk of apprehension and punishment severity for robbery. The estimated cointegrating vector coefficients for each of the modelled relationships show that high levels of heroin use are significantly associated with high levels of robbery. The relationship between robbery and clear-up rates and between robbery and the imprisonment rate are each negative and significant. The long-run cointegrating relationship with unemployment is not significant in the presence of heroin use and the clear-up rate, but shows marginal significance when modelled with the imprisonment rate. In the following section, we estimate each of these long-run models using standard regression procedures, and quantify the relationship between robbery and dependent heroin use.

RESULTS

ESTIMATING THE RELATIONSHIP BETWEEN ROBBERY AND HEROIN USE

In the section above, we established the existence of a long-run cointegrating relationship between the rate of robbery and the rate of heroin overdose in NSW. In this section we model this relationship and estimate the impact of a change in the level of the heroin dependent population on the level of robbery in NSW.

The following long-term relationship between robbery and heroin overdose, controlling for unemployment and clear-ups or imprisonment, is estimated:

$$Y_t = ß_0 + ß_1X_{1t} + ß_2X_{2t-1} + ß_3X_{3t-1} + \varepsilon_t \quad (1)$$

where

Y_t = robbery rate at time t

X_{1t} = heroin overdose rate at time t

X_{2t} = male unemployment rate at time t

X_{3t} = robbery clear-up rate at time t, *or* robbery imprisonment rate at time t

ε_t = random error term

$ß_i$ = constants

The model described by equation (1) depicts a contemporaneous relationship between robbery and heroin use, incorporating a lagged effect for unemployment and robbery clear-up rates (in Model A) or unemployment and the imprisonment rate (in Model B). Using annual data from 1966 to 2000 described earlier, each model was fitted and estimated by the method of OLS regression. The parameter estimates and summary diagnostics for the full models are shown in Table A8 in the Appendix. For each of the full model specifications, A and B, the model was reduced and re-estimated in order to exclude the lagged unemployment variable that was not statistically significant in either of the full models.

Table 1 shows the parameter estimates and test statistics for the final models that predict the robbery rate from the rate of heroin overdose and lagged robbery clear-up and imprisonment rates. As noted above, the coefficient on male unemployment was not significant when entered in each model, but this is not an uncommon finding in time series analyses of unemployment and crime overseas and in Australia (Chiricos 1987; Weatherburn, Lind & Ku 2001).

ROBBERY, HEROIN DEPENDENCE AND POLICE CLEAR-UP RATE

Consider, firstly, Model A, the modelled relationship that controls for the effect of clear-up rates. The regression coefficient for heroin overdose for this model, shown in Table 1, is positive and significant ($\beta = 1.55, t = 15.73, p < 0.0001$). This result suggests that high levels of heroin dependence in NSW over time are strongly associated with high levels of robbery. Moreover, the relationship exists while controlling for the effect of the rate of apprehension for robbery. (Note that the estimated regression coefficient for heroin overdose was also positive and highly significant in the full model when the unemployment rate was included, shown in Table A8.) As expected, the estimated coefficient for the lagged clear-up rate in Model A is negative and significant ($\beta = -1.14, t = -2.11, p = 0.0432$).

