Supply-side reduction policy and drug-related harm

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Aim: The aim of this study was to examine the question of whether seizures of heroin, cocaine or amphetamine type substances (ATS) or supplier arrests for heroin, cocaine or ATS trafficking have any effect on the ED admissions related to or arrests for use and possession of these drugs.

Method: Two strategies were employed to answer the question. The first involved a time series analysis of the relationship between seizures, supplier arrests, emergency department (ED) admissions and use/possession arrests. The second involved an analysis of three specific operations identified by the NSW Crime Commission as has having had the potential to have affected the market for cocaine.

Results: Over the short term (i.e. up to four months), increases in the intensity of high-level drug law enforcement (as measured by seizures and supplier arrests) directed at ATS, cocaine and heroin did not appear to have any suppression effect on ED admissions relating to ATS, cocaine and heroin, or on arrests for use and/or possession of these drugs. The three major operations dealing with cocaine listed by the NSW Crime Commission as significant (Operation Balmoral Athens, Operation Tempest and Operation Collage) did exert a suppression effect on arrests for use and possession of cocaine.

Conclusions: Increases in the quantities of ATS, cocaine and heroin drugs seized by law enforcement authorities are normally a signal of increased rather than reduced supply. Very large seizures, however, may temporarily suppress consumption of these drugs. Even if drug seizures and drug supplier arrests have no short term effects on ED admissions and arrests for drug use and/or possession, they may still suppress drug consumption through risk compensation.

Key words: supply control, heroin, cocaine, amphetamine-type substance, overdose, crime

Introduction

Australia's drug policy is founded on supply reduction, demand reduction and harm reduction[i]. Treatments such as methadone maintenance are effective in reducing the demand for illicit drugs (Ward, Mattick and Hall 1998) and harm reduction measures such as needle and syringe programs (Wodak & Cooney 2006) are effective in limiting the spread of diseases such as HIV-AIDS and Hepatitis C. Some, however, have argued that supply reduction policy has failed because Australia (along with many other countries) spends very large sums of money on drug law enforcement but illegal drugs remain readily available and widely used (see, for example, Wodak and Owens 1996).

There is no doubt that Australia spends a large sum of money on drug law enforcement (Ritter et al. 2013) or that illegal drug use in Australia remains widespread (Australian Institute of Health and Welfare 2011, pp. 8-9). However this does not necessarily mean that supply control policy has failed. Arguments to this effect ignore the counterfactual—we have no idea how much drug consumption and drug related harm there would be if the drugs that are currently prohibited were made more readily available. Indeed, if the co-occurrence of heavy investment in law enforcement and high levels of non-compliance with the law were evidence that law enforcement is failing, we would have to declare speed radars and random breath testing a failure on the grounds that, despite these measures, speeding and drink-driving remain widespread.

Supply control policy does not need to create a scarcity of illegal drugs in order to reduce drug use and drug related harm. According to the Risks and Prices Theory (RPT) of drug markets (Reuter and Kleiman 1986; Caulkins and Reuter 1998), the severe punishments associated with conviction for drug cultivation, manufacture, importation and supply make these activities very risky. The consequent need to avoid detection makes drug production and distribution very inefficient. RPT maintains that drug traffickers compensate themselves for these risks and efficiencies by demanding higher premiums. These premiums are then passed onto drug consumers in the form of higher retail drug prices. Higher retail drug prices, according to standard economic theory, should lead to lower levels of drug consumption. To the extent that drug-related harm is a positive function of drug consumption, this should also lead to lower levels of drug-related harm.

RPT has empirical support. According to Grossman, Chaloupka and Shim (2002), the black-market price of cocaine in the United States in 2002 was between 2.5 and five times higher than it would be in a legal market. The black-market price of heroin was estimated to be between eight and 19 times higher than it would be in a legal market. There is strong evidence these high prices result in lower levels of drug consumption. The sensitivity of demand for a product to changes in its price is what economists call its price-elasticity. An elasticity of -1.0 means that when the price of a commodity increases by one per cent, consumption of the commodity falls by one per cent. In his meta-analysis Gallet (2013) found price-elasticities of around -0.5 to -0.6 for heroin and cocaine and -0.2 to -0.3 for cannabis. Higher drug prices also mean lower levels of drug related harm. Dave (2005) found the price elasticities associated with cocaine and heroin emergency department (ED) episodes were -0.27 and -0.10, respectively. He estimated that a 10 per cent increase in prices would prevent about 11,000 hospital visits, with savings of between $21-47 million.

More dramatic evidence that higher drug prices result in lower levels of drug related harm can be seen in the effects of the heroin shortage in Australia. Around Christmas 2000, the real price (i.e. price divided by purity) of a gram of heroin in Australia rose from around $360 to over $1,200 (Weatherburn et al. 2003). In the period leading up to the heroin shortage, robbery and theft offences were all rising. In the eight years after the heroin shortage, robbery rates in NSW fell by 38 per cent; burglary by 50 per cent; motor vehicle theft by 56 per cent; and general theft by 37 per cent (Weatherburn and Holmes 2013). The fall in heroin consumption produced health benefits as well. Non-fatal opioid overdoses in NSW declined by 63 per cent between the onset of the heroin shortage

(December 2000) and June 2003, while over the same period fatal overdoses declined by 43 per cent (Degenhardt, Day, Gilmour and Hall, 2006).

Higher drug prices may result in lower levels of drug consumption and drug related harm, but it does not follow that more frequent arrests of drug traffickers, more frequent drug seizures or larger drug seizures produce higher drug prices, lower levels of drug purity or lower levels of drug availability. Drug manufacturers or importers may expect to lose a certain quantity of their product to seizures and keep stockpiles to cover any shortfall. Alternatively, they may ship (manufacture or cultivate) more than is necessary to cover the losses they expect to suffer. The arrest of a key figure in a drug distribution syndicate may disrupt that syndicate's business, but other syndicates may simply expand their output to fill the resulting void. If it can be shown that increasing the frequency with which drug traffickers are arrested or increasing the number or quantities of drugs seized drives up drug prices and thereby drives down consumption, a case can be made for higher levels of investment in supply-reduction policy. If supply-reduction policy only affects drug consumption and drug-related harm indirectly, through risk compensation and inefficiency, there may be little benefit from higher levels of investment in supply control.

Sophisticated attempts have been made to model the overall impact of supply reduction policy (Everingham and Rydell 1993; Crane et al 1997). Rydell & Everingham (1994), for example, developed a simulation model of the cocaine market in the United States in which potential users of cocaine flowed between three states: non-use, light use and heavy use. The model was able to give a good account of trends in the prevalence of cocaine use in the United States between 1962 and 1992. On the basis of the model, Rydell and Everingham (1994) concluded that further investment in supply reduction would be less cost-effective than increased investment in demand reduction. Models such as these are attractive to policy makers because they generate clear and unambiguous policy implications. However the predictions of any simulation model are only as reliable as the assumptions on which it is based. The US National Research Council, in its review of research on US drug policy observed that the then current models of the US cocaine market 'rest on weak empirical foundations' (Manski, Pepper & Petrie 2001, p. 157). Slight changes in the assumptions about the price elasticity of demand for cocaine and the outflow into treatment in the model developed by Rydell and Everingham, for example, have significant effects on the relative cost-effectiveness of drug law enforcement versus treatment (Rydell & Everingham 1994, p. 112). This would not be a problem if these two quantities were known with reasonable precision but they are not. While there is strong evidence that demand for cocaine is price elastic, estimates of the scale of that effect range from -0.42 and -1.26 (Gallet 2013).

Direct evidence of the effect of seizures and supplier arrests is fairly sparse. In their review, Mazerolle, Soule and Rombouts (2007) identified four studies which examined the specific impact of supply control initiatives on drug use and drug related harm (Rumbold and Fry 1999; Weatherburn and Lind 1997; Wood et al. 2003; Smithson, McFadden, Mwesigye and Casey 2004). Three of these studies (Rumbold and Fry 1999; Weatherburn and Lind 1997; Wood et al. 2003) found no effect of drug seizures on drug use patterns, drug-related deaths or overdoses, treatment enrolment or rates of crime and arrest. McFadden, Mwesigye and Casey (2004) are alone in finding substantial effects from seizures. They observed that the decline in heroin supply in the Australian Capital Territory from July 1996 to April 2002 reduced non-fatal overdoses, crime and entry into methadone treatment. The period over which their study was conducted straddled the Australian heroin shortage. This was an exceptional event. To date, therefore, there is little evidence to suggest that 'routine' drug seizures are followed by a drop in drug consumption and drug related harm.

