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Did the heroin shortage increase amphetamine use?
A time series analysis

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Over the last decade, Australia has experienced a substantial growth in the use of amphetamine type substances (ATS). A number of studies have found evidence that the growth in ATS use may have been stimulated or exacerbated by the heroin shortage that began around Christmas 2000. One limitation of these studies is that they mostly involved interviews with groups of street or treatment-based former or current heroin users. There is no guarantee that street or treatment based drug users are typical of heroin users in general. The present study reports the results of a time series analysis designed to see whether there is any statistical relationship between trends in heroin use and trends in ATS use. After examining a number of models, no evidence of a temporal relationship between heroin and amphetamine use was found.

Keywords: *Heroin shortage, heroin use, amphetamine use, supply reduction, drug substitution, time series analysis*

INTRODUCTION

Between 1993 and 1998 the prevalence of amphetamine use in Australia rose by 85 per cent (Australian Institute of Health and Welfare 2005). The use of amphetamine-type substances (ATS) appears to have briefly stabilised between 1998 and 2002 but, in late 2002, emergency department (ED) admissions for ATS use in New South Wales (NSW) began to rise again (see Figure A2 in the Appendix 1). Between the September quarter 2002 and the March quarter 2007 the number of ED admissions for ATS use rose by 139 per cent. The increase in ATS use is a matter of concern for two reasons. Firstly, frequent and prolonged ATS use appears to increase the risk of aggressive and violent behaviour (Vincent et al. 1998; McKetin 2006; Jones et al. 2005). Secondly, at the moment, illicit drug treatment services in Australia are less well equipped to deal with increases in ATS use than they are to deal with other forms of drug addiction (Topp et al. 2003).

There have been suggestions in the media and elsewhere (see Weatherburn et al 2003; Rouen et al. 2001, Day et al. 2003) that the heroin shortage prompted many heroin users to either switch to ATS use or increase their ATS consumption (Hall, 2001; Bush, Roberts and Trace 2004). There is some evidence to support this concern. Shortly after the heroin shortage began, Weatherburn et al. (2001) found that dependent heroin users in Cabramatta, NSW were ‘topping up’ with other drugs, such as cocaine, cannabis, benzodiazepines and amphetamines. Some time later, Dietze et al. (2004), noted an increase in amphetamine and benzodiazepine use in Victoria. Around the same time, Longo et al. (2004) found a similar change in Adelaide. Most recently, Maher et al. (2007), in a longitudinal study of intravenous drug users in Sydney, found that the proportion injecting amphetamines increased from 20 to 27 per cent immediately following the onset of the heroin shortage and remained at more than 30 per cent during 2001.

Because supply-side law enforcement is believed by some experts to have caused the heroin shortage (Degenhardt et al. 2004), the suggestion that it contributed to ATS use raises questions about the value of supply-side policy. Maher et al. (2007, p. 249), for example, contend that the benefits of the shortage have been ‘overstated’ and the costs ‘overlooked’ and have called for a reappraisal of supply control policy, arguing that:

‘…attempts to suppress illicit drug markets by manipulating the availability of heroin may result in significant collateral damage and indicate a need for more sophisticated understandings of the potential tradeoffs involved in attempting to suppress the supply of illicit drugs.’ (Maher et al. 2007, p. 249)

The effect of heroin shortage on ATS use, however, is not as clear as it might seem. Although there were sudden changes in all the indicators of heroin use around Christmas 2000, there were no sudden increases in indicators of ATS use (Degenhardt et al. 2007).

This bulletin has been independently peer reviewed. Our thanks to NSW Health for providing data on ED admissions for opioid and amphetamine overdose.

