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THE IMPACT OF THE AUSTRALIAN HEROIN SHORTAGE ON ROBBERY IN NSW[1]

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Around Christmas 2000 Australia began to experience an acute heroin shortage. The shortage was associated with a steep fall in the rate of heroin overdose and a somewhat slower fall in many of the major categories of property crime in NSW. The incidence of robbery, however, increased markedly after the heroin shortage but then began falling in tandem with the other major categories of property crime. This bulletin examines the factors behind the unusual trend in robbery and discusses their significance for future drug law enforcement policy.

INTRODUCTION

In Australia, as in other western countries, dependent drug users often resort to crime to fund their purchases of illicit drugs. Heroin dependence, in particular, has been a major factor behind the growth in robbery in New South Wales over the last thirty-five years (Chilvers & Weatherburn 2003). Despite the close connection between heroin dependence and robbery, experts have often disagreed over the likely impact on robbery (and other drug-related offences) of a reduction in the supply of heroin. Because heroin is an addictive drug it has been argued by some that demand for heroin is price-inelastic.[2] This means that any reduction in the supply of heroin will push up the price of the drug and prompt heroin users to commit more crime to fund their addiction. Others, however, have argued that demand for heroin is price-elastic and that higher heroin prices will reduce heroin consumption and heroin-related crime (cf. Manski, Pepper & Petrie 2001).

Around Christmas 2000, media reports began surfacing of a major heroin shortage in Sydney and in other Australian capital cities (Debelle, 2001; Totaro, 2001). Research by Rou.en et al. (2001) at the National Drug and Alcohol Research Centre (NDARC) and by Weatherburn et al.. (2002) at the NSW Bureau of Crime Statistics and Research (BOCSAR) confirmed the existence of a shortage. Weatherburn et al. (2002) found that the average cost of a gram of heroin in Cabramatta (then Australia's largest heroin market) had risen by 75 per cent: from $218.00 before the heroin shortage to $381.00 afterwards. The heroin users interviewed as part of that study also reported a sharp drop in heroin purity and a significant increase in the time it took to 'score' heroin. The supply of heroin in Australia seems to have recovered somewhat since the first few months of 2001. However at no stage have heroin prices returned to the level they were at prior December 2000 (National Drug and Alcohol Research Centre 2003).

Figure 1 shows the trend in ambulance call-outs to incidents of heroin overdose during the period leading up to and following the onset of the heroin shortage (marked by a vertical line in this and succeeding graphs). It shows a substantial reduction in the rate of heroin overdose occurred in both in NSW and Cabramatta. Most major categories of property crime in NSW also fell after the onset of the heroin shortage (NSW Bureau of Crime Statistics and Research 2003), although the fall in

Figure 1: Trends in non-fatal overdose, NSW and Cabramatta

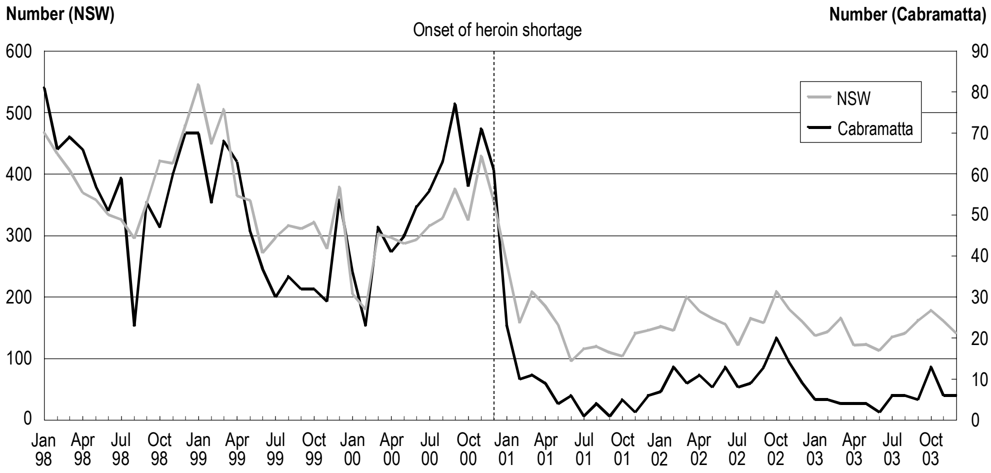
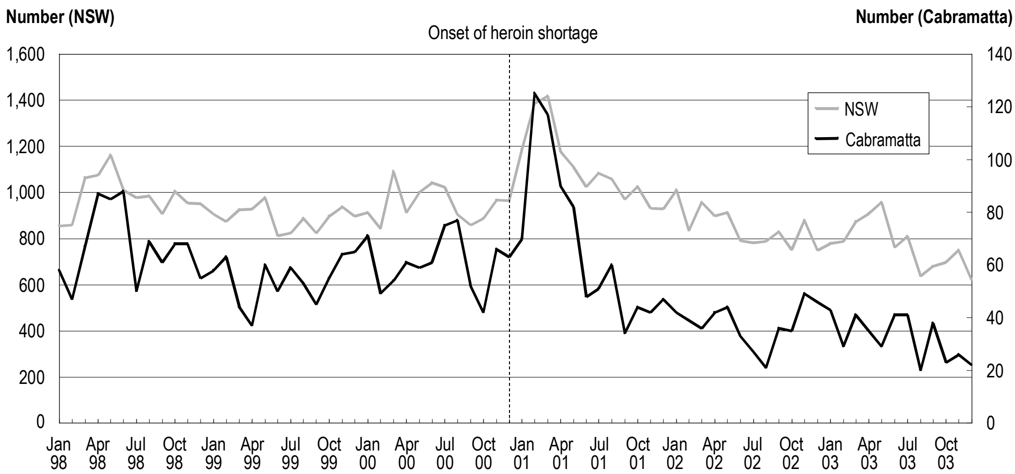