The current study

The aim of the current study was to examine the impact of seizures and supplier arrests on the use of and harms associated with three drugs: heroin, cocaine and amphetamine type substances (ATS). Heroin, cocaine and ATS were selected for examination for three reasons. Firstly, all three are known to cause significant harm both to users of the drugs (Ross 2007) and to the broader community (Blumstein, Cohen, Roth and Visher 1986; Nurco et al. 1991; Degenhardt et al. 2005; McKetin et al. 2006; Tyner and Fremouw 2008).

Secondly, although the prevalence of heroin use has declined in recent years, all three drugs remain significant problems in Australia. According to the last National Drug Strategy Household Survey (Australian Institute of Health and Welfare 2011), in the 12 months preceding the survey, 2.1 per cent of those aged 14 years and older used ATS, while 2.1 per cent used cocaine. While the prevalence of recent heroin use is much lower (0.2 per cent), heroin use remains a problem in NSW, which in 2008 accounted for 204 (58%) of the 351 opioid overdose deaths that occurred nationally (Stafford and Burns 2013, p. 93).

Thirdly, seizures of and arrests for supplying these drugs are sufficiently frequent and variable to permit an examination of the effects of large scale seizures and high-level arrests. Border detections of ATS (excluding MDMA) have ranged in number from around 200 (in 2003/4) to over 1,000 (in 2011/12). In terms of weight over the same period, they ranged from less than 50kg to nearly 350 kg. Heroin border detections ranged in number from less than 100 in 2003/4 to around 400 in 2006/7, and in weight over the same period, from less than 50kg in 2003/4 to around 400kg in 2011/12. Cocaine border detections ranged in number from around 100 in 2002/3 to more than 1,000 in 2011/12, and in weight over the same period, from around 50 to nearly 800kg in 2011/12 (Australian Crime Commission 2013).

Our study improves on past research in three ways. Two of the four previous studies of the effect of drug seizures on drug markets have restricted their attention to one seizure (Rumbold and Fry 1999; Wood et al. 2003). In this study we examine all significant seizures of heroin, cocaine and ATS in Australia over a 10 year period (from July 2001 to June 2011). Rather than infer changes in consumption and harm from changes in drug price, purity and availability, we measure consumption and harm more directly, though ED admissions for drug overdose and arrests for drug use and possession. We use arrests for drug use and possession (UP arrests) as a supplementary measure of drug use because they have been shown in past Australian research to be strongly correlated with ED admissions for heroin, ATS and cocaine use (Nordt and Stohler 2010; Rosenfeld and Decker 1999; Moffatt, Wan and Weatherburn 2011). They also have the advantage (particularly in the case of cocaine and ATS) of being more frequent than ED admissions.

Finally, in addition to conducting a general analysis of the effects of variation in seizures and supplier arrests we conducted an interrupted time series analysis of the effects of a single high-level drug law enforcement operation that resulted in the seizure of a very substantial quantity of cocaine and the arrest of several key players in the Sydney cocaine market. The distinctive feature of this operation is that NSW Crime Commission identified it, in advance of our analysis, as having the potential to have affected the market for cocaine.

Since the effects of changes in the number of high level arrests or large scale seizures may only last a matter of weeks or months, we need to measure changes in consumption and drug related harm on a monthly basis. The consumption and harm measures employed in this study, therefore, are the monthly number of emergency department (ED) admissions for heroin, cocaine and ATS and the monthly number of arrests for narcotic, cocaine and ATS use and possession. We also include measures of the monthly number of recorded thefts, robberies and assaults, on the grounds that these crimes known or though to be often committed by users of heroin, cocaine and ATS (Blumstein, Cohen, Roth and Visher 1986; Nurco et al. 1991; Degenhardt et al. 2005; McKetin et al. 2006; Tyner and Fremouw 2008). The question we seek to address is whether seizures of heroin, cocaine and ATS, and/or supplier arrests, have any effect on ED admissions and UP arrests for (a) heroin (b) cocaine and (c) ATS or on offences often committed by users of these drugs, namely (d) theft (e) robbery and (f) assault. More specifically, we are interested in determining whether there is an inverse contemporaneous or lagged relationship between any of the outcomes (a)-(f) and:

1. The number of heroin seizures
2. The weight of heroin seized
3. The number of heroin supplier arrests
4. The number of cocaine seizures
5. The weight of cocaine seized
6. The number of cocaine supplier arrests
7. The number of ATS seizures
8. The weight of ATS seized
9. The number of ATS supplier arrests

Seizures and supplier arrests in jurisdictions outside NSW were included because they may affect the market for heroin, cocaine or ATS in NSW. NSW was chosen as the site for an examination of the effects of seizures and supplier arrests because it has one of the largest markets for these three drugs in Australia. In the next section we describe in more detail the methods used to answer these questions.

Method

Data

As noted earlier, the study period extended from July 2001 to June 2011. Data on monthly drug seizures (weight and frequency) and drug supplier arrests were obtained from the National Illicit Drug Reporting Format (NIDRF) system maintained by the Australian Crime Commission. Data on monthly arrests of use/possess (UP arrests), theft, robbery and assault were sourced from the NSW crime and operational policing system (COPS) database. Data on heroin, cocaine and ATS ED admissions were obtained from the NSW Department of Health. The ED data is based on diagnosis codes recorded in the "Presenting problem" and "Final problem" fields. These are entered by the Emergency Department clinician (typically the responsible medical officer) following their assessment. Their diagnosis would be based on all available information, including history, examination, and laboratory testing where this was available.

Treatment of seizure data

Small seizures (e.g. a gram) could not reasonably be expected to influence the availability, price or purity of illicit drugs on the street. The selection of a weight threshold for seizures involves balancing the need to focus on seizures that have some potential to influence a drug market with the need to ensure that the drug seizures we examine are frequent enough to allow for meaningful analysis. We defined a seizure for the purpose of this study as a quantity of heroin, cocaine or ATS that lay in the top 20 per cent of the distribution of heroin, cocaine or ATS seizures by weight. The mean weight of seizures at or above these thresholds in each of the three drug type categories examined (along with the standard deviations) was:

- Heroin 173.46 grams (SD = 2129.48 grams)
- Cocaine 267.13 grams (SD = 1825.71 grams)
- ATS 326.69 grams (SD = 4146.59 grams)

It should be noted that the mean weights for cocaine and ATS listed above, exceed the thresholds listed in Schedule 1 of the NSW Drug Use and Trafficking Act (1985) as the basis for charges of commercial trafficking in cocaine or amphetamines (250 grams). The mean weight for heroin, however, is somewhat below the threshold for a charge of supplying a commercial quantity of heroin (also 250 grams). Separate analyses of the effect of heroin seizures above 250 grams (i.e. heroin seizures in the top 14 per cent by weight) were therefore carried out. The results are not reported here (although they are available from the authors) because they followed essentially the same pattern as the analyses of heroin seizures in the top 20 per cent by weight reported below.

Treatment of drug supplier arrest data

The ACC classifies drug arrest data into two types, consumer arrests and 'provider' (i.e. drug supplier) arrests. A supplier arrest is any arrest of a person charged with any supply-type offence (importation, trafficking, selling, cultivation and manufacture), regardless of the quantity involved. Supplier arrests, as defined by the ACC, clearly include a wide range of players in the drug distribution process, from small-scale suppliers at street level to high-level traffickers involved in the importation and/or distribution of large quantities of illicit drugs. It might be argued that, even though we restricted our focus to seizures in the top 20 per cent by weight, only some of these seizures are significant (i.e. market affecting). As noted earlier, our general analysis of supplier arrests was therefore supplemented with an analysis of three specific operations identified by the NSW Crime Commission as has having had the potential to have affected the market for cocaine. The three operations identified by the Commission were: (1) Operation Balmoral Athens which in June 2010 resulted in the arrest of four people and the seizure of 240 kg of cocaine; (2) Operation Tempest, which in September 2010 resulted in the arrest of four people and the seizure of 50 kg of cocaine; and (3) Operation Collage, which in October 2010 resulted in the arrest of three people and the seizure of 450 kg of cocaine in October 2010. Because the arrests occurred over a five month period, they were treated as a single intervention. It bears emphasis that the NSW Crime Commission identified these three operations as significant solely on the basis of their own intelligence data. No indication of the results obtained in this study was given to the Commission in advance.