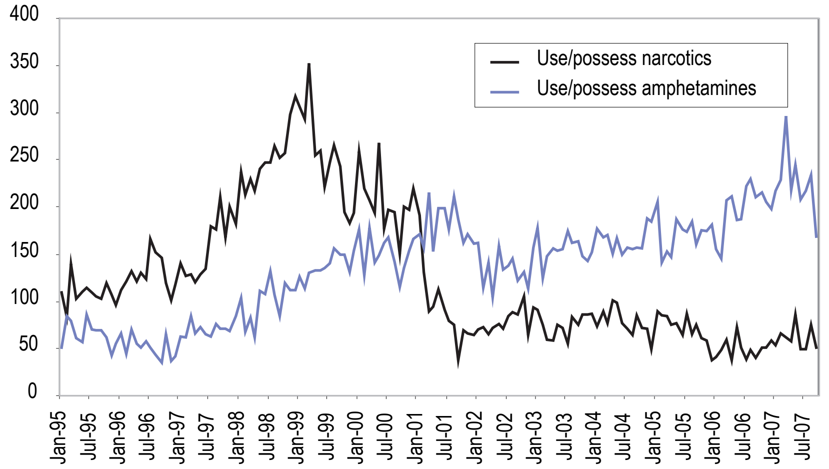
Some interview studies, moreover, have failed to observe a shift to greater ATS use. Darke et al (2006), for example, used data from the Australian Treatment Outcome Study to investigate whether reductions in the frequency of heroin use were associated with reductions in use of other drugs over a 24-month period and found no evidence of drug substitution as heroin use declined. There are other considerations as well. The studies by Longo et al. (2004) and Maher et al. (2007) were based on fairly small samples. In the Maher et al. (2007) study, moreover, there was substantial sample attrition. Over the course of her study, the number of intravenous drug users (IDU) available for interview fell from 127 to 31 – raising the possibility that the apparent increase in amphetamine use was actually just an artefact of changes in sample composition.

Perhaps the most important problem with existing evidence suggesting that the heroin shortage stimulated ATS consumption, however, is that most of the evidence linking the heroin shortage to ATS use comes from interviews with street or treatment-based IDU. There is no guarantee that the patterns of drug switching evident in street or treatment-based drug users are typical of heroin users in general. This is important because the key question for policy makers is not whether some heroin users responded to the heroin shortage by switching to other, more harmful drugs – some undoubtedly did – but how much of the growth in ATS use is attributable to a shift from heroin to ATS. The only way to answer this question is to examine the relationship between heroin and ATS use over time and see whether, and to what extent, the two are related.

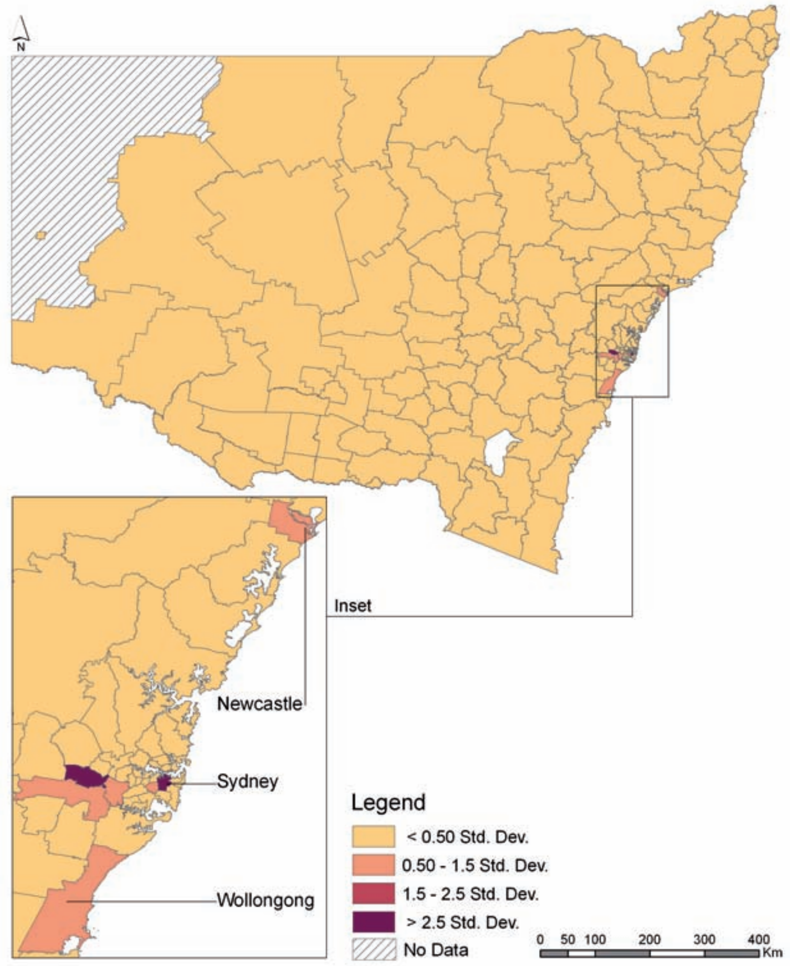
THE PRESENT STUDY

In order to examine the temporal relationship between heroin and ATS use we need measures of both. Annual surveys of illicit drug use do not provide enough data for a time series analysis. The present study therefore examined two proxy measures of heroin and ATS use. The first was the rate of admission to NSW emergency departments (ED)