Table 1: Estimates of regression coefficients for robbery regression models

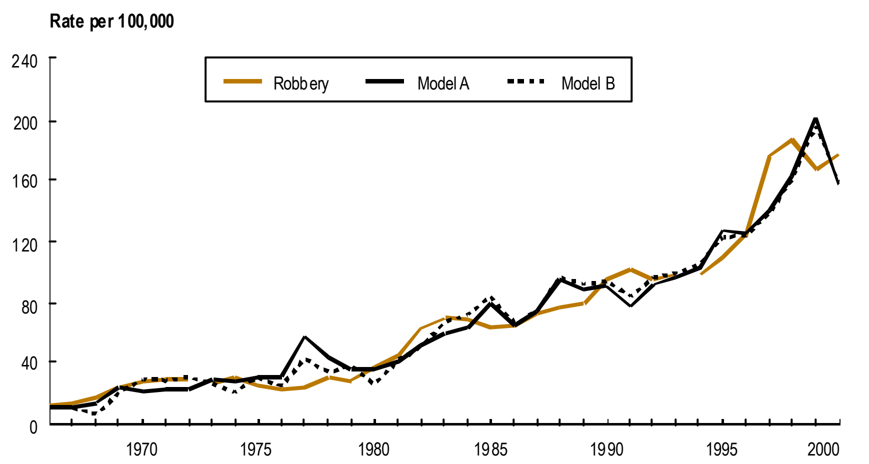
	MODEL A		MODEL B	
Coefficient	***b* (SE)**	***t-statistic* (p-value)**	***b* (SE)**	***t-statistic* (p-value)**
Heroin overdose	1.55 (0.10)	15.73 (0.0000)	1.31 (0.13)	10.23 (0.0000)
Clear-up (lagged)	-1.14 (0.54)	-2.11 (0.0432)		
Imprisonment (lagged)			-1.07 (0.33)	-3.27 (0.0026)
Constant	47.02 (12.24)	3.84 (0.0005)	56.21 (10.63)	5.29 (0.0000)

Selected multiple regression diagnostics for the final robbery models are shown in Table A9 in the Appendix. The overall test of significance for Model A shows that the modelled relationship is strong and significant (F=181.7, $p < 0.0001$). The R-squared coefficient shows that, altogether, the modelled predictor variables explain more than 90 per cent of the variation in NSW robbery between 1966 and 2000 (adjusted $R^2 = 0.914$). Figure 4 graphs the actual and modelled series over the time period, comparing the actual values of the dependent variable, robbery, with the estimated values from Model A. The modelled values track the significant upward trend in the robbery series during the 1980s and 1990s.

ROBBERY, HEROIN DEPENDENCE AND IMPRISONMENT RATE

Consider now the modelled relationship between robbery and dependent heroin users that controls for the effect of imprisonment rates for robbery. The regression coefficient for heroin overdose in Model B is also positive and significant ($\beta = 1.31, t = 10.23, p < 0.0001$). Again, high levels of heroin dependence in NSW are strongly associated with high levels of robbery, and the relationship exists while controlling for the effect of

Figure 4: Actual and modelled robbery rate, Models A and B, NSW, 1966-2000



the rate of imprisonment for robbery. (As before, the estimated regression coefficient for heroin overdose was also positive and highly significant in the full model when the unemployment rate was included.) The estimated coefficient for the lagged imprisonment rate in Model B is negative and significant ($ß = -1.07, t = -3.27, p = 0.0026$).

Selected multiple regression diagnostics for Model B are also shown in Table A9 in the Appendix. The model is strong and significant (F=198.5, $p < 0.0001$). The R-squared coefficient shows that the modelled predictor variables together explain more than 90 per cent of the variation in NSW robbery between 1966 and 2000 (adjusted $R^2 = 0.923$). Figure 4 shows the relationship between the actual and the modelled series over the time period, comparing actual values of the robbery rate with estimates from Model B.

MODEL DIAGNOSTICS AND RESIDUALS ANALYSIS

The validity of the OLS regression model described in equation (1) above depends on the satisfaction of a number of assumptions about the random error terms in the equation: namely that the errors are normally distributed, are homoscedastic, have zero mean and exhibit no serial correlation. It should be noted that while the error terms in the linear regression model are assumed to be independent, in models based on time series data serial correlation is likely to exist. This most frequently occurs when important explanatory variables are omitted from the regression and are thus present in the error term. As any such omitted variable represents a set of observations which itself is a time series, the error terms are related across time (see, for example, Greene 1997). Evidence of no serial correlation in the residuals is therefore a useful indication that important covariates have not been omitted from the model.

Diagnostic tests on the residuals in the final models were performed. The normality assumption was examined by visual inspection of the normal-scores and confirmed by the Jarque-Bera test result shown in Table A9 in the Appendix. The homogeneity assumption was confirmed through examination of the plot of residuals against fitted values. The serial correlation of the residuals in the model was tested by firstly calculating the Durbin-Watson statistic which, for each model, showed no evidence of serial correlation. Because the Durbin-Watson test only examines serial correlation at lag 1, however, further tests for serial correlation were undertaken. The ACF, PACF and associated Ljung-Box Q-statistics were examined for the residual series to lag 16. The plotted functions, Q-statistics and associated *p*-values are shown for Model A in Table A10 and for Model B in Table A11 in the Appendix. As expected in a cointegrating relationship, there was no evidence of significant autocorrelation in the residuals of either model.