Statistical analysis

ARDL Model construction

There are three challenges in addressing the research questions listed above. The first is that we have no prior knowledge of the lags involved in the process linking drug seizures or supplier arrests to drug outcomes. In other words, we have no way of knowing whether the effect of a seizure on overdoses or use/possession arrests will be immediate or delayed and, if delayed, how long it will take for the effect of the seizure to be felt. The second is the risk of omitted variable bias: factors other than supply side policy may affect overdoses, use/possession arrests and crime[1]. The third challenge is that the causal relationships we are interested in may be bi-directional. Changes in use/possession arrest rates may influence seizures and supplier arrests, a problem known as simultaneity. These problems must be overcome if we are to understand the true impact of supply side policy on drug markets.

[1]Overdoses can be affected by changes in patterns of poly-drug use. Crime rates and use/possession arrests can be affected by changes in enforcement tactics or policy.

We deal with these problems using autoregressive distributed lag (ARDL) models. ARDL models provide a means of correctly identifying the appropriate lag structure of a time series while also controlling for omitted variable bias and simultaneity. The tactic is to explain the present behaviour of a series (e.g. overdoses at time t) in terms of its past values (e.g. overdoses at t-1, t-2, etc) plus measures of the variables thought to affect it (seizures, supplier arrests), plus a randomly distributed error term. By including past values of the series in the model we control for any extraneous factor that influenced the series up to the present point in time. Granger causality tests were used to test for simultaneity. If simultaneity was found among the variables, either the current value of the endogenous variable was excluded and only lagged values of the endogenous variable was included or vector auto-regression (VAR) was used to overcome the problem. VAR model is commonly used for modelling multivariate time series with causal relationships. Each endogenous variable has an equation explaining its evolution based on its own lagged values plus the lagged values of the other endogenous variables.

In the study the dependent variables of interest (y_t) include use/possess of drugs arrests, ED admissions for drugs, and drug-related crimes. The independent variables ($x_{k,t}$) are number of seizures, weight of seizures (in kg) and number of supplier arrests from six different states and AFP. The ARDL model to be fitted has the following form:

$$y_t = \mu + \sum_{i=1}^{p} a_i\, y_{t-i} + \sum_{i=1}^{q_1} b_{1,i}\, x_{1,t-i} + \cdots + \sum_{i=1}^{q_k} b_{k,i}\, x_{k,t-i} + c_1 m_1 + \cdots + c_{11} m_{11} + e_t \qquad (1)$$

In Equation (1), p, q_1, q_2, …, q_k are the largest significant lags for the dependent variables and k independent variables respectively; t = 1,…, 120 represents the month starting from July 2001 and ending in June 2011; $x_{j,t}$, … , $x_{j,t-qj}$ represent the current and lagged values of the j^{th} ($j=1,\ldots,k$) independent variables x_j and y_t , …, y_{t-p} represent the current and lagged values of the dependent variable. The terms m_1, …, m_{11} represent monthly dummy variables to account for any seasonality in the dependent variable. The e_t represent the monthly residual error, which are assumed to be identically and independently distributed with a zero mean and constant variance (i.e. serially uncorrelated white noise). The lag order of p, q_1, …,q_k was determined based on the method described as follows. The method adopted in determining the model was to start on a reasonably long lag, say lag twelve, and shorten the lag by one period at a time until all lags had been tested or we reached a lag whose coefficient was statistically significant. The choice of lag was also influenced by the error structure of the residual errors. Increasing the lag order usually helps to reduce the autocorrelation in the residual errors. Ideally, the chosen lag order should be able to reduce the residual errors to white noise while at the same time revealing any significant coefficients on lagged independent variables. All the analyses were carried out using STATA 12.0.

ARDL model diagnostic checking

Before we fit the ARDL models, we need to make sure that the dependent variables and independent variables are stationary so that ordinary least square (OLS) method can be used to estimate the model parameters. To test if the series is non-stationary, the augmented Dickey-Fuller unit root test was performed with and without a linear trend in the regression model. If the ARDL model is correctly specified, it should be free from the following characteristics (1) simultaneity; (2) non-constant variance in residuals; and (3) serial correlation in the residuals. As already noted, Granger tests were used to assess (1). Engle's Lagrange multiplier test was used to test (2). The Ljung-Box test was used to test (3). Large p-values of the last two tests confirm that the model assumptions for the residual errors were satisfied in the final ARDL models.

Interrupted time series analysis of Operations Balmoral Athens, Tempest and Collage

To test the effect of these three operations we regressed the number of cocaine UP arrests and ED admissions against an independent variable measuring elapsed time, a dummy variable indicating the onset of the operations (0 before June 2010 and 1 otherwise) and an interaction term between time and dummy variable. By using the dummy variable we are able to capture any change in the average level of UP arrests or ED admissions after the three significant operations. Adding the interaction between elapsed time and dummy variable allows us to measure any change in the direction of the trend after June 2010.

Expectations

Since our primary interest is to investigate the effect of seizures and supplier arrests on UP arrests and ED admissions for heroin, cocaine and ATS, the key parameters of interest are the coefficients $b_{1,0},\ldots, b_{k,qk}$. Positive/negative regression coefficients indicate that an increase in seizures or seizure weight or supplier arrests are associated with an increase/decrease in UP arrests and ED admissions. More specifically, a positive/negative coefficient ($b_{j,0}$) indicates that when the number/weight of seizures or supplier arrests goes up by one unit, the UP arrests or ED admissions goes up/down by $b_{j,0}$ units in the same month. Similarly, a positive coefficient ($b_{j,l}$) indicates that when seizures or supplier arrests goes up in this month by one unit, the UP arrests or ED admissions by $b_{j,l}$ units rise/drop l months later. For drug-related crimes, we want to test if the regression coefficients are negative as we are interested in determining whether heroin seizures and heroin supplier arrests produce a reduction in theft and robbery and whether seizures of ATS and cocaine supplier arrests produce a reduction in assault.

Our expectation so far as the effects of Operations Balmoral Athens, Tempest and Collage is concerned, is that the interaction term and/or the dummy variable marking the point where the operations began will be significantly negative. The former would suggest that the operations in question altered the slope of the trend in cocaine arrests. The latter would suggest a change in the level.

Results

Preliminary analysis

The analysis began by fitting ten ARDL models using two sets of independent variables (number and weight of seizures and number of supplier arrests, from all states and AFP) to five different outcome variables in NSW: UP arrests, ED admissions, theft, assaults and robbery. This was done to address the possibility that supplier arrests and seizures in States and Territories other than NSW could influence drug markets and drug-related crime in NSW. At this stage, no restriction was imposed on the weight of a drug that constituted a ‘seizure’. The results of these ARDL models are summarised in Tables A1 (heroin), A2 (cocaine) and A3 (ATS) in the Appendix. It suffices to note here there that no consistent pattern of results could be found for any of the three drugs.

Preliminary analysis revealed no consistent relationships with the UP arrests or ED admissions for any of the three drugs in any state other than NSW. The analysis that follows is therefore limited to seizures, supplier arrests, use/possession arrests and drug-related crime in NSW. The results are presented in three sections. First we present basic descriptive statistics on the variables included in the study separately for each jurisdiction. Next we present the results of ARDL modelling. Finally we present the results of the interrupted time series analysis carried out on a series of operations carried out by the NSW Crime Commission to disrupt the market for cocaine.

Descriptive statistics

Table 1 shows the mean monthly number of seizures, monthly weight of drugs seized and monthly number of supplier arrests in NSW. Also shown are the standard deviation (SD), minimum and maximum values; and the results of an augmented Dickey-Fuller unit root test conducted to see if the series are stationary. The test results show that all of the series are stationary and the ARDL models can be fitted without differencing.