Figure 1: Monthly use/possess arrests for amphetamines and narcotics, January 1995 - September 2007



Map 1. Spatial distribution of Local Government Area arrest rate for use/possess narcotics, displayed using standard deviation from mean, January 1995 - September 2007 (standard deviation = 3.8, mean = 0.8, median = 0.1)



for heroin or ATS use. The second was the rate of arrest for use/possession of heroin or amphetamines.[2] The hospital and law enforcement measures turned out to be highly correlated (see Appendix 1). In fact analyses carried out using both sets of data produced identical results. As the arrest series is longer than the ED admission series, in the body of this report we focus on analyses involving arrest data. The results of our analysis of ED admissions can be found in Tables A5 to A8 of Appendix 2.

Figure 1 shows the trends in NSW Police arrests for use/possess narcotics and use/possess amphetamines between January 1995 and September 2007 (the most recent data point at the time of the study).[3] The heroin and amphetamine series display a highly variable relationship, sometimes moving up and down together and sometimes moving in opposite directions. The correlation between the two series over the entire period is significant and negative (r = -0.39). In March 1999, there was a sharp fall in the narcotics series. This is important because, while the heroin shortage is generally thought to have started around Christmas 2000, there is some evidence[4] that the NSW heroin market began contracting in early 1999. The correlation between the narcotics and amphetamine series from March 1999 to September 2007 is -0.38. There was a second, more precipitous fall in the narcotics series around December 2000. December 2000 is widely regarded as the point where the heroin shortage started. The correlation between the narcotics and amphetamine series from this point forward to September 2007 is also -0.38. The largest fall in narcotics arrests is that between March 1999 and April 2002. The correlation between the narcotics and amphetamine series during this period was -0.58.

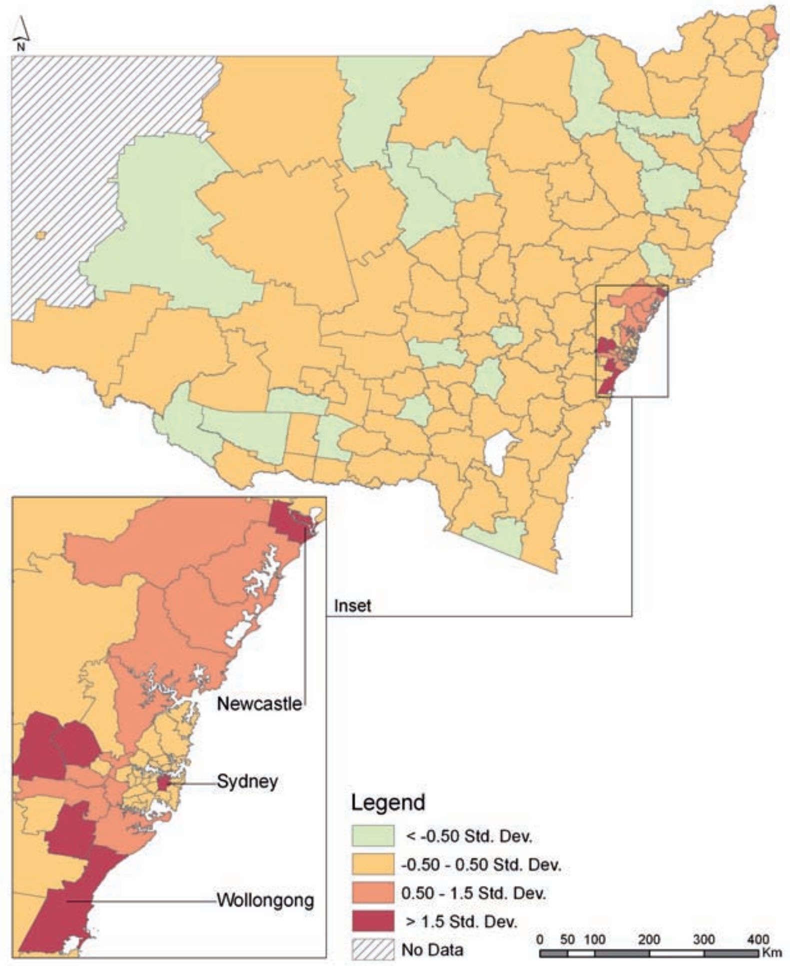
The persistent negative relationship between our proxy measures of heroin and amphetamine use suggests that usage of the two types of drug may be inversely related. The spatial distributions of arrests for use/possess narcotics and use/possess amphetamines across NSW, however, are quite different. Map 1 shows the distribution of arrests for use/possess narcotics across NSW Local Government Areas (LGAs). All but seven of 153 LGAs are clustered within half a standard deviation from the NSW rate. Two outlier LGAs are visible, Fairfield and Sydney, which have an arrest rate of more than 2.5 standard deviations from the NSW mean. Marrickville, Bankstown, Liverpool, Newcastle and Wollongong LGAs also have relatively high rate of arrest for use/possess narcotics.