CHECKING CAUSALITY

The regression model estimated above represents a causal relationship between robbery (the dependent variable) and heroin use (the 'predictor' or 'independent' variable of interest). However, particularly in the case of time series regression, significant correlation does not imply causality. While the causal relationship modelled here is based on theoretical rather than merely observational grounds, it is useful to confirm its existence by applying a Granger test for causality. The Granger statistical test is used to evaluate the explanatory power of a predictor variable in the presence of lagged values of the dependent variable (see, for example, Koop 2000). In our case, the test results shown confirmed that over the period 1966 to 2000, the level of dependent heroin use did 'Granger cause' robbery (F = 6.72, $p = .0002$).

IMPACT OF HEROIN USE ON ROBBERY

In order to estimate the magnitude of the impact of the level of heroin use on robbery, the long-run elasticity of the level of dependent heroin use (approximated by overdose) on robbery is calculated. The elasticity is estimated by calculating the impact of a percentage change in heroin use on the level of robbery. The calculation is performed using the parameter estimates shown for Models A and B at the mean value of each time series. (The mean value for each of the time series is shown in the descriptive summary in Table A12 in the Appendix.) For heroin use, we calculate from Model A that a 10 per cent increase in the number of dependent heroin users in NSW results in a 6.4 per cent increase in the recorded rate of robbery. For the deterrence variable, we find from the same model that a 10 per cent decrease in the rate of police clear-up for robbery results in a 3.1 per cent increase in robbery. The elasticity of 0.6 between dependent heroin use and robbery is confirmed by Model B. From Model B we calculate that a 10 per cent increase in dependent heroin users effects a 5.6 per cent increase in robbery, and that a 10 per cent decrease in the imprisonment rate for robbery simultaneously effects a 3.4 per cent increase in the robbery rate.

CONCLUSION

This study note examines the relationship between the number of dependent heroin users and the level of robbery in NSW. Because a reliable measure of the number of dependent heroin users was not available, we used a proxy measure, namely the annual number of deaths due to heroin overdose. If we assume, following Law et al. (2001, p. 435), that there is a linear relationship between the number of dependent heroin users and the rate of heroin overdose, it becomes possible to calculate the elasticity between robbery and dependent heroin use. Proceeding on this basis we estimate that, since 1966, each 10 per cent increase in the annual number of dependent heroin users has led to a 6 per cent increase in the NSW robbery rate. By comparison, each 10 per cent decrease in the robbery clear-up or imprisonment rate has led to a 3-4 per cent increase in robbery.

This is not the place for a full discussion of the policy implications of these findings but a few comments are in order. The contribution that heroin dependence has made to the upward trend in robbery underscores the importance of measures designed to reduce the number of dependent heroin users. Methadone maintenance treatment has been shown in rigorous trials to be effective in reducing heroin dependence (Hall 1996). One way of reducing or limiting the growth in robbery, therefore, is to increase the proportion of heroin dependent people in treatment. It might be objected that the last two decades have seen a substantial increase in the number of robberies *and* in the number of heroin users in methadone treatment. It is entirely possible, however, that the growth in robbery would have been higher but for the expansion of methadone maintenance treatment.

Recent evidence suggests that another way of reducing the rate of robbery may be to increase the price of heroin. Around Christmas 2000, a major shortage of heroin occurred in Australia, forcing heroin prices up and heroin purity and availability down (Weatherburn, Jones, Freeman & Makkai 2003). The initial effect of higher heroin prices appeared to be an increase in robbery. Within just a few months, though, robbery rates began to fall and have since fallen quite substantially. Weatherburn, Donnelly and Chilvers (2003) found strong evidence that the fall in robbery was closely associated with the drop in heroin consumption, even controlling for other factors that might have influenced the incidence of robbery, such as the rate of unemployment.