Figure 2: Trends in robbery, NSW and Cabramatta

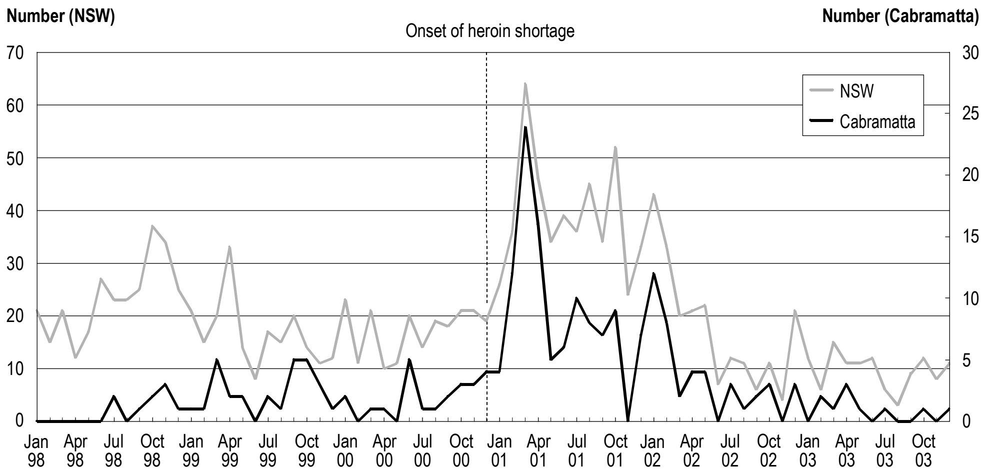


these offences was less abrupt than the fall in heroin overdoses shown in Figure 1. As can be seen from Figure 2, however, the trend in robbery was rather unexpected. Immediately after the shortage took hold, the robbery rate across NSW jumped 55 per cent in the space of just two months. It then began to fall quite rapidly, so that by December 2003 the monthly number of robberies was lower than it had been in the preceding five years. As can be seen from Figure 2, this rise and subsequent fall in robbery is even more pronounced in Cabramatta, a suburb which, before the shortage, was one of Australia's leading heroin markets.

In the interviews Weatherburn et al. (2002) conducted with heroin users a few months after the shortage, they found that those with very large heroin habits compensated for the lack of heroin by 'topping up' with other drugs, particularly cocaine. Because the effects of cocaine and other stimulants (e.g. amphetamine) do not last as long as those of heroin, cocaine tends to be used much more frenetically by dependent users (van Beek, Dwyer, & Malcolm, 2001). This makes cocaine dependence quite expensive compared with heroin dependence. Van Beek et al. have provided strong evidence that, unlike heroin, frequent use of cocaine renders an individual prone to violence and aggression. This suggests that robberies in NSW may have risen after the shortage, partly because more deeply entrenched heroin users began switching to cocaine and partly because cocaine itself leads to increased violence and aggression on the part of the user.

Why, though, did the incidence of robbery fell almost as soon and as sharply as it had risen? One possibility is that the fall in robbery occurred because cocaine, like heroin, became much harder

Figure 3: Trends in arrests for cocaine, NSW and Cabramatta



to obtain. There are two lines of evidence supporting this possibility. Data collected by the Australian Institute of Criminology as part of the DUMA program (Makkai & McGregor 2002) show a steep rise in the proportion of arrested persons (police detainees) testing positive for cocaine shortly after the heroin shortage, followed by a sharp decline (Makkai & Milner 2004). As can be seen from Figure 3, police arrests for cocaine use and/or possession across NSW as a whole and in Cabramatta, also show a sharp rise immediately after the heroin shortage and then a sharp decline.

These considerations suggest that changing patterns of heroin and cocaine consumption may account for both the spike and the fall in robbery in the months immediately following the heroin shortage. It is unclear from the evidence so far examined, however, how much of the recent variation in robbery can be explained in terms of changes in heroin and cocaine consumption. To address this issue, multiple time series regression analyses were conducted in order to measure independent effects of heroin and cocaine use on the number of monthly robberies. Because Cabramatta was Australia's leading heroin market at the time of the heroin shortage, these analyses were conducted for Cabramatta as well as for NSW as a whole.