Map 2 shows the distribution of arrests for use/possess amphetamines across NSW. The LGAs with higher rates are more widely disburst than Map 1, although, as with narcotics, arrests for use/possess amphetamines are concentrated on the east coast of NSW between Wollongong and Newcastle LGAs. Sydney, Blacktown, Newcastle, Wollongong, Penrith and Campbelltown LGAs also have relatively high rates of arrest for use/possess amphetamines.

In light of the above, the present study examines four questions:

1. Is there is a long-term inverse relationship between heroin use and amphetamine use?
2. Is there an inverse relationship between heroin use and amphetamine use after March 1999?
3. Is there an inverse relationship between heroin use and amphetamine use after December 2000?
4. Was there an inverse relationship between heroin and amphetamine use that only lasted while heroin use was falling (viz. between March 1999 and April 2002)?

Map 2. Spatial distribution of Local Government Area arrest rate for use/possess amphetamines, displayed using standard deviation from mean, January 1995 - September 2007 (standard deviation = 1.7, mean = 0.89, median = 0.4)



Because Maps 1 and 2 show differences in the spatial distribution of arrests for use/possess heroin and use/possess amphetamine, we conducted separate analyses for the state as a whole and for LGAs with a high mean risk of arrests for use/possess narcotics (Sydney, Fairfield, Marrickville, Bankstown, Liverpool, Newcastle and Wollongong). The next section of this bulletin describes the methods used to carry out these analyses.

DATA AND METHODOLOGY

As noted earlier, two sets of analyses were undertaken. The first involved an examination of the time series relationship between arrests for use/possess narcotics and arrests for use/possess amphetamines. The police arrest data were extracted from the Computerised Operational Policing System (COPS) database over the period from January 1995 to September 2007 (the most recent data point available at the time of the study). The second involved a separate confirmatory analysis over a shorter time period using quarterly data on ED admissions for heroin and amphetamines obtained from NSW Health. As the results of the two sets of analyses were identical, in what follows we concentrate on the analysis of drug arrest data.

Our earlier examination of the correlation between arrests for heroin use/possession and amphetamine use/possession suggested that the two series were inversely related. Two non-stationary time series, however, can be spuriously related (e.g. both may be responding to changes in some other variable). The first step in our analysis, then, was to test for stationarity. This was done using the Phillips-Perron test with four lags. The results of this test revealed that both narcotics and amphetamines use/possess arrests were non-stationary. The same test, when applied to the two differenced series, revealed a stationary result for both series. Instead of examining the time series relationship between the raw arrest frequencies for heroin use/possession and amphetamine use/possession, then, we examine the relationship between monthly changes in arrest frequency for heroin use/possession and monthly changes in arrest frequency for amphetamine use/possession.

To test for the presence of any long run equilibrium relationship or cointegration between the two series, the Johansen unrestricted rank test was applied. The test, using Eviews 4 statistical software, was carried out for the entire period (January 1995 to September 2007) and for the period from the start of the drop in narcotics arrests (March 1999) to September 2007. The test results indicated no cointegrating relationships for either periods.

Two techniques were employed to analyse the relationship between the two drug arrest series: vector autoregression (VAR) and Autoregression Integrated Moving Average (ARIMA) modelling. VAR models were developed for arrests for the whole of NSW and for the subset of arrests in LGAs identified above as having high use/possess narcotics arrests. Because no difference was found between these results, the ARIMA modelling was carried out only on the NSW dataset. Four ARIMA models were developed. The first model tested the relationship between use/possess narcotics and use/possess amphetamines over the entire period of observation (i.e. from January 1995 to September 2007).

The second tested the relationship from the point where the first drop in narcotics use/possess arrests occurred (i.e. March 1999) through to September 2007. The third tested the relationship from the point where the heroin shortage is generally though to have begun (i.e. December 2000) through to September 2007. The fourth tested the relationship during the period of falling narcotics use/possess arrests (i.e. from March 1999 to April 2002).