The fact that we obtained significant coefficients on the clear-up rate and imprisonment rate variables suggests that a reduction in robbery might also be achieved by increasing robbery clear-up or imprisonment rate. Given the collinearity between these two variables, however, there is no way of telling which of them is more important (both could be equally important or one of them irrelevant). One advantage of pursuing strategies designed to increase the clear-up rate is that more than 80 per cent of convicted robbers receive a prison sentence in NSW. Increasing the robbery clear-up rate will therefore automatically bring with it an increase in the imprisonment rate for robbery. It is, of course, possible to increase the imprisonment rate (without increasing the clear-up rate) by imposing mandatory prison penalties on convicted robbers. Given that the vast majority of convicted robbers already receive a prison sentence, however, the scope for further increasing the imprisonment rate for robbers must be regarded as fairly limited. Even if it were not, the daily cost of methadone treatment is considerably less than the daily cost of keeping someone in prison (Lind et al. 2002).

On the available evidence, then, it would seem prudent for authorities to pursue a range of strategies to reduce the incidence of robbery, rather than focusing on any one strategy. Increasing the availability of treatment for heroin-dependent robbers, while at the same time endeavouring to make heroin harder to get and more expensive, should help reduce the number of people motivated to commit robbery to fund their purchases of heroin. Increasing the clear-up rate for robbery, on the other hand, should help reduce robbery through the more familiar mechanisms of deterrence and incapacitation.

NOTES

1 National crime victim surveys conducted before 1983 and after 1993 used non-comparable questions when asking about robbery.

2 There is no consistent series of NSW recorded crime data over the period 1966 to 2000. A consistent series was compiled as follows: (1) 1966-1981 incidents were obtained from Mukherjee et al. (1989). These data were confirmed, where possible, from the Appendix tables of published Annual Reports of the NSW Police Department. Incidents recorded by police in 1966-1970 were inflated by a factor of 1.5 to reflect a change in recording practice by NSW Police in 1971. The inflation rate was calculated on the assumption that the clear-up rate in 1970 was the same as in 1971. (2) 1989-2000 incidents were obtained from official recorded crime statistics published by the NSW Bureau of Crime Statistics and Research (BOCSAR), excepting 1994. (3) Due to a change in the police computer system, the 1994 data only covered the last three quarters of that year and had to be inflated by a factor (1.31). The inflation factor was calculated by comparing incidents recorded in quarters 2-4 with annual data in the succeeding four years.

3 As with the crime series, there was no consistent clear-up series available for the period 1966-2000. A consistent series was compiled as follows: (1) For the years 1966-1988, the data were obtained from Mukherjee et al. (1989), as for the crime data. (2) From 1989 to 1993, the clear-up series that were published in BOCSAR's annual recorded crime statistics reports were used. For these years, the BOCSAR reports divided clear-ups between those incidents that occurred in the reference year and those recorded in previous years. In order to establish a consistent series over the whole time period, and because there was no such distinction in reports prior to 1989, the clear-up series from 1966 to 1988 were deflated by a factor of 0.84. This factor represents the proportion of clear-ups that referred to incidents in the current year, averaged over the years 1989 to 1993. (3) For the years 1995-2000, the number of crimes cleared each year that were recorded in the same reference year, was obtained from BOCSAR (unpublished data). (4) For 1994, clear-ups for only the last three quarters of the year were available and, as with the crime data, were inflated by a calculated factor (1.38).

4 The number of persons in prison with robbery as principal offence was obtained from a number of sources provided by the NSW Department of Corrective Services, as follows: (1) For the years 1966 to 1970, the principal offence for inmates was not identified. In 1971, the ratio of robbery offenders to the total number of persons imprisoned for General offences against the persons was 0.48. This ratio was applied to the total number of General against the person offenders each year to obtain an estimate of imprisoned robbers. (2) For the years 1971 to 1979, the June 30 prison census was published by the Australian Bureau of Statistics and was the source of our data. (3) For the years 1982 to 2000, the number of robbery offenders under sentence who were in prison at the time of the June 30 prison census each year were obtained from the Statistical Supplement to the Annual Report, published by the Department of Corrective Services. (4) As no data were available for the years 1980 and 1981, we interpolated the census counts between 1979 and 1982.

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APPENDIX

Appendix tables A1 to A12 follow.