The use of multiple regression analysis raises the question of whether any factors other than heroin and cocaine might have influenced the trend in robbery between January 1998 and December 2003. In a previous analysis of long-term robbery trends, Chilvers and Weatherburn (2003) included controls for unemployment and the risks of arrest and imprisonment. That analysis, however, examined robbery trends over a thirty-four year period during which the risk of arrest and imprisonment for robbery fell significantly. The present analysis examines robbery trends over a six-year period during which there has been no noticeable change in the risk of arrest or imprisonment for robbery but there has been some change in the rate of unemployment among young men. In the analysis that follows we therefore control for the confounding influence of changes in male youth unemployment rates.

METHOD

In order to model the relationship between robbery, unemployment, heroin and cocaine use, we need monthly measures of each. The first three variables present few problems. Data on the incidence of robbery can be obtained from NSW police records of the number of reported robberies. Monthly male unemployment data for the age group 15-24 years can be obtained from the Australian Bureau of Statistics. Monthly changes in the rate of heroin use cannot be measured directly but are fairly well reflected in the rate of heroin overdose (Law, Lynskey, Ross & Hall 2001). Data on non-fatal opiate overdose incidents attended by ambulance officers in New South Wales can be obtained from the NSW Department of Health. Unfortunately, because cocaine overdose (in Australia) is much less prevalent than heroin overdose and far less likely to prove life threatening, hospital reports of cocaine overdose are a less reliable guide to trends in cocaine use. DUMA data on the percentage of police detainees who test positive to cocaine use provide one measure of trends in cocaine use by active offenders but DUMA data are only collected on a quarterly basis. This would give us too few observations for the analysis we wish to conduct. The only readily accessible source of monthly data on cocaine use among active offenders is the monthly number of arrests for use/possession. The principal limitation of this series is that changes in the arrest rate for cocaine use/possession tends to lag behind changes in cocaine use. We shall have more to say about this problem shortly.

The period chosen for the analysis was January 1998 through December 2003. This provides us with about three years of data prior to the shortage and an equivalent period after it began. The main aim of the analyses was to estimate a statistical model which was predictive of the number of recorded monthly robberies over time on the basis of changes in heroin use (as measured by non-fatal overdoses) and cocaine use (as proxied by the number arrests for possess/use cocaine) over the period 1998-2003.

When regressing one time dependent variable on another (or others), it is important to establish whether or not any of these series contains a stochastic trend component, as this will have important implications for the type of statistical analysis which needs to be applied. If none of the time dependent variables contain a stochastic trend component (as measured by the absence of a unit root), then a conventional regression based methodology (incorporating auto-correlated errors where necessary) can be adopted (Koop 2000). Where these variables are found to contain a stochastic trend component, co-integration tests and error correction models are required (Enders 1995). As it turned out, the overdose, robbery and cocaine arrest series did not appear to contain stochastic trend components and it was therefore possible to proceed with a conventional linear regression approach. Details of the findings from the unit root testing that led to this conclusion are provided in Appendix A.

Linear regression models incorporating auto-correlated errors were estimated using the SAS PROC AUTOREG procedure. Initial models were estimated using ordinary least squares. Autocorrelation function (ACF) plots and partial autocorrelation function (PACF) plots were used to assess the presence of autocorrelation.[3] The Durbin-Watson test for serial autocorrelation was also applied. Where autocorrelation was identified, the regression model was re-fitted with auto-correlated errors using the Yule-Walker estimating procedure (estimated generalised least squares). Residuals from this re-fitted model were then inspected once again to ensure that all autocorrelation had been adequately accounted for.

Another methodological issue that arises when regressing one time dependent variable on another relates to what is known as Granger causality conditions. If changes in an independent variable are to be interpreted as having at least the potential of playing a causal role in changes in the dependent variable of interest, then changes in this predictor variable should either precede or at the very least occur contemporaneously with changes in the outcome variable. The Granger testing procedure addresses this issue by assessing whether prior lags of the independent variable are predictive of the outcome variable and, importantly, whether or not the reverse applies (i.e. whether prior lags of the outcome of interest are predictive of the independent variable).

Granger causality was assessed between each of the opiate overdose and cocaine arrest series with the robbery series (in NSW overall and Cabramatta, respectively) using the Eviews statistical software package. For NSW overall, it was found that opiate overdose "Granger caused" robbery at a lag of three months with no lagged relationship in the opposite direction.[4] This same pattern of results between opiate overdose and robbery was also found for the Cabramatta series.[5] Thus in each of the regression models for NSW and for Cabramatta, it was the number of overdoses which occurred three months prior to the month in which the robberies occurred which was used as the predictor variable.

The situation with respect to cocaine arrests was more complex. It was found that for NSW overall and for Cabramatta, robbery actually "Granger-caused" cocaine arrests (at a lag of one month) and not vice versa.[6] In other words, changes in arrests for cocaine use tended to lag behind the changes in the rate of robbery by around one month. The most likely explanation for this apparent reversal of causal order is that there is a lag between police receiving intelligence about a growth in the level of cocaine use and the mounting of operations designed to arrest more street-level cocaine users and dealers. For this reason changes in the arrest rate of offenders for use/possession of cocaine tend to lag somewhat behind changes in cocaine use. If this explanation is accepted, it is reasonable to model the relationship between cocaine use and robbery using the number of cocaine arrests in a given month as a predictor of the number of robberies in the same month.