We used a series of diagnostics to specify the lag order selection for the VAR and choice of ARIMA models and then to check the validity of the final models. These included the log-likelihood, ACF, PACF and associated Ljung-Box Q-statistics and Phillips-Perron unit root tests. Some final statistical checks on the residuals of the ARIMA models are included in Appendix tables A1-A4 and A7-A8 (the latter tables being for the analysis of ED admissions).

RESULTS

The results of the VAR model are shown in Table 1 below. Note that lagged dependent variable coefficients and standard errors are not included as we are focusing on evidence of cross-over influence between narcotics and amphetamines.

There is no evidence in the VAR model that a drop in the number of arrests

Table 1: Results of the VAR(5) analysis modelling narcotics and amphetamines use/possess arrests

	Whole of NSW		*LGAs with high narcotics use/ possess arrests*	
Lag	*Coefficient (with standard error)*	*p-val*	*Coefficient (with standard error)*	*p-val*
1	-0.092 (0.076)	0.223	0.024 (0.050)	0.625
2	0.029 (0.080)	0.714	-0.026 (0.052)	0.619
3	0.005 (0.077)	0.949	-0.056 (0.052)	0.275
4	-0.075 (0.077)	0.332	0.020 (0.051)	0.700
5	0.028 (0.072)	0.694	0.063 (0.049)	0.202
R-squared = 0.348			R-squared = 0.324	

** Significant at 5 per cent level.*

Table 2: Results of the ARIMA (I=1) analysis modelling narcotics and amphetamines use/possess arrests

	Model 1 Jan 1995 - Sep 2007	**Model 2 Mar 1999 - Sep 2007**	**Model 3 Dec 2000 - Sep 2007**	**Model 4 Mar 1999 - Apr 2002**
Narcotics	0.079 (0.090)	0.055 (0.105)	0.020 (0.086)	0.105 (0.264)
Constant	-0.368 (1.354)	-2.470 (1.705)	-1.793 (1.833)	-6.366 (4.601)
AR(1)	-0.367 (0.055)*	-0.384 (0.061)*	-0.264 (0.106)*	-0.366 (0.149)*
AR(3)	-0.136 (0.069)*	-0.158 (0.080)*	-	-

** Significant at 5 per cent level.*

across NSW for use/possess narcotics is accompanied or followed by an increase in arrests for use/possess amphetamines. This is true even when we constrain the analysis to LGAs with a high rate of arrest for narcotics use/possess.

Table 2 gives the results of the ARIMA modelling. The models show that there is no significant effect of narcotics use/possess arrests on amphetamines use/possess arrests over either (a) the entire period (Model 1); (b) from March 1999 to September 2007 (Model 2); (c) from December 2000 to September 2007 (Model 3); or (d) during the period when arrests for heroin use/possession fell most sharply (Model 4).

DISCUSSION

This study sought to test the hypothesis that the heroin shortage led to higher levels of ATS use. Using arrests for use/possess narcotics as an indicator of heroin use and arrests for use/possess amphetamines as a proxy for amphetamine use, we conducted four tests of this hypothesis, one covering the entire period from January 1995 to September 2007 and the other three covering different segments of this period identified on a priori grounds as likely points where changes in the heroin market might have stimulated ATS consumption. None of the tests revealed any evidence that the heroin shortage increased the level of ATS consumption, whether contemporaneously or after a lag (delay). The growth in ATS use appears, for all intents and purposes, to be unrelated to the fall in heroin use.

The question naturally arises as to why our results differ from those obtained in interview studies with heroin users. There are two possible reasons for the discrepancy. The first is that our measures of heroin and amphetamine use (viz. arrests for narcotic use/possession and amphetamine use/possession) are too weak or contaminated to allow us to detect a relationship. Since there is no way to actually measure levels of heroin and ATS use, this possibility cannot be discounted. When we measure trends in heroin and amphetamine use using ED admission data, however, we obtain the same result. The fact that we obtain consistent findings across independent measures suggests that our results are not just artefacts of poor measurement.