Table 1. Descriptive summary for dependent and independent variables in NSW

Variables	Mean	SD	Minimum	Maximum	Unit root test
UP arrests of ATS	263.67	85.00	141	533	stationary
UP arrests of cocaine	29.86	18.63	3	98	stationary
UP arrests of heroin	69.34	16.19	35	105	stationary
ED admissions for ATS	28.03	8.48	12	55	stationary
ED admissions for cocaine	5.18	2.74	0	13	stationary
ED admissions for heroin	62.08	13.56	32	108	stationary
Property crime	25554.9	4731.0	19366	38928	trend stationary
Assaults	5821.93	506.96	4956	6920	stationary
Robbery	650.96	175.01	351	1133	stationary
Number of seizure of ATS	286.91	114.32	118	512	stationary
Number of seizure of cocaine	33.42	19.88	2	82	stationary
Number of seizure of heroin	56.43	14.30	26	113	stationary
Weight of seizure of ATS (grams)	19.11	36.06	0.84	236.15	stationary
Weight of seizure of cocaine (grams)	1.84	4.66	0.01	39.01	stationary
Weight of seizure of heroin (grams)	2.00	7.13	0.03	70.55	stationary
Number of supplier arrests of ATS	65.82	31.17	18	127	stationary
Number of supplier arrests of cocaine	9.43	5.90	0	26	stationary
Number of supplier arrests of heroin	20.50	8.57	5	48	stationary

Trends in the number of drug seizures, the number of supplier arrests, the number of UP arrests, the number of ED admissions and the weight of drugs seized (right hand axis) in NSW are shown in Figures 1 (heroin), 2 (cocaine) and 3 (ATS) below.

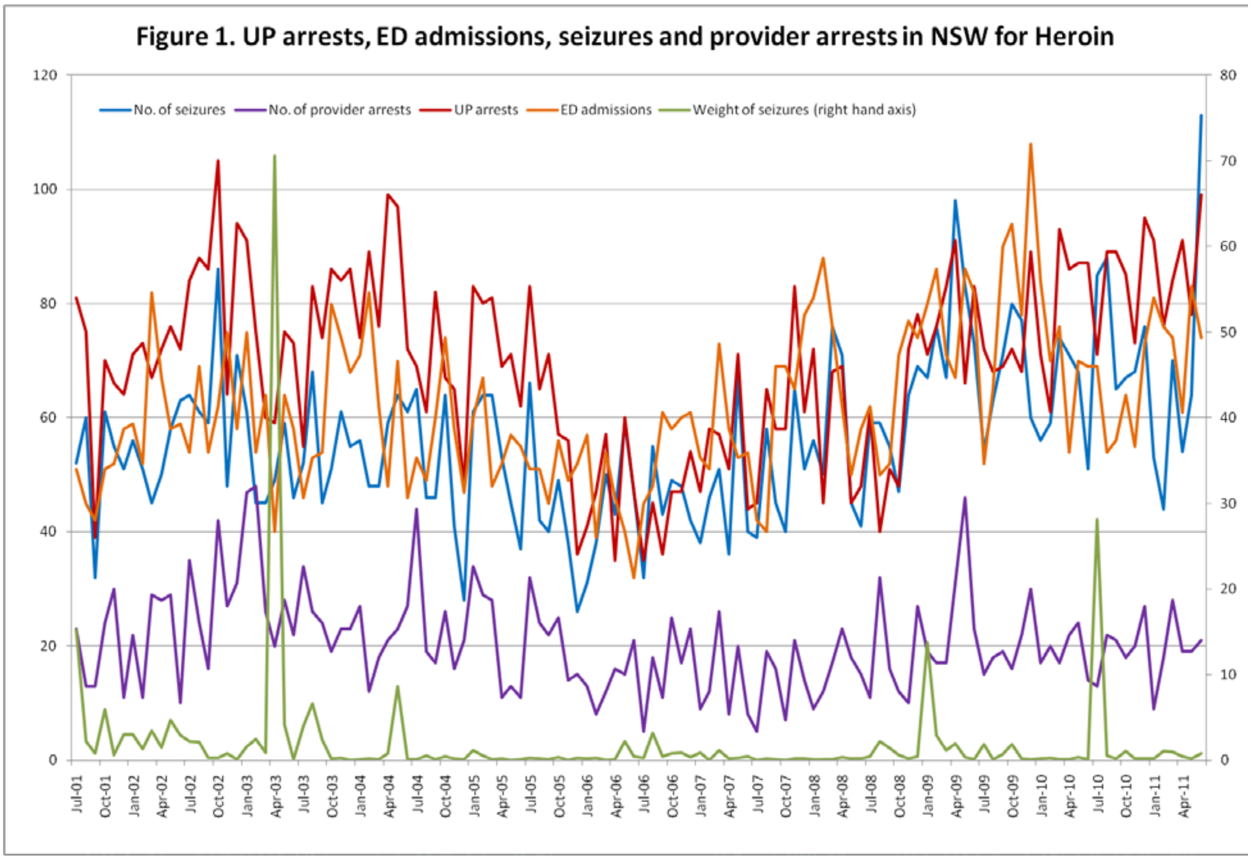

Figure 1. UP arrests, ED admissions, seizures and provider arrests in NSW for Heroin
No. of seizures
No. of provider arrests
UP arrests
ED admissions
Weight of seizures (right hand axis)
0
20
40
60
80
100
120
0
10
20
30
40
50
60
70
80
Jul-01
Oct-01
Jan-02
Apr-02
Jul-02
Oct-02
Jan-03
Apr-03
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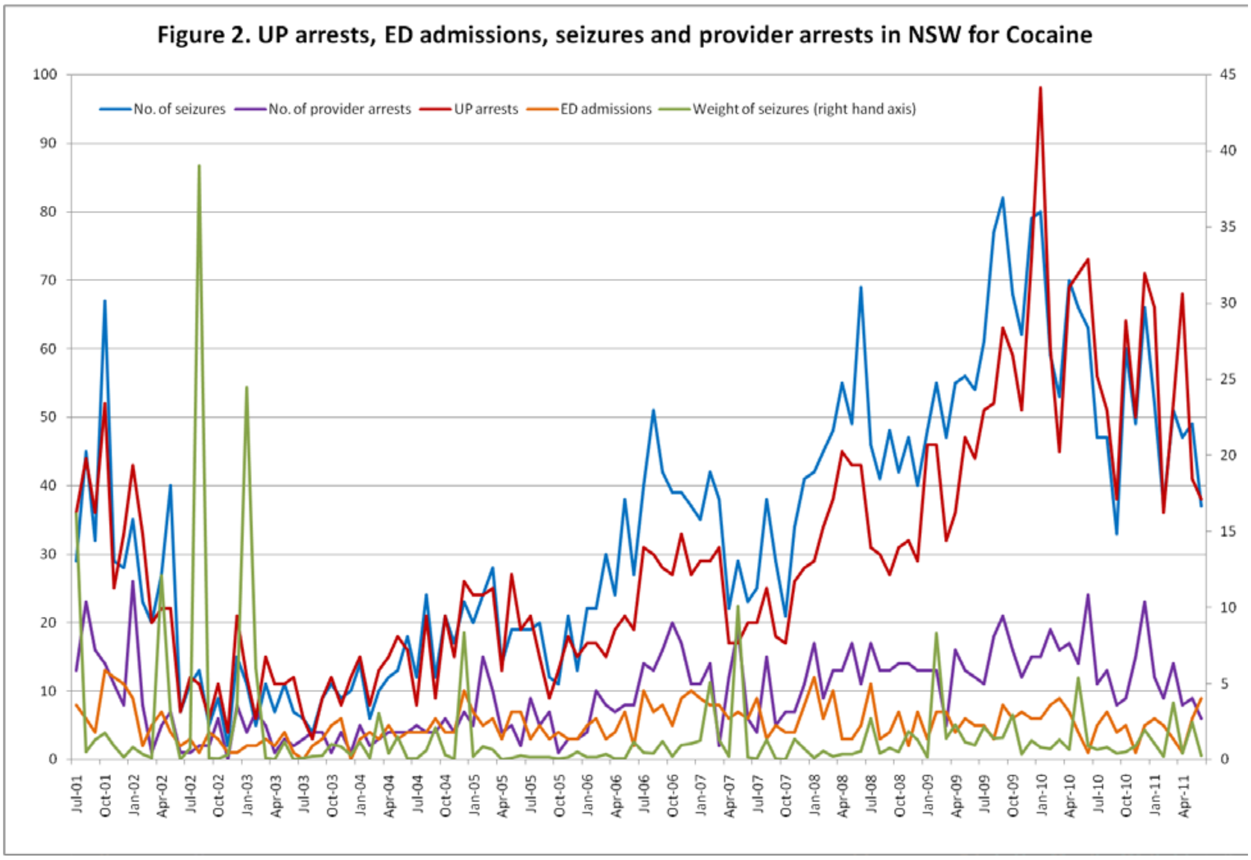