RESULTS

Table 1 shows the estimates from a model which regresses the number of robberies per month on the number of non-fatal opiate overdoses and the number of cocaine arrests for NSW overall. The model accounted for 68 per cent of the variability in the number of monthly robberies and showed both

Table 1: Linear regression with autocorrelated errors (Estimated Generalised Least Squares) Outcome variable = Robbery (NSW)

Term	*Coefficient*	*SE*	*T*	*P value*
Structural component				
Intercept	689.5	47.4	14.5	<0.0001
Opiate overdose (lag 3)	0.5	0.1	3.3	=0.002
Cocaine arrests	5.4	1.1	4.8	<0.0001
Autoregressive component				
AR(1)	0.3	0.1	2.4	=0.02
AR(2)	0.2	0.1	2.0	=0.06

Table 2: Linear regression with autocorrelated errors (Estimated Generalised Least Squares) Outcome variable = Robbery (NSW), incorporating male youth unemployment rate as a covariate

Term	*Coefficient*	*SE*	*T*	*P value*
Structural component				
Intercept	606.1	116.8	5.2	<0.0001
Opiate overdose (lag 3)	0.5	0.1	3.2	=0.002
Cocaine arrests	5.3	1.1	4.6	<0.0001
Male youth unemployment	7.4	9.4	0.8	=0.4
Autoregressive component				
AR(1)	0.3	0.1	2.4	=0.02
AR(2)	0.2	0.1	2.0	=0.05

opiate overdoses and cocaine arrests to be independently predictive variables. For every extra arrest for cocaine use/possession, in a given month, there are over five extra robberies in the same month. On the other hand, for every two opiate overdoses in a given month, there is about one extra robbery three months later. This model incorporated auto-correlated error terms at lags 1 and 2 (i.e. AR1 and AR2). Analysis of the residuals from this model showed that there was no residual autocorrelation that needed to be accounted for.

Figure 4 shows the observed number of robberies per month plotted against the predicted number from the structural part of the model shown in Table 1 (i.e. all terms except the autoregressive parameters AR1 and AR2).

Figure 4: Observed and predicted robberies in NSW (autoregressive component excluded)

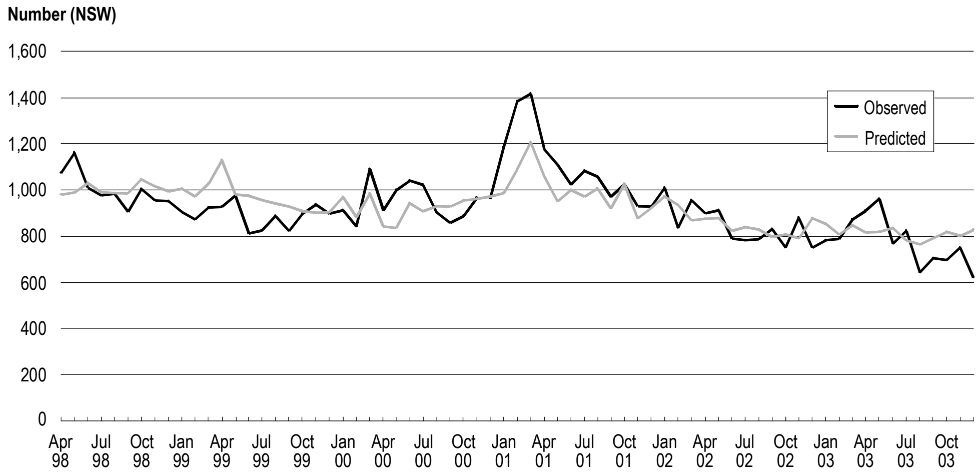


Table 3: Linear regression with autocorrelated errors (Estimated Generalised Least Squares)
Outcome variable = Robbery (Cabramatta)

Term	*Coefficient*	*SE*	*T*	*P value*
Structural component				
Intercept	33.4	3.7	9.0	<0.0001
Opiate overdose (lag 3)	0.5	0.1	5.6	<0.0001
Cocaine arrests	1.6	0.5	3.5	=0.001
Autoregressive component				
AR(1)	0.3	0.1	2.4	=0.02

This graph shows that, while the predicted number of robberies follows a similar pattern to the observed number of robberies over time, there are some parts of the plot where the fit does not appear to be ideal. In the period before the onset of the heroin shortage, the predicted number of robberies appears to over-estimate the actual number. The magnitude of the peak number of observed robberies (three months after the onset of the heroin shortage) is also substantially underestimated. Once we incorporate the autoregressive component of this model (i.e. the AR1 and AR2 terms), however, improves the fit of the model markedly[7] (see Figure 5).