A second, more likely possibility is that some heroin users did move into the ATS market but their contribution to the growth in ATS use was comparatively small. One consideration that counts in favour of this explanation is that, while there is some overlap in the spatial distribution of heroin and ATS use (see Maps 1 and 2), the distribution of ATS use is much broader than that of heroin use. The impression of limited overlap in the heroin and ATS markets is further strengthened by the fact that the percentage of Australians aged 12 years and over who have ever used ATS (9.1 per cent) is 6.5 times larger than the percentage that have ever used heroin (1.4 per cent) (Australian Institute of Health and Welfare 2005, p. 4).[5] Even if all those who once used heroin are now using ATS, much of the growth in ATS use must have come from other sources.[6]

If the upward trend in ATS use is essentially unrelated to the heroin shortage, there may be less reason for concern about the collateral damage caused by Australian supply control policy than researchers such as Maher et al. (2007) suggest. This is not to say the growth in ATS use is not a serious problem or that the heroin shortage caused no collateral harm. The growth and scale of ATS use in Australia is serious problem in its own right. The fact that some heroin users responded to the heroin shortage by shifting to ATS (or other drug use) is a timely warning of the need for close monitoring of the impact of supply side policy. However, just as it is important not to overstate the benefits that flow from drug policy, it is important not to overstate the harms. The heroin shortage undoubtedly caused some IDU to shift from heroin to ATS use. The evidence presented here, however, suggests that the shift (in NSW, at least) was comparatively small.

We conclude by highlighting the need for further research on drug substitution in Australia. Although we found no evidence in the present study that changes in heroin use were systematically associated with changes in ATS use, the study reported here does not by any means settle the general issue. We note, for example, that Degenhardt et al. (2005) observed an increase in the number of persons seeking treatment for psycho-stimulant (cocaine and methamphetamine) use immediately after the heroin shortage in Victoria and South Australia. That study strongly suggested that heroin users in some States responded to the heroin shortage by switching to psycho-stimulants but did not provide a formal test of the hypothesis and contained only limited information about its likely magnitude and duration. Much more detailed statistical analysis is necessary if we are to properly understand the population-level relationship between various forms of illicit drug use. Replicating the present study in Victoria and South Australia would be a valuable step in this direction.

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NOTES

1. We would like to thank our reviewers for their comments on an earlier draft on this article. Thanks also to NSW Health for providing the data on which this study was based.
2. Arrests for injectable drugs have found to be a good indicator of trends injecting drug use over time (Rosenfeld and Decker 1999)
3. It should be noted that more than 90 per cent of arrests for use/possess narcotics are in fact for use/possess heroin. It should also be noted that arrests for amphetamine use/possession only include arrests for drugs properly classed as amphetamines. They do not include arrests for use/possession of ecstasy.
4. Fatal opioid overdoses began to fall in that year, as did the number of enquiries to the Alcohol and Drug Information Service. The total quantity of heroin seized by the Australian Customs Service also peaked in 1999 (Australian Crime Commission 2007, p. 43). The two most likely points at which the heroin shortage might have begun to stimulate ATS use, then, are March 1999 and December 2000.
5. We are indebted to Associate Professor Rebecca McKetin from the National Drug and Alcohol Research Centre for pointing this out.
6. We also undertook a third analysis in which we examined the proportion of people arrested for heroin use/possession prior to the heroin shortage (December 2000) who were arrested after the heroin shortage for heroin use/possession and/or amphetamine use/possession. We found no evidence that heroin use/possession offenders had subsequently been arrested for an amphetamine use/possess offence. This is a weak test, however,

because the heroin shortage could have stimulated amphetamine use without necessarily prompting large numbers of heroin users to switch to amphetamine use. It is also worth remembering that drug offenders who are arrested by the police do not necessarily share the same characteristics as other drug users.

APPENDIX 1

To test the hypothesis that trends in heroin and ATS use are related we need indicators of heroin and ATS use extending over a reasonable period before and after the onset of the heroin shortage. It is, of course, impossible to obtain precise direct measures of the monthly or quarterly quantities of heroin and ATS consumed across NSW. For the purposes of the present study, however, it is not necessary to measure the true level of heroin and ATS consumption. Since we are only concerned about the relationship between changes in heroin use and changes in ATS use, it suffices to obtain indicators that rise and fall with the level of heroin and ATS use. There are two obvious sources of such indicators: police arrest data and emergency department (ED) presentation data. Both sources had strengths and weaknesses as far as the present study is concerned.