Figure 2. UP arrests, ED admissions, seizures and provider arrests in NSW for Cocaine
No. of seizures
No. of provider arrests
UP arrests
ED admissions
Weight of seizures (right hand axis)
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30
35
40
45
Jul-01
Oct-01
Jan-02
Apr-02
Jul-02
Oct-02
Jan-03
Apr-03
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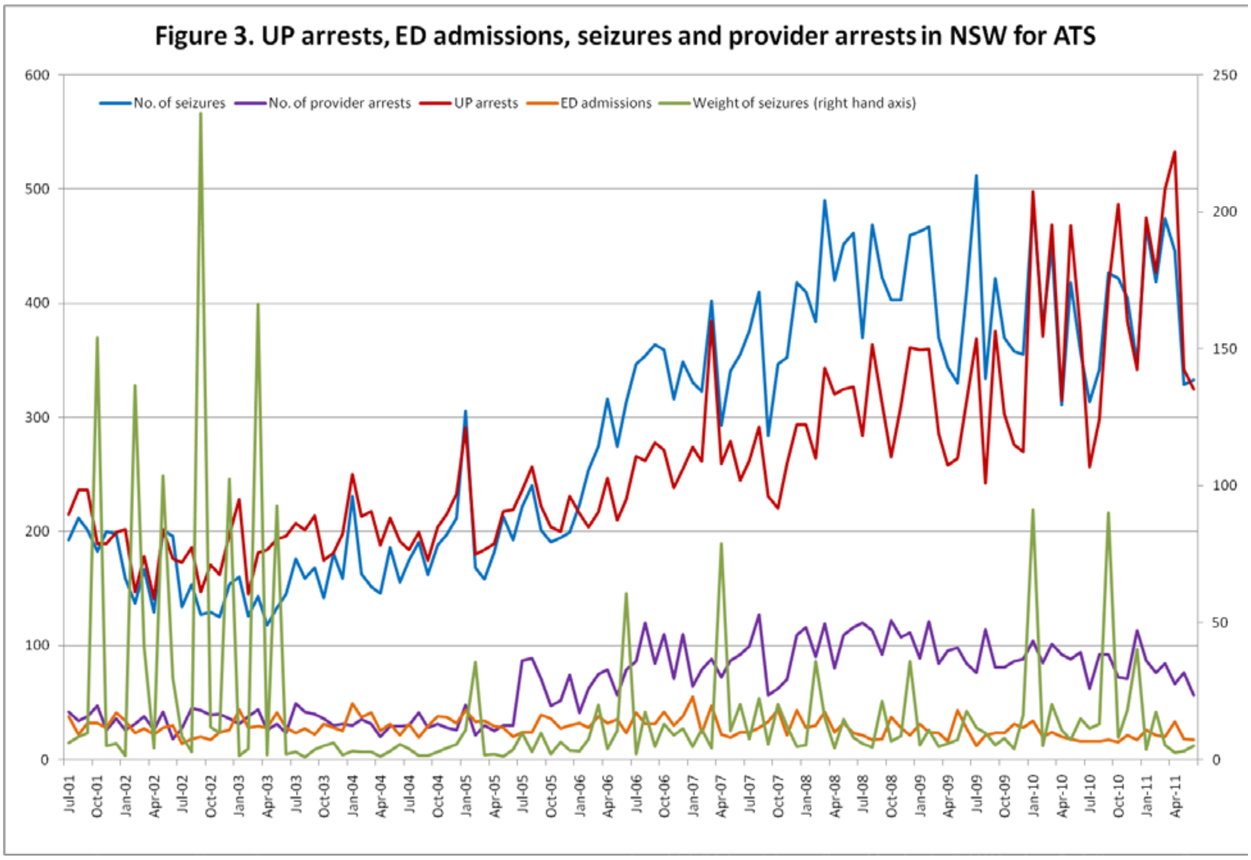


For heroin, Figure 1 indicates that the UP arrests, ED admissions number of seizures and supplier arrests in NSW all followed a similar trend . The trend was relatively stable with a small dip in 2006. The number of seizures, supplier arrests and UP arrests for cocaine in NSW demonstrated similar trend to that of heroin (see Figure 2). After a downtrend occurred in 2002, the three series continued to rise till 2010 at which point they became stable again. The ED admissions for cocaine did not show any similar increasing trend after 2006. For ATS, Figure 3 shows that the number of seizures and UP arrests followed each other quite closely. The two series had an uptrend throughout the study period with a higher increase rate after January 2006 but slowed down again and became more volatile around 2010. The ED admissions for ATS remained flat throughout the study period, while the number of supplier arrests rose substantially in mid 2005 and remained stable after mid 2006. The correlation between the number of seizures and the number of supplier arrests are high in NSW for heroin, cocaine and ATS. To avoid the problem of multicollinearity seizures and supplier arrests were incorporated in separate ARDL models of their effects on UP arrests, ED admissions and drug-related crimes.

ARDL model results

The results for UP arrests and ED admissions are shown in Tables 8 (heroin), 9 (cocaine) and 10 (ATS) below.

Table 2: Summary of reduced ARDL model results for heroin

Independent variables	**Dependent variables**									
	UP arrests					ED admissions				
	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4
Number of seizures	0.725				0.549					
Weight of seizures	-0.163	0.220	0.215							
Number of supplier arrests	0.354							-0.310		
Diagnostic checking	**p-value**					**p-value**				
	M1	**M2**				**M1**	**M2**			
Ljung-Box test (up to lag 24)	.327	.476					.562			
Engle's LM test	.881	.631					.163			
Granger causality test	**p-value**									
Number of seizures	.474									
Weight of seizures	.065									
Number of supplier arrests	.054									

Note: M1 refers the ARDL model using number and weight of seizures as independent variables; M2 refers to the model with number of supplier arrests as independent variable.

Table 3: Summary of reduced ARDL model results for cocaine

Independent variables	**Dependent variables**									
	UP arrests					ED admissions				
	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4
Number of seizures	1.052						0.175			
Weight of seizures										
Number of supplier arrests								0.156		
Diagnostic checking	**p-value**					**p-value**				
	M1	**M2**				**M1**	**M2**			
Ljung-Box test (up to lag 24)	.372	.146				.436	.628			
Engle's LM test	.728	.235				.782	.948			
Granger causality test	**p-value**									
Number of seizures	.130									

Table 4: Summary of reduced ARDL model results for ATS

Independent variables	**Dependent variables**									
	UP arrests					ED admissions				
	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4
Number of seizures	1.162									
Weight of seizures										
Number of supplier arrests	0.578									
Diagnostic checking	**p-value**									
	M1	**M2**								
Ljung-Box test (up to lag 24)	.073	.192								
Engle's LM test	.075	.195								
Granger causality test	**p-value**									
Number of seizures	.067									
Number of supplier arrests	.143									