One potential shortcoming of the model in Table 1 is that it does not adjust for unemployment, which may influence the incidence of robbery. A further model was therefore estimated which included a term for the monthly male youth unemployment rate, as shown in Table 2.[8] As can be seen from Table 2, youth unemployment was not independently predictive of robbery over and above the effects of cocaine arrests and opiate overdoses. Further, the magnitude of the regression coefficients for each of the opiate overdose and cocaine arrest variables was essentially the same as for the model in Table 1, which did not control for male youth unemployment.

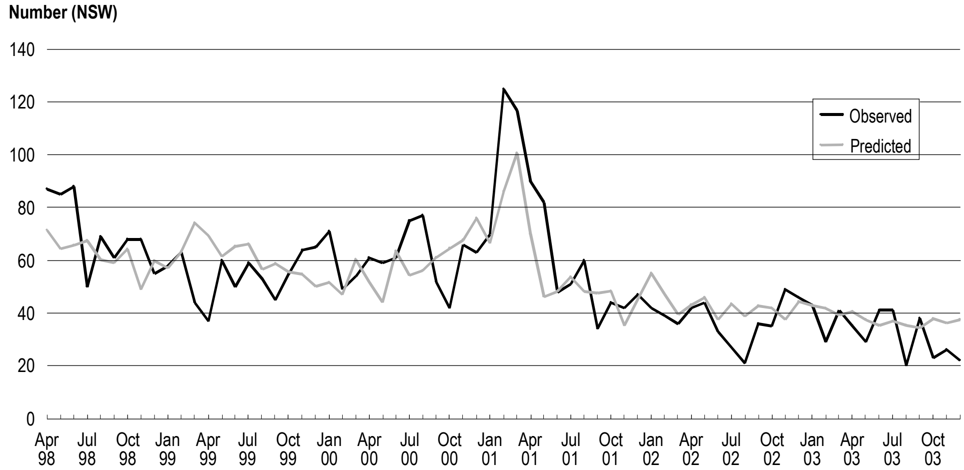
Cabramatta

A similar modelling approach was also undertaken to modelling trends in robbery in the Cabramatta area over the study period. The final regression model for these analyses is shown in Table 3. This model accounted for 60 per cent of the total variance in robberies in Cabramatta, and, once again, opiate overdoses and cocaine arrests were again significant, independent predictors. The coefficient of 0.5 for the overdose term means that, for every two overdoses in a given month in Cabramatta, there is one robbery three months later. The coefficient of 1.6 for cocaine arrests, on the other hand, indicates that, for every two cocaine arrests, there are over three robberies occurring in Cabramatta in the same month.

The model in Table 3 contained a first order (serial) autoregressive term, indicating that adjacent months were correlated in terms of the

Figure 5: Observed and predicted robberies in NSW (autoregressive component included)

Figure 6: Observed and predicted robberies in Cabramatta (autoregressive component excluded)



number of robberies. Examination of the residuals from this model revealed evidence of a modest degree of third order autocorrelation (AR3). As the addition of an AR3 term to the model did not markedly affect any of the other terms in the model (which all remained statistically significant), it was decided to rely on the more parsimonious model containing only an AR1 autoregressive term.

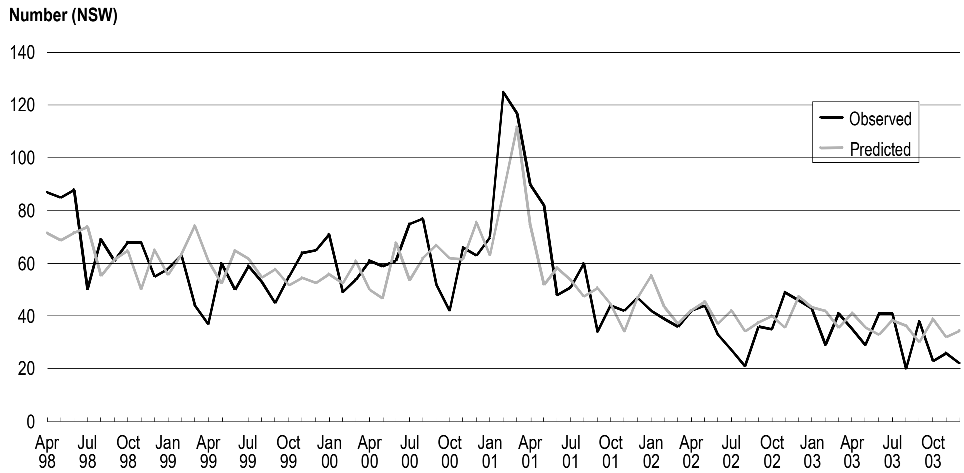
Figure 6 shows the observed number of robberies in Cabramatta over the study period, plotted against the number of robberies predicted from the model in Table 3, utilising the structural component of that model only. The predicted trend in robbery tracks the observed trend fairly closely. Once again, however, the model underestimates the magnitude of the peak in robberies around three months after the onset of the heroin shortage. There is also a tendency for the model to over-estimate the number of robberies in subsequent time points.

Figure 7 shows the plot of observed versus predicted robberies utilising both the structural and the autoregressive components of the model in Table 3. This provides a much closer fit to the data.