Other things being equal, we would expect the health harms associated with a drug to increase with the level of drug consumption. Over periods in which other key determinants of drug-related harm (e.g. drug toxicity, method of administration) remain stable, therefore, ED admission data probably provide a reasonable basis for measuring trends in drug consumption. NSW Health, however, only compiles ED data for ATS use on a quarterly basis. A quarterly time series would furnish too few observations for a rigorous time series analysis. Arrests involving injectable drugs provide a much longer time series and have also been shown to be a good indicator of trends injecting drug use over time (Rosenfeld & Decker 1999). Drug arrest data, however, can be affected by changes in law enforcement activity or in the way police involved in drug law enforcement choose to exercise their discretion to arrest.

As it happens, in NSW since 1995, trends in arrests for narcotics and amphetamines and trends in ED presentations for these same drugs, tell a very similar story. Figure A1 plots the trend in arrests for use/possess narcotics and ED presentations for narcotics from the March quarter in 1998 to the March quarter in 2007. Figure A2 plots the corresponding trend for use/possess amphetamines and ED presentations for amphetamines.

It can be seen from Figure A1 that trends in arrests for use/possess narcotics track ED presentation trends for heroin use very well (r = 0.834). The correlation (r = 0.727) is not quite as high for the use/possess amphetamines and ED presentation series but it is still very strong. Rather than choose between these two indicators of drug use, then, separate analyses were carried using both.

Figure A1: Quarterly heroin-related ED presentations and use/possess narcotics arrests, Mar qtr 1998 - Mar qtr 2007

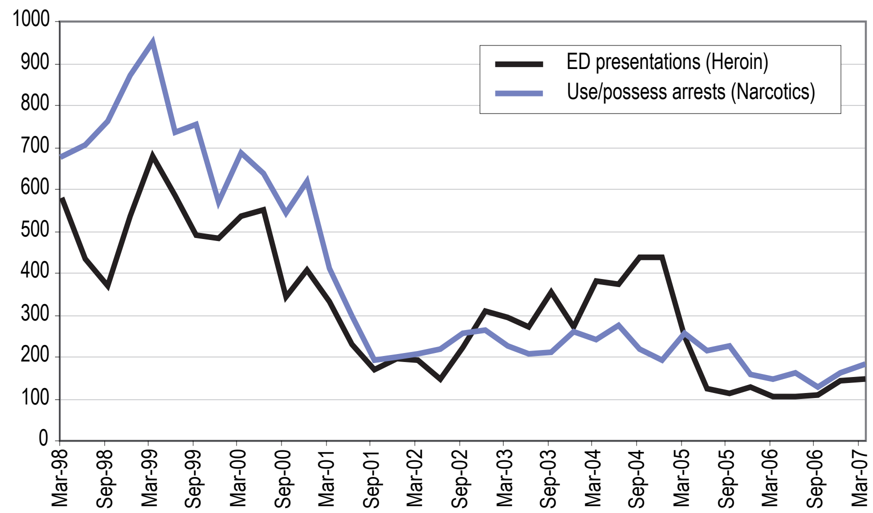
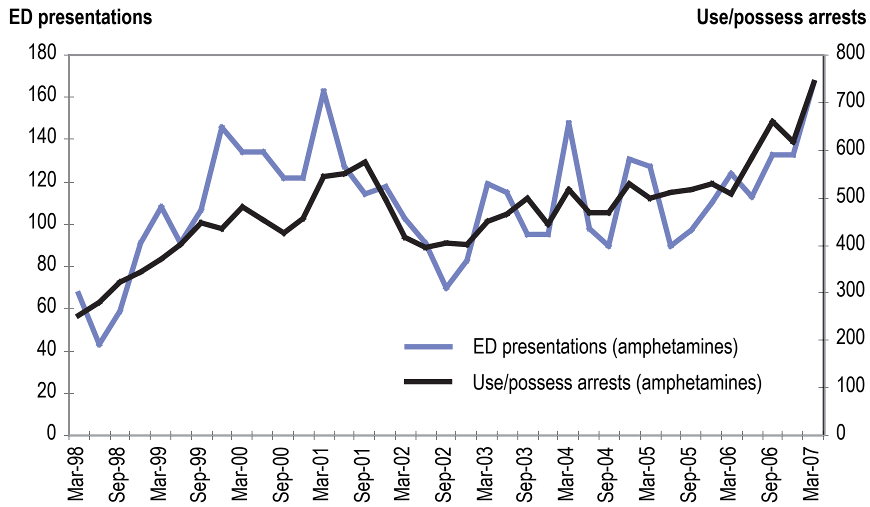


Figure A2: Quaterly emphatemines related ED presentations and amphetamines use/possess arrests, Mar qtr 1998 - Mar qtr 2007