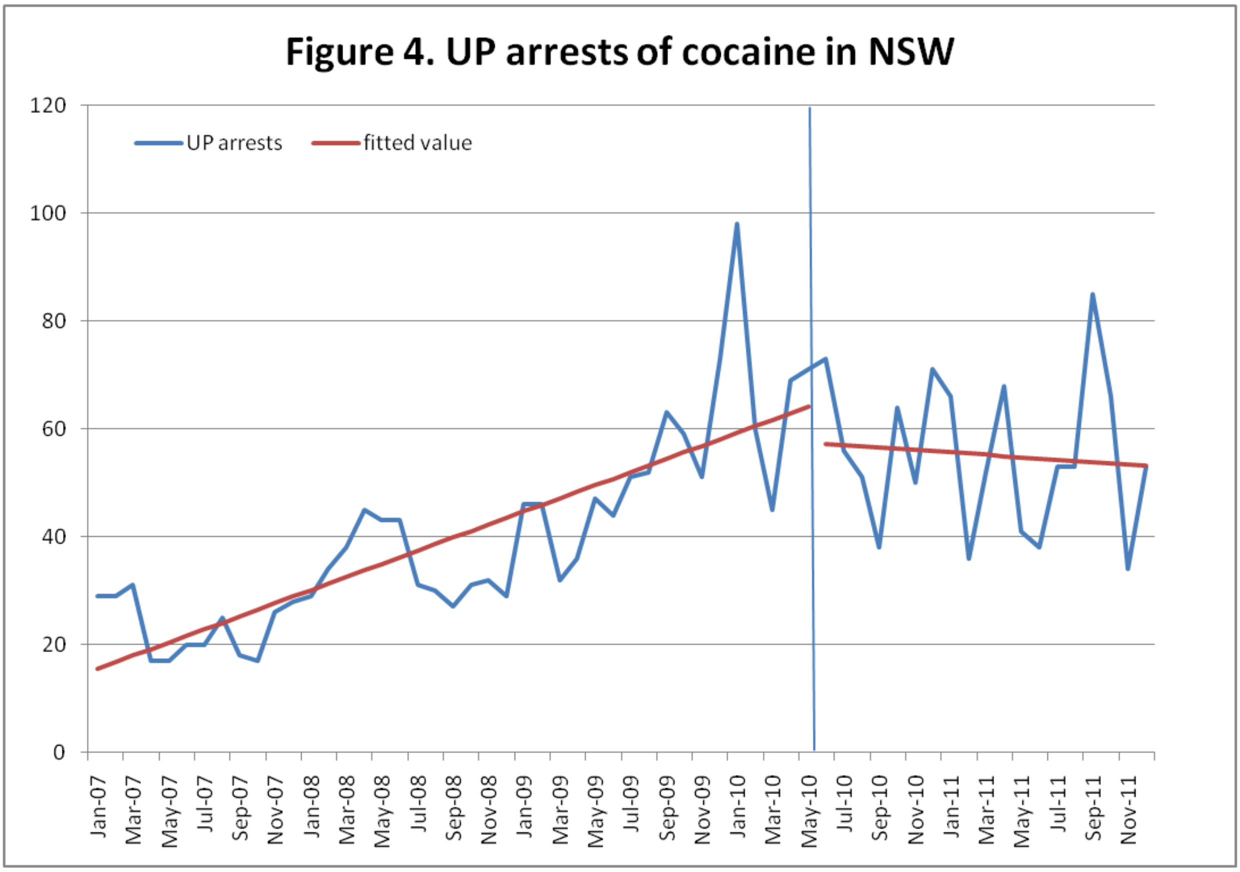
Table 2 indicates that when the number of large-scale seizures of heroin increases by 10 units, UP arrests go up by 7.25 units in the same time period and by 5.49 units four months later. Similarly, if the number of supplier arrests of heroin increases by 10 units, the UP arrests in NSW go up by 3.54 units in the same time period. Notice, however, that there is a significant negative contemporaneous relationship between the quantity of heroin seized in a particular month and the number of UP arrests in the same month. There is also a significant negative relationship between the number of supplier arrests in a given month and the number of ED admissions two months later.

The results for cocaine and ATS are shown in Table 3. A 10 unit increase in the number of cocaine seizures is associated with a contemporaneous 10.52 unit increase in the number of UP arrests for cocaine. Positive effects are also found in relation to cocaine ED admissions. When the number of seizures increases by 10 units, ED admissions for cocaine increase by 1.75 units one month later. When the number of supplier arrests rises by 10 units, ED admissions for cocaine increase by 1.56 units two months later. In the case of ATS (Table 4), the number of seizures and supplier arrests are both significantly and contemporaneously related to UP arrests. When the number of large-scale seizures increases by 10 units, ATS UP arrests jump up by 11.62 units. Similarly, when the number of ATS supplier arrests increases by 10 units, the number of UP arrests goes up by 5.78 units.

No consistent effects of supply control measures (seizure frequency, seizure weight, supplier arrests) were found for theft, robbery or assault (see Tables A4 to A6 of the Appendix). In fact in most instances, no significant effect of any kind was found. Where significant effects were found, they were often inconsistent. An increase in the monthly weight of heroin seized, for example, was associated with an increase in theft offences at lag one and a decrease in theft offences at lag four. Increases in the monthly weight of cocaine seized were associated with an increase in assault at lag 1 and an increase in robbery at lag 4 but increases in the number of cocaine seizures or the number of cocaine supplier arrests were associated with *decreases* in theft offences at lag 1.

Interrupted time series analysis

Figure 4 below shows the results of the first interrupted time series analysis on UP arrests of cocaine. The vertical line in June 2010 marks the point where the first of the three major cocaine operations began. The fitted line shows the modelled trend before and after the operation and those which followed.



Rates of UP arrest for cocaine can be seen to increase up to June 2010 and then level off. According to the fitted values, there was an uptrend prior to June 2010 and the trend turned downwards afterwards. This suggests that the three operations lead to a drop in the UP arrests in NSW. The result of the interrupted time series analysis are summarised in Table 5.

Table 5. Results for interrupted time series analysis on UP arrests of cocaine in NSW during January 2007 and December 2011

Variable	Estimate	SE	p-value
time	1.214	0.163	<.001
dummy variable	173.387	81.902	.039
time*dummy	-1.440	0.621	.024
constant	-87.677	16.404	<.001

The results indicate that the interaction between time and the dummy variable is significantly negative and this confirms a change in the trend of UP arrests after June 2010.

Figure 5 indicates the observed series and fitted trends for ED admissions of cocaine from the interrupted time series analysis. ED admissions remained stable before June 2010 but dipped sharply immediately after the three operations before it rose again in mid 2011. They then bounced back to their original level. This suggests that the three operations also lead to a drop in the ED admissions in NSW. The result of the interrupted time series analysis are summarised in Table 6.

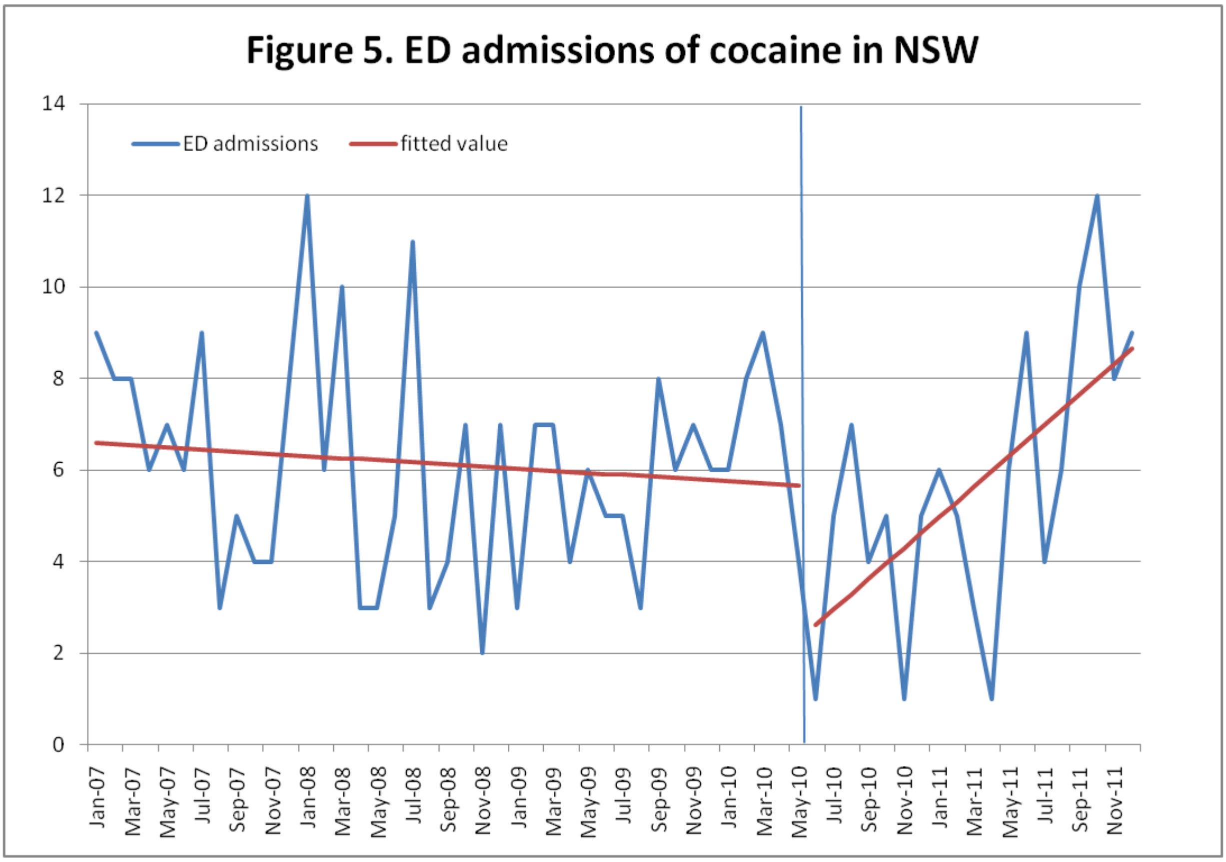


Table 6. Results for interrupted time series analysis on ED admissions of cocaine in NSW during January 2007 and December 2011

Variable	Estimate	SE	p-value
time	-0.023	0.032	.473
dummy variable	-48.379	14.043	.001
time*dummy	0.360	0.106	.001
constant	8.537	3.360	.014

The results indicate that the dummy variable is significantly negative and this confirms a drop in the ED admissions after June 2010, and the significant positive interaction between time and the dummy variable reveals that the ED admissions rose again.