Table A1: Correlogram of robbery rate, NSW, 1966-2000

Autocorrelation	Partial correlation		AC	PAC	Q-Stat	Prob
. *******	. *******	1	0.885	0.885	29.831	0.000
. ******	.* .	2	0.765	-0.084	52.797	0.000
. *****	.* .	3	0.623	-0.169	68.515	0.000
. ****	. .	4	0.494	-0.024	78.722	0.000
. ***	. **.	5	0.430	0.228	86.688	0.000
. ***	. .	6	0.384	0.025	93.286	0.000
. ***	.* .	7	0.346	-0.079	98.821	0.000
. **.	.* .	8	0.290	-0.125	102.86	0.000
. **.	. .	9	0.235	0.042	105.60	0.000
. * .	.* .	10	0.163	-0.063	106.97	0.000
. * .	.* .	11	0.090	-0.079	107.41	0.000
. .	. .	12	0.034	-0.004	107.47	0.000
. .	. .	13	-0.011	0.009	107.48	0.000
.* .	.* .	14	-0.060	-0.115	107.70	0.000
.* .	. .	15	-0.102	-0.049	108.38	0.000
.* .	. .	16	-0.152	-0.054	109.95	0.000

Table A2: Correlogram of heroin overdose rate, NSW, 1966-2000

Autocorrelation	Partial correlation		AC	PAC	Q-Stat	Prob
. *******	. *******	1	0.880	0.880	29.469	0.000
. ******	.** .	2	0.714	-0.262	49.497	0.000
. *****	. * .	3	0.598	0.168	63.973	0.000
. ****	. .	4	0.515	-0.015	75.037	0.000
. ***	.* .	5	0.430	-0.060	83.021	0.000
. ***	. .	6	0.341	-0.041	88.211	0.000
. **.	. * .	7	0.280	0.076	91.834	0.000
. **.	.* .	8	0.220	-0.112	94.156	0.000
. * .	. * .	9	0.179	0.103	95.747	0.000
. * .	. .	10	0.161	0.027	97.084	0.000
. * .	.* .	11	0.115	-0.175	97.800	0.000
. .	. .	12	0.054	-0.006	97.964	0.000
. .	.* .	13	-0.016	-0.109	97.980	0.000
. .	. .	14	-0.055	0.063	98.166	0.000
.* .	.* .	15	-0.099	-0.140	98.798	0.000
.* .	. .	16	-0.159	-0.042	100.52	0.000

Table A3: Correlogram of male unemployment rate, NSW, 1966-2000

Autocorrelation	Partial correlation		AC	PAC	Q-Stat	Prob
. *******	. *******	1	0.896	0.896	30.582	0.000
. ******	.** .	2	0.744	-0.300	52.294	0.000
. *****	.* .	3	0.615	0.099	67.620	0.000
. ****	.* .	4	0.527	0.067	79.213	0.000
. ***	. .	5	0.456	-0.029	88.205	0.000
. ***	. .	6	0.389	-0.028	94.951	0.000
. ***	.* .	7	0.337	0.067	100.20	0.000
. **.	.* .	8	0.283	-0.086	104.05	0.000
. * .	.** .	9	0.191	-0.233	105.86	0.000
. * .	. * .	10	0.101	0.075	106.38	0.000
. .	.** .	11	-0.004	-0.243	106.38	0.000
.* .	. .	12	-0.095	-0.006	106.89	0.000
.* .	. * .	13	-0.149	0.089	108.21	0.000
.** .	.* .	14	-0.190	-0.122	110.44	0.000
.** .	.* .	15	-0.236	-0.112	114.05	0.000
.** .	. .	16	-0.295	-0.044	120.00	0.00