SUMMARY AND DISCUSSION

The Australian heroin shortage has produced some very positive effects on public health and crime in NSW. The average monthly non-fatal heroin overdose rate in the three years following the onset of the heroin shortage (i.e. January 2001) was 50 per cent lower than it had been in the preceding three years. In the three years since the shortage most major categories of property crime in NSW have fallen significantly. The NSW robbery rate is now

Figure 7: Observed and predicted robberies in Cabramatta (autoregressive component included)



lower than it has been at any point in the previous five years. The only notable adverse effect on crime was a sudden jump in the number of robberies straight after the heroin shortage as heroin users began to switch to (or top up with) cocaine. This adverse effect, however, appears not to have been sustained.

What implications do these findings hold for the drug law enforcement? In answering this question it is important to note that supply-side drug law enforcement policy rests on three key assumptions. The first is that heroin traffickers compensate themselves for the risks they take and the losses they suffer by demanding substantial profits. This is what keeps the price of heroin much higher than one would expect from a consideration of the costs involved in heroin production and distribution (see: Reuter & Kleiman 1986). The second assumption is that the demand for heroin is price-elastic. If the demand for heroin were not price-elastic, forcing up the price of heroin would increase aggregate expenditure on heroin even if it succeeded in reducing heroin consumption.[9] This would increase profits to drug dealers and induce drug users to commit more property crime. The third assumption is that many of the harms associated with heroin (e.g. heroin overdose) are inversely related to the price of heroin and the total amount of heroin consumed. If it were not so, there would be little point trying to increase heroin prices and reduce total heroin consumption. Support for this assumption can be found in Caulkins (2001).

There is little dispute about the first and third of these assumptions. However the second, as we noted in the introduction, has been vigorously contested. The present study adds weight to a growing body of evidence suggesting that demand for drugs such as heroin and cocaine is in fact price-elastic (Manski, Pepper & Petrie 2001). This is very important evidence for drug law enforcement policy. It means that, regardless of whether the current heroin shortage was caused by drug law enforcement or some other set of factors, the efforts of drug law enforcement agencies to keep the price of heroin high (or prevent it falling) have a critical role to play in drug harm reduction. As a result of the heroin shortage we may be more confident that, even if the process of investigating, arresting and sanctioning heroin importers and distributors fails to prevent a rise in heroin consumption, it does serve to limit both the scale of any increase in heroin consumption and therefore the scale of any increase in heroin-related harm. There is no longer any justification, therefore, for the common assumption that rising rates of heroin consumption and heroin related harm mean drug law enforcement has failed.

Of course, the present study would provide a more impressive vindication of supply control policy, if it could be shown that the heroin shortage was *in fact* attributable in whole or in part to the actions of drug law enforcement agencies. It is impossible to provide definitive evidence on this issue but there are three reasons for suspecting that the heroin shortage was at least partly attributable to the combined efforts of Federal and State drug law enforcement agencies. Firstly, although there is some evidence of a slow fall-off in heroin overdoses prior to Christmas 2000, the fall in heroin overdoses at this time was so precipitous it is hard to see how any natural occurrence (such as insufficient rainfall in source countries) could have been responsible for the heroin shortage.[10] Secondly, the shortage occurred soon after a substantial increase in the quantity of heroin seized at the customs barrier (Australian Crime Commission 2003). Finally, the shortage also occurred soon after the arrest of a large number of heroin importers and distributors[11] by the Joint Asian Crime Group (Owens, 2004, personal communication).

Although State and Federal police must be credited for their role in reducing the supply of heroin into Australia the apparent willingness of heroin users to shift to cocaine and other stimulants, although temporary, carries with it a salutary warning. It is quite likely that the switch to cocaine and other stimulants as a result of the recent heroin shortage was only temporary because supplies of psycho-stimulants (especially cocaine) fell not long after heroin became more expensive and harder to obtain (NDARC 2004). Prolonged use of psycho-stimulants is in many ways more dangerous to the user and the community than prolonged use of heroin (van Beek et al. 2001). The outcome of the heroin shortage in Australia might well have been very different had the drop in heroin consumption been matched by an equally large (and sustained) jump in the availability of psycho-stimulants. Agencies involved in supply-side drug control policy need to be mindful of this when fashioning strategies designed to further reduce the availability of heroin.

REFERENCES

Australian Crime Commission (2004) *Australian Illicit Drug Report*, Australian Crime Commission, Canberra.

Australian Institute of Criminology (2004) *Drug use monitoring in Australia (DUMA) Program*, unpublished data.

Caulkins, J.P. (2001), Drug Prices and Emergency Department Mentions for Cocaine and Heroin, *American Journal of Public Health*, 91, 9, pp. 1446-1448.

Chilvers, M. and Weatherburn, D. (2003) *The impact of heroin dependence on long-term robbery trends*, Crime and Justice Bulletin 79, NSW Bureau of Crime Statistics and Research, Sydney.

Debelle, P. (2001) Police work hits the heroin trade, *The Age*, 7 March, Melbourne.

Enders, W. (1995) *Applied econometric time series*, John Wiley & Sons, New York.

Fitzgerald, J. and Chilvers, M. (2002) *Multiple drug use among police detainees*, NSW Bureau of Crime Statistics and Research, Sydney.