Table 7 summarizes the results of the testing. A positive sign indicates a significant positive relationship between the independent variable (IV) in the same row and the outcome (UP arrests or ED admissions) in the same column. A negative sign indicates a significant negative relationship between the IV in the same row and the outcome in the same column. The lag at which the relationship is significant is indicated in brackets.

Table 7: Summary of results

IV	*UP arrests*	*ED admissions*
No. heroin seizures	+ (lag 0),+(lag 4)	NS
Weight heroin seizure	- (lag 0),+ (lag 1),+ (lag 2)	NS
No. heroin supplier arrests	+ (lag 0)	- (lag 2)
No. cocaine seizures	+ (lag 0)	+ (lag 1)
Weight cocaine seizure	NS	NS
No. cocaine supplier arrests	NS	+ (lag 2)
No. ATS seizures	+ (lag 0)	NS
Weight ATS seizures	NS	NS
No. ATS supplier arrests	+ (lag 0)	NS
Special operations on cocaine	N/A	N/A

Discussion

The principal question we sought to address in this study was whether supply reduction efforts exert any measurable effect on ED admissions for drug use and arrests for use and possession of drugs. The measures of supply reduction policy examined were monthly seizures (number and weight) and supplier arrests. The specific question we sought to address was whether ED admissions and UP arrests for heroin, cocaine and ATS in any given month are inversely related to the frequency of seizures and the quantity of drugs seized, either in the same month or up to four months earlier. A secondary question of interest was whether the reported incidence of certain drug-related offences; namely theft, robbery and assault, is inversely related to the frequency and quantity of heroin, cocaine and ATS seized. No consistent effects were found between any of the supply reduction measures and police reports of theft, robbery and assault.

The associations between supply reduction variables and use and harm measures for cocaine and ATS were all either non-significant or positive. Increases in the number of cocaine seizures were associated with increases in the number of arrests for cocaine use and possession (same month) and increases in ED admissions for cocaine (one month later). Increases in the number of cocaine supplier arrests were associated with an increase in ED admissions for cocaine two months later. Increases in the number of ATS seizures and the number of ATS supplier arrests were associated with contemporaneous increases in arrests for use and possession of ATS. These findings suggest that increases in cocaine or ATS seizures or ATS supplier arrests are signals of increased (rather than reduced) supply.

The only significant negative effects in the ARDL models were confined to heroin but the results for this drug were mixed. On the one hand, a significant negative relationship was found between the weight of heroin seized in a particular month and the number of persons arrested for use and possession of heroin in the same month. A significant negative relationship was also found between the number of heroin supplier arrests in a particular month and the number of ED admissions for heroin use two months later. These findings suggest that increases in the weight of heroin seized or the number of heroin supplier arrests may signal a reduction in heroin availability. This interpretation of the data, however, is hard to reconcile with two other findings. The first is that the number of heroin seizures was positively related to the number of arrests for heroin use and possession in the same month. The second is that the *number* of heroin supplier arrests was positively related to the number of ED admissions in the same month. The explanation for these inconsistent findings is unclear but the results may reflect the effects of some unobserved and unmeasured factors.

The results of the interrupted time series analysis were clearer. The three major operations dealing with cocaine listed by the NSW Crime Commission as significant (Operation Balmoral Athens, Operation Tempest and Operation Collage) which, over five months resulted in the arrest of 11 major suppliers and the seizure of 690 kg of cocaine, did bring an end to the upward trend in the rate of arrest for use and possession of cocaine. Prior to these operations, the number of UP arrests for cocaine was rising by an average of 1.21 incidents per month during the period January 2007 to May 2010. After the operations, the frequency of UP arrests for cocaine actually fell slightly from 71to 53 at an average rate of 0.23 incidents per month till the end of 2011. The number of ED admissions also fell from an average of 6.12 incidents during January 2007 to May 2010 to 3.91 incidents during June 2010 to April 2011 before it started to bounced back again in May 2011.

No consistent effects were found between any of the supply reduction measures and police reports of theft, robbery and assault (see Appendix tables A4, A5 and A6). The only significant negative effects in the ARDL models were confined to heroin. A significant negative relationship was found between the *weight* of heroin seized in a particular month and the number of persons arrested for use and possession of heroin in the same month. A significant negative relationship was also found between the *number* of heroin supplier arrests in a particular month and the number of ED admissions for heroin use two months later (See Table 2). These findings suggest at first sight that increases in the number of heroin suppliers arrested or the weight of heroin seized in a given month reduces the heroin consumption and heroin-related harm over the next one to two months. The problem with this interpretation of the data, however, is that the *number* of arrests for heroin use and possession was *positively* related to the number of heroin seizures in the same month. The contemporaneous relationship between ED admissions and heroin supplier arrests was also *positive*. As noted earlier, the positive contemporaneous relationship between the number of heroin supplier arrests and the number of arrests for use and possession of heroin may be due to the fact that increases in supplier arrests and use/possession arrests are signals of increased heroin availability. It is also possible, however, that they are 'false positives' arising from the large number of tests carried out on the data.

As always, there are qualifications surrounding our results. It is possible that our principal outcome measures, UP arrests and ED admissions, are not sensitive to changes in consumption or drug related harm that occur in response to variations in seizures or supplier arrests. This seems unlikely in the case of ED admissions because past research has shown them to have a strong inverse relationship with the purity-adjusted price of these drugs (Dave 2005). It is more likely with UP arrests because they are sometimes affected by changes in police resources or policing policy.

It is also possible that one or more of our supply reduction measures failed to pick up changes in supply[2]. There is no reason to doubt our measurement of the weights of heroin, cocaine and ATS seized. In the case of seizure weight and frequency, however, we had to make a somewhat arbitrary judgement about what constituted a 'significant' seizure in terms of weight. Although this judgement was reached after trying out different weight thresholds to see which produced the most coherent pattern of results, there is no independent way of knowing whether the thresholds we finally settled on were of a size that would be expected to affect the use of and harms associate with heroin, cocaine and ATS. Supplier arrests present a similar problem. The data on supplier arrests collected by the ACC include all arrests for supply, regardless of the level of the drug distribution chain at which arrests are effected. It is entirely possible that the 'signal' coming from the few high level supplier arrests that do influence the drug market is hidden in the 'noise' coming from large numbers of low-

[2] At one level this is obviously true. The key supply variables — proportions of heroin, cocaine and ATS seized — is impossible to measure since we have no independent means of ascertaining the quantities of heroin, cocaine and ATS entering the market.

level supplier arrests. Since the ACC does not record any information about the significance of each individual supplier arrest, there is no way to test this possibility, other than the one we pursued in relation to Operations Balmoral Athens, Tempest and Collage.

Setting these issues to one side, on the whole our results are not especially favourable to the hypothesis that increases in seizure frequency, seizure weight and supplier arrests, within the normal range, are have an effect over the short-run on heroin, cocaine and ATS related harm. In only three of the 18 ARDL analyses did a supply reduction measure have a significant relationship with ED admissions (number of heroin supplier arrests, cocaine seizures, cocaine supplier arrests). In only two of these analyses was the expected negative relationship confirmed for one or other of the two outcome variables. In no analysis was it confirmed for both. The majority of significant effects suggested a positive relationship between the relevant measures of supply reduction activity on the one hand, and UP arrests and ED admissions, on the other. If UP arrests are a guide to consumption, increases in heroin, cocaine and ATS seizure quantity or frequency, within the normal range, are more likely to signal an increase rather than a reduction in drug consumption. If ED admissions are accepted as a guide to drug-related harm, increases in heroin, cocaine and ATS seizure quantity or frequency, within the normal range, have little if any impact on the harms associated with heroin, cocaine and ATS. It is not clear whether these results arise because the supply control measures examined here have no effect at all on the purity-adjusted price of the drug or because they have effects that are too small to influence UP arrests and ED admissions. It may be that only the very largest seizures, such as those that occurred in conjunction with the earlier-mentioned Operations Balmoral Athens, Tempest and Collage, affect the markets for heroin, cocaine and ATS.