Table A4: Correlogram of robbery clear-up rate, NSW, 1966-2000

Autocorrelation		*Partial correlation*			*AC*	*PAC*	*Q-Stat*	*Prob*
.	*****	.	*****	1	0.635	0.635	15.380	0.000
.	***	.	.	2	0.425	0.035	22.464	0.000
.	***	.	* .	3	0.390	0.180	28.617	0.000
.	***	.	.	4	0.339	0.034	33.411	0.000
.	**.	.	.	5	0.242	-0.039	35.935	0.000
.	* .	. *	.	6	0.096	-0.153	36.344	0.000
.	* .	.	* .	7	0.115	0.119	36.951	0.000
.	.	.	.	8	0.124	0.009	37.687	0.000
.	* .	.	* .	9	0.119	0.074	38.394	0.000
.	.	. *	.	10	0.053	-0.084	38.541	0.000
.	* .	.	* .	11	0.099	0.130	39.065	0.000
.	* .	. *	.	12	0.106	-0.067	39.694	0.000
.	.	.	.	13	0.045	-0.030	39.811	0.000
.	.	. *	.	14	-0.041	-0.141	39.914	0.000
. *	.	. *	.	15	-0.143	-0.134	41.237	0.000
. *	.	.	.	16	-0.109	0.033	42.054	0.000

Table A5: Correlogram of imprisonment rate for robbery, NSW, 1966-2000

Autocorrelation		*Partial correlation*			*AC*	*PAC*	*Q-Stat*	*Prob*
.	******	.	******	1	0.837	0.837	26.702	0.000
.	*****	. *	.	2	0.663	-0.126	43.968	0.000
.	****	.	* .	3	0.550	0.103	56.211	0.000
.	****	.	.	4	0.479	0.052	65.794	0.000
.	***	.	.	5	0.421	0.012	73.449	0.000
.	***	. *	.	6	0.421	0.189	81.359	0.000
.	***	. *	.	7	0.372	-0.168	87.772	0.000
.	**.	.	.	8	0.310	0.018	92.383	0.000
.	**.	. *	.	9	0.296	0.132	96.746	0.000
.	**.	. **	.	10	0.216	-0.310	99.167	0.000
.	* .	.	.	11	0.118	0.018	99.921	0.000
.	.	.	.	12	0.053	-0.054	100.08	0.000
.	.	. *	.	13	0.005	-0.076	100.08	0.000
. *	.	. **	.	14	-0.117	-0.262	100.93	0.000
. **	.	.	.	15	-0.192	-0.017	103.30	0.000
. **	.	. *	.	16	-0.256	-0.095	107.77	0.000

Table A6: Unit root tests* for robbery, heroin overdose, clear-up, imprisonment and unemployment rate time series, NSW, 1966-2000

Variable	*Series*	*ADF test statistic*	*1% critical value*	*5% critical value*
Robbery	in levels	-1.7655	-4.2412	-3.5426
	differenced	-4.6386	-3.6353	-2.9499
Heroin overdose	in levels	-1.0771	-4.2412	-3.5426
	differenced	-4.4993	-3.6353	-2.9499
Clear-ups	in levels	-2.9506	-4.2412	-3.5426
	differenced	-3.9663	-3.6353	-2.9499
Imprisonment	in levels	-3.0952	-4.2605	-3.5514
	differenced	-4.2332	-3.6496	-2.9558
Unemployment	in levels	-2.3271	-4.2605	-3.5514
	differenced	-4.4848	-3.6496	-2.9558

* *The undifferenced series were modelled with trend and intercept, while the differenced series were modelled with intercept only.*

Table A7: Cointegrating relationships between robbery rate and rates of heroin overdose, clear-ups, imprisonment and male unemployment, NSW, 1966-2000

Model	*Heroin overdose*	*Clear-ups*	*Imprisonment*	*Unemployment*
1	1.84 (0.12)			
2	1.79 (0.12)	-1.24 (0.45)		
3	1.90 (0.12)	-1.84 (0.59)		-0.94 (0.83)
4	1.57 (0.12)		-0.56 (0.25)	
5	1.54 (0.09)		-1.02 (0.20)	-1.51 (0.57)

Table A8: Results and summary diagnostics for full robbery regression models

		MODEL A		
Variable	*Coefficient*	*Std. Error*	*t-Statistic*	*Probability*
Heroin overdose	1.585	0.121	13.145	0.0000
Clear-up (lagged)	-1.393	0.754	-1.847	0.0746
Unemployment (lagged)	-0.746	1.220	-0.612	0.5453
Constant	54.833	18.525	2.960	0.0060
Adjusted R-squared	0.908	F-statistic		110.16
Durbin-Watson stat	1.779	Prob(F-statistic)		0.0000
		MODEL B		
Variable	*Coefficient*	*Std. Error*	*t-Statistic*	*Probability*
Heroin overdose	1.345	0.129	10.395	0.0000
Imprisonment (lagged)	-1.297	0.365	-3.550	0.0013
Unemployment (lagged)	-1.425	1.070	-1.331	0.1931
Constant	68.136	13.803	4.936	0.0000
Adjusted R-squared	0.928	F-statistic		142.22
Durbin-Watson stat	2.070	Prob(F-statistic)		0.0000