Koop, G. 2000, *Analysis of economic data*, John Wiley & Sons, Chichester.

Law, M. G., Lynskey, M., Ross, J. & Hall, W. (2001) 'Back-projection estimates of the number of dependent heroin users in Australia', *Addiction,* 96, pp. 433-443.

Makkai, T. & Milner, L. 2002, *Drug Use Monitoring in Australia, 2001 Annual Report on Drug Use Among Police Detainees*, Australian Institute of Criminology, Canberra.

Makkai. T. & Milner, L. 2004, *Drug Use Monitoring in Australia: 2003 Annual Report on Drug Use Among Police Detainees*, Australian Institute of Criminology Research and Public Policy Series, forthcoming.

Manski, C.F., Pepper, J. V., and Petrie, C.V. (2001) *Informing America's Policy on Illegal Drugs: What We Don't Know Keeps Hurting Us*, Committee on Data and Research for Policy on Illegal Drugs, National Academy Press, Washington, D.C.

National Drug and Alcohol Research Centre 2003, *Australian Drug Trends 2002*, National Drug and Alcohol Research Centre, University of New South Wales, Sydney.

National Drug and Alcohol Research Centre 2004, *NSW Drug Trends 2003*, National Drug and Alcohol Research Centre, University of New South Wales, Sydney.

New South Wales Bureau of Crime Statistics and Research (2003), *Recorded Crime Statistics 2002*, NSW Bureau of Crime Statistics and Research, Sydney.

Owens, G. (2004), (Detective Superintendent, NSW Police), *Personal Communication*.

Reuter, P. & Kleiman, M.A.R. (1986), 'Risks and prices: an economic analysis of drug enforcement', In Tonry M. Morris, N. eds. *Crime and Justice: An Annual Review of Research*, 7, University of Chicago Press, Chicago, pp. 289-340.

Rouen, D., Dolan, K., Day, C., Topp, L., Darke, S., & Hall, W. (2001) *Changes in Heroin Availability in Sydney Australia in Early 2001,* Technical Report no. 119, National Drug and Alcohol Research Centre, Sydney.

Totaro, P. (2001) Heroin shortage may bring more fatalities, *Sydney Morning Herald*, 19 February, Sydney.

van Beek, I., Dwyer, R., & Malcolm, A. (2001) 'Cocaine injecting: The sharp end of drug-related harm', *Drug and Alcohol Review*, 20, 333-342.

Weatherburn, D., Jones, C., Freeman, K. & Makkai, T. (2002) 'Supply control and harm reduction: lessons from the Australian heroin 'drought", *Addiction*, 98, pp. 83-91.

APPENDIX A: Unit root testing for the NSW and Cabramatta robbery, opiate overdose and cocaine arrest series

An issue that arises when assessing the relationship between time dependent variables is that the extent of association or correlation between such variables can appear much higher than is actually the case. This situation can arise when firstly, the variables of interest contain what is known as a stochastic trend component and secondly such components are not co-integrated (Enders 1995; Koop 2000). Given this, the first step when conducting analyses involving time dependent variables is to assess whether or not the variables of interest contain a stochastic trend component, as if they do not, then a conventional regression based approach can be undertaken. In order to assess the presence of a stochastic trend component, the Dicky-Fuller test was undertaken for each of the robbery, opiate overdose and cocaine arrest series. The null hypothesis which is tested in this procedure is that the series contains a unit root and should this null hypothesis not be rejected the conclusion would be that the series contains a stochastic trend component and requires differencing. A short-coming of the Dickey-Fuller test however which has been well documented in the econometric literature, is that this test has relatively low statistical power to reject the null-hypothesis of a unit root, when in fact a series does not contain such a stochastic trend component (Enders 1995).

Given this, it has been argued that it is appropriate to utilise a more liberal Type I error rate than the conventional five per cent level and for this reason the 10 per cent level was also assessed when appraising the likelihood that each of the series did or did not contain a stochastic trend component.

Table A1: Unit root tests for robbery, opiate overdose and cocaine arrests, NSW, January 1998 – December 2002

Variable	*ADF test statistic*	*5% critical value*	*10% critical value*
Robbery[1]	-3.24	-3.47	-3.16
Opiate overdose[1]	-3.41	-3.47	-3.16
Cocaine arrests	-3.43	-2.90	-2.59

1. These variables include deterministic trend & intercept terms, otherwise intercept only

Table A2: Unit root tests for robbery, opiate overdose and cocaine arrests, Cabramatta, January 1998 – December 2002

Variable	*ADF test statistic*	*5% critical value*	*10% critical value*
Robbery[1]	-3.93	-3.47	-3.16
Opiate overdose[1]	-3.41	-3.47	-3.16
Cocaine arrests	-3.82	-2.90	-2.59

1. These variables include deterministic trend & intercept terms, otherwise intercept only

This low power property of the Dickey-Fuller test is even more problematic when a series contains a major structural break such as is the case for the overdose series (Enders 1995).