ED data: Courtesy of NSW Health

APPENDIX 2

Table A1: Model 1 diagnostics: Q-Stats for residuals and Phillips-Perron unit root test

Lag	AC	PAC	Q-Stat	p-val
1	-0.040	-0.040	0.243	0.622
2	-0.096	-0.098	1.666	0.435
3	0.021	0.016	1.732	0.630
6	0.137	0.150	6.739	0.346
9	0.010	0.001	7.272	0.609
12	0.091	0.072	8.706	0.728
15	-0.034	-0.066	18.882	0.326
18	-0.025	-0.003	19.216	0.379

Phillips-Perron unit root test
Test Statistic -12.832
1% Critical value -2.593

Table A2: Model 2 diagnostics: Q-Stats for residuals and Phillips-Perron unit root test

Lag	AC	PAC	Q-Stat	p-val
1	-0.031	-0.031	0.149	0.699
2	-0.096	-0.098	1.586	0.453
3	0.040	0.038	1.837	0.607
6	0.130	0.137	6.965	0.324
9	0.016	0.008	7.546	0.581
12	0.091	0.071	8.973	0.705
15	-0.031	-0.070	16.702	0.337
18	-0.030	0.000	19.207	0.379

Phillips-Perron unit root test
Test Statistic -11.199
1% Critical value -2.6

Table A3: Model 3 diagnostics: Q-Stats for residuals and Phillips-Perron unit root test

Lag	AC	PAC	Q-Stat	p-val
1	-0.138	-0.139	2.969	0.085
2	-0.035	-0.053	3.157	0.206
3	-0.153	-0.170	6.835	0.077
6	0.147	0.160	12.160	0.059
9	-0.039	-0.010	12.961	0.164
12	0.137	0.111	16.963	0.151
15	-0.082	-0.035	28.879	0.017
18	-0.008	-0.012	31.152	0.028

Phillips-Perron unit root test
Test Statistic -9.072
1% Critical value -2.607

Table A4: Model 4 diagnostics: Q-Stats for residuals and Phillips-Perron unit root test

Lag	AC	PAC	Q-Stat	p-val
1	-0.075	-0.076	0.230	0.632
2	-0.215	-0.215	2.179	0.336
3	-0.093	-0.118	2.555	0.465
6	0.117	0.076	4.921	0.554
9	-0.015	-0.040	6.258	0.714
12	0.055	-0.017	6.446	0.892
15	0.038	-0.129	12.596	0.634

Phillips-Perron unit root test
Test Statistic -6.938
1% Critical value -2.639

Table A5: Results of the VAR(5) analysis modelling heroin and amphetamines ED admissions

Lag	Coefficient (with standard error)	p-val
1	0.060 (0.048)	0.206
2	0.046 (0.046)	0.321
3	0.057 (0.043)	0.189
4	0.022 (0.042)	0.596
5	0.028 (0.042)	0.506

R-squared = 0.430

Table A6: Results of the ARIMA (I=1) analysis modelling heroin and amphetamines ED admissions

	Model A1 Mar qtr 1998 - Mar qtr 2007	Model A2 Dec qtr 2000 - Mar qtr 2007
Heroin	0.020 (0.023)	0.005 (0.025)
Constant	-3.567 (7.050)	-0.444 (6.647)
AR(2)	-0.457 (0.215)*	-
MA(1)	-	-0.543 (0.196)

Table A7: Model A1 diagnostics: Q-Stats for residuals and Phillips-Perron unit root test

Lag	AC	PAC	Q-Stat	p-val
1	-0.268	-0.294	2.802	0.094
2	0.049	-0.021	2.900	0.235
3	0.129	0.154	3.586	0.310
6	-0.127	0.167	4.588	0.598
9	-0.139	-0.032	6.458	0.693
12	0.201	0.118	16.716	0.161
15	0.000	-0.347	18.154	0.255

Phillips-Perron unit root test
Test Statistic -7.358
1% Critical value -3.682

Table A8: Model A2 diagnostics: Q-Stats for residuals and Phillips-Perron unit root test

Lag	AC	PAC	Q-Stat	p-val
1	0.055	0.063	0.088	0.767
2	-0.258	-0.303	2.104	0.349
3	0.167	0.317	2.987	0.394
6	-0.343	-0.251	11.918	0.064
9	-0.060	0.235	13.720	0.133

Phillips-Perron unit root test
Test Statistic -6.778
1% Critical value -3.74

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