Table A9: Summary diagnostics for final robbery regression models

Test statistic	*Model A*	*Model B*
Adjusted R-squared	0.914	0.923
F-statistic	181.7	198.5
Prob (F-statistic)	0.000	0.000
Durbin-Watson statistic	1.722	1.889
Jarque-Bera statistic	1.429	2.263
Prob (Jarque-Bera stat.)	0.489	0.323

Table A10: Correlogram of residuals from robbery regression Model A

Autocorrelation	*Partial correlation*		*AC*	*PAC*	*Q-Stat*	*Prob*
. |* .	. |* .	1	0.111	0.111	0.4697	0.493
. *| .	. *| .	2	-0.168	-0.182	1.5753	0.455
. *| .	. | .	3	-0.059	-0.018	1.7181	0.633
. | .	. *| .	4	-0.039	-0.062	1.7811	0.776
.**| .	.**| .	5	-0.207	-0.219	3.6238	0.605
. | .	. | .	6	-0.057	-0.029	3.7701	0.708
. |* .	. | .	7	0.077	0.007	4.0479	0.774
. *| .	. *| .	8	-0.068	-0.131	4.2697	0.832
. | .	. | .	9	-0.015	0.000	4.2808	0.892
. |* .	. | .	10	0.111	0.039	4.9238	0.896
. |* .	. |* .	11	0.165	0.128	6.3946	0.846
. *| .	. *| .	12	-0.094	-0.100	6.8974	0.864
. *| .	. *| .	13	-0.106	-0.067	7.5643	0.871
. | .	. | .	14	-0.005	-0.006	7.5661	0.911
. | .	. | .	15	-0.026	-0.021	7.6091	0.938
. | .	. | .	16	0.008	0.053	7.6132	0.960

Table A11: Correlogram of residuals from robbery regression Model B

Autocorrelation	*Partial correlation*		*AC*	*PAC*	*Q-Stat*	*Prob*
. | .	. | .	1	0.029	0.029	0.0315	0.859
. *| .	.**| .	2	-0.188	-0.189	1.3900	0.499
. *| .	. *| .	3	-0.107	-0.098	1.8399	0.606
. | .	. | .	4	0.008	-0.024	1.8425	0.765
. *| .	. *| .	5	-0.121	-0.167	2.4598	0.783
. |* .	. |* .	6	0.080	0.075	2.7375	0.841
. |* .	. | .	7	0.118	0.063	3.3659	0.849
. *| .	. *| .	8	-0.124	-0.141	4.0887	0.849
. *| .	. | .	9	-0.076	-0.019	4.3734	0.885
. | .	. | .	10	0.057	0.014	4.5388	0.920
. |* .	. |* .	11	0.122	0.099	5.3255	0.914
. *| .	. *| .	12	-0.179	-0.178	7.1018	0.851
. *| .	. *| .	13	-0.108	-0.113	7.7760	0.858
. | .	. | .	14	0.016	-0.017	7.7926	0.900
. | .	. | .	15	0.026	-0.019	7.8355	0.930
. | .	. | .	16	0.055	0.051	8.0447	0.948

Table A12: Descriptive statistics for robbery, heroin overdose, clear-up, imprisonment and unemployment rate time series, NSW, 1966-2000

	Robbery	*Heroin overdose*	*Clear-ups*	*Imprisonment*	*Unemployment*
Mean	68.96	28.36	18.71	21.61	5.68
Median	64.69	22.11	18.01	17.91	5.90
Maximum	186.37	113.00	34.62	46.39	11.40
Minimum	11.66	0.53	12.72	7.12	0.90
Standard deviation	50.02	28.98	4.41	11.38	3.21
Observations	35	35	35	35	35

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