Table A1 shows the results of the Augmented Dickey Fuller (ADF) tests for each of the robbery, opiate overdose and cocaine arrest series for NSW overall. In summary, each of the Robbery and Opiate Overdose series, while not significant at the five per cent level were clearly significant at the 10 percent level. The cocaine arrest series was significant at the five per cent level, as shown in Table A1 (with no lagged difference terms included in this model).

However testing for the presence of lagged difference components revealed that for cocaine arrests (unlike the other two variables), there was a first order lagged difference effect, which was just significant at the five per cent level (p=0.05). The consequence of including this term, however, was that the ADF test statistic no longer rejected the null hypothesis of a unit root at the 10 per cent level (ADF=-2.41; 10% critical value=-2.59). As inclusion of lagged difference terms also reduces the power of the unit root test, particularly in combination with the disruption to the cocaine arrest series, which occurred around the time of heroin shortage, it was decided to conduct unit root tests for each of the pre and post-shortage cocaine arrest series separately. This approach has been described by Enders (1995) as one means of dealing with power problems presented by series, which contain structural disruptions. Given the smaller number of time points being tested in each of the pre and post series, it is a conservative strategy for dealing with this problem. It was found that for each of the pre and post cocaine arrest series, the null hypothesis of a unit root was clearly rejected at the five per cent level (pre series ADF=-3.88, critical value=-2.95; post series ADF=-4.66, critical value=-3.54).

Given these results and the well-documented low power property of the ADF test, we conclude that for all three of these variables the null hypothesis that each series contains a unit root can be rejected. This means that none of these variables require differencing and that a linear regression based approach can be adopted.

Table A2 shows the ADF test findings for each of these three variables in the Cabramatta area only. For both the robbery and the cocaine arrests series, the null hypothesis of a unit root was clearly rejected at the five per cent level. For the opiate overdose series however the ADF test statistic just failed to exceed the five per cent critical value (-3.41 v –3.47), however was clearly significant at the 10 per cent level. Given this pattern of findings from the unit root testing, a conventional regression based approach was therefore adopted for the Cabramatta series.

NOTES

1 An earlier draft of this paper was delivered at the Annual Australian and New Zealand Society of Criminology Conference held at the Australian Technology Park, Sydney, 1st - 3rd October 2003. We would like to express our gratitude to Ms Devon Indig (Centre for Drug and Alcohol, NSW Health) and Detective Superintendent Geoff Owens, NSW Police for their assistance in preparing this report.

2 Technically, demand for a commodity is price elastic if a one percent change in the price of the commodity produces a greater than one percent fall in aggregate consumption.

3 Autocorrelation occurs when time points (e.g. months) at a given lag of distance are correlated with one another. Serial (or first order autocorrelation) refers to the situation where adjacent time points are correlated with each other. Second order autocorrelation is where time points two lags (months) apart are correlated. The presence of autocorrelation requires statistical adjustment, and failure to adjust can result in both biased significance testing and mis-specified regression models

4 $F=2.95$, $p=0.04$

5 $F=4.4$, $p=0.007$

6 NSW: $F=13.1$, $p<0.001$; Cabramatta: $F=5.2$, $p=0.03$

7 Note that the poorer fit without the autoregressive component evident in Figure 4 means that caution should be exercised when basing predictions of the number of robberies solely on the opiate overdose and cocaine arrest variables.

8 Unit root testing showed that the youth unemployment rate series did not contain a stochastic trend component and that incorporating this terms in the conventional linear regression based analyses was appropriate (ADF statistic = -4.18; 5% critical value –2.90).

9 Suppose, for example the price of heroin rose 10 per cent from $20 a cap to $22 a cap but that this reduced aggregate consumption by only five per cent, from 43 million caps per annum to 40,850,000 caps per annum. Then aggregate expenditure on heroin would rise from (20 x 43,000,000) $860,000,000 per annum to (22 x 40,850,000) $898,700,000 per annum.

10 Other non-law enforcement explanations for the heroin shortage, or the reduction in heroin overdoses have occasionally been put forward in the media. These include expansion of the NSW methadone program, the deliberate withholding of heroin from the market by drug traffickers (in order to raise heroin prices and increase profits) and a return to 'normal' levels of heroin availability following an alleged heroin 'glut'. The first of these explanations cannot explain the sudden nature of the drop in heroin overdoses around Christmas 2000. The second lacks supporting evidence and is, in any event, implausible because the drop in consumption and expenditure that occurred in the wake of the heroin shortage would have nullified any benefits obtained from higher heroin prices. The 'glut' thesis, on the other hand, is hard to reconcile with the fact that even prior to the shortage, heroin was far more expensive to buy than gold. The drop in heroin overdose following Christmas 2000, on the other hand, was far larger than any similar drop since the mid-sixties. This fact is hard to reconcile with the notion that, after the shortage, the heroin market simply 'returned to normal'.

11 The arrests in 1999 included Lai Hon-ming (24/7/99), (Jim Shui-tai 24/7/99), Ye Zhonghe (24/7/99), Chan Kong-goi (7/11/99) and Soh Bak-seng (7/11/99). The last arrest involved the seizure of 219 kilograms of heroin.