In the highly contested arena of drug policy, this conclusion is likely to be interpreted by some as evidence that investment in supply reduction policy is a waste of time and money. It is important to remember, however, that the present results have no bearing on the second of the two mechanisms through which prohibition might influence drug consumption and drug-related harm. Regardless of whether variations in seizures and supplier arrests have measurable effects, the severe punishments associated with conviction for drug cultivation, manufacture, importation and supply make these activities very risky. The consequent need to avoid detection makes drug production and distribution very inefficient. Drug traffickers compensate themselves for these risks and efficiencies by demanding higher premiums from those they sell to; which are then passed onto drug consumers in the form of higher retail drug prices. Higher retail drug prices, according to standard economic theory, should lead to lower levels of drug consumption. To the extent that drug-related harm is a positive function of drug consumption, it will also lead to lower levels of drug-related harm. We may well spend too much on supply reduction policy relative to other ways of reducing illicit drug consumption and drug related harm. The present results, however, should not be read as indicating that we can reduce expenditure on supply reduction initiatives without any adverse effect on drug consumption and drug-related harm.

There is a strong need to replicate and extent the research carried out here but that will require changes to the information routinely collected by drug law enforcement agencies about their activities. One of the most significant limitations of the current research is that it was not possible to separate minor drug supply arrests from serious (high level) drug supply arrests. If the Australian Crime Commission were able to distinguish between arrests for drug supply that involve a large or commercially significant quantity of illegal drugs from those that do not, it would be possible to carry out a more effective analysis of the short-term relationship between supply control measures and drug related harm than that carried out here. It would also be interesting to see whether drug seizures or high level drug supply arrests influence the price and purity of illegal drugs. This sort of research, however, would require monthly data on the price and purity of illegal drugs seized at street level (e.g. from people arrested for possession of illegal drugs). The Australian Crime Commission does collect and publish quarterly data on the price and purity of illegal drugs. Unfortunately, quarterly measurement of changes in drug price and purity may be too infrequent to pick up the effects of drug seizures or high level drug supply arrests. As the Commission itself points out, moreover, some jurisdictions do not collect any information at all on the purity of illicit drugs seized. Those that do, vary significantly in the way they obtain drug purity data (Australian Crime Commission 2013, p. 195). Improvements in data collection by law enforcement agencies would greatly enhance the scope for rigorous evaluation of drug law enforcement policy.

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References

Australian Crime Commission 2013, *Illicit Drug Data Report 2011/12*.Canberra: Australian Crime Commission.

Australian Institute of Health and Welfare 2011, *2010 National Drug Strategy Household Survey report*. Drug statistics series no. 25. Cat. no. PHE 145. Canberra: AIHW.

Blumstein A, Cohen J, Roth JA and Visher CA (Eds) (1986), *Criminal Careers and Career Criminals.*vol. 1. Washington DC: National Academy Press.

Caulkins, J.P. & Reuter, P. 1998, What price data tell us about illicit drug markets. *Journal of Drug Issues*, 28(3) 593- 612.

Crane, B.D., Rivolo, A.R., & Comfort, G.C. 1997, *An Empirical Examination of Counterdrug Interdiction Program Effectiveness*, IDA paper P-3219. Alexandria, VA: Institute for Defence Analyses.

Dave, D. 2005, The effects of cocaine and heroin price on drug-related emergency department visits, *Journal of Health Economics*, doi: 10.1016/j.healeco.2005.08.003.

Degenhardt, L., Day, C., Hall, W., Conroy, E. & Gilmour, S. 2005, Was an increase in cocaine use among injecting drug users in New South Wales, Australia, accompanied by an increase in violent crime? *BMC Public Health* 2005, **5**:40 doi:10.1186/1471-2458-5-40.

Degenhardt, L., Day, C., Gilmour, S. & Hall, W. 2006, The “lessons” of the Australian “heroin shortage”, Substance Abuse Treatment, Prevention, and Policy, 1:11 doi: 10.1186/1747-59X-1-11.

Everingham, S. & Rydell, C. 1994, *Modeling the Demand for Cocaine*, California: Drug Policy Research Centre, RAND.

Gallet C.A. 2013, Can price get the monkey off our back? A meta-analysis of illicit drug demand. *Health economics*. Jan 10. doi: 10.1002/hec.2902. [Epub ahead of print]

Grossman M, Chaloupka, and F. & Shim K. 2002, Illegal Drug Use and Public Policy.*Health Affairs* 21(2): 134-145.

Manski, C., Pepper, J., & Petrie, C. 2001, *Informing America’s Policy on Illegal Drugs: What we don’t know keeps hurting us*, National Academy Press, Washington D.C., p. 42.

Mazerolle, L., Soule, D. &Rombouts, S. 2007, Drug Law Enforcement: A Review of the Evaluation Literature, *Police Quarterly*, 10(2), pp. 115-153.

McKetin, R., McLaren, J., Riddell, S. & Robins, L. 2006, *The relationship between methamphetamine use and violent behavior*. Crime and Justice Bulletin 97. Sydney: NSW Bureau of Crime Statistics and Research.

Moffatt, S., Wan, Y. &Weatherburn, D. 2012, Are drug arrests a valid measure of drug use? *Policing: An international journal of police strategies and management*, 35(3), 458-467.

Nordt C., & Stohler R. 2010, Combined effects of law enforcement and substitution treatment on heroin mortality, *Drug and Alcohol Review*, 29, 540-545.

Nurco, D.N., Hanlon, T.E. & Kinlock, T.W. 1999, Recent Research on the Relationship Between Illicit Drug Use and Crime, *Behavioural Sciences and the Law*, 9, 221-242.

Reuter, P. & Kleiman, M. 1986, *Risks and prices: An economic analysis of drug enforcement*. In N. Morris and M. Tonry (eds.), *Crime and justice: An annual review of research*, 7, (pp. 289-340). Chicago: Chicago University Press.

Ritter, A., McLeod, R. & Shanahan, M. 2013,*Government Drug Policy Expenditure in Australia-2009/10*.Drug Policy Modelling Program Monograph 24. Sydney: National Drug and Alcohol Research Centre.

Rosenfeld R. & Decker S.H. 1999, Are arrest statistics a valid measure of illicit drug use? The relationship between criminal justice and public health indicators of cocaine, heroin and marijuana use, *Justice Quarterly*, 16(3), pp. 686-699.

Ross, J. 2007, *Illicit drug use in Australia: Epidemiology, use patterns and associated harm* (2nd Edition). Sydney: National Drug & Alcohol Research Centre

Rumbold, G., & Fry, C. 1999, *The heroin Market Place Project: Examining the short term impact of the Port Macquarie heroin seizure on the characteristics of the retail heroin market in Melbourne*. Melbourne: Turning Point Alcohol and Drug Centre Inc.

Rydell, C.P. & Everingham, S.S., 1994, *Controlling cocaine: Supply versus demand programs*, Drug Policy Research Centre, RAND Corp.

Smithson, M., McFadden, M., Mwesigye, S. E. & Casey, T. 2004, The illicit drug supply reduction on health and social outcomes: the heroin shortage in the Australian Capital Territory, *Addiction*, 100, 1110-1120.

Stafford, J. & Burns, L. 2013, Australian Drug Trends 2012,*Findings from the Illicit Drug Reporting System (IDRS)*.Australian Drug Trend Series No. 91.Sydney, National Drug and Alcohol Research Centre, University of New South Wales.

Tyner, E.A. & Fremouw, W.J. 2008, The relation of methamphetamine use and violence: A critical review,*Aggression and Violent Behaviour*, 13(4), 285–297.

Ward, J., Mattick, R.P. & Hall, W. 1998, *Methadone Maintenance Treatment and Other Opioid Replacement Therapies*. Australia: Hardwood.

Weatherburn, D. & Lind, B. 1997, The Impact of Law Enforcement Activity on a Heroin Market, *Addiction*, 93(5): 557-569.

Weatherburn, D., Jones, C., Freeman, K. & Makkai, T. 2003, Supply Control and Harm Reduction: Lessons from the Australian Heroin ‘drought’ *Addiction*: 83-91.

Weatherburn, D. & Holmes, J. 2013, *The decline in robbery and theft: Interstate comparisons*, Bureau Brief 89. Sydney: NSW Bureau of Crime Statistics and Research.

Wodak, A. 2008, What caused the recent reduction in heroin supply in Australia? *International Journal of Drug Policy*, *19*, 279–286.

Wodak, A. & Cooney, A. 2006, Do Needle Syringe Programs Reduce HIV Infection Among Injecting Drug Users: A Comprehensive Review of the International Evidence, *Substance Use and Misuse*, 41, 777-813.

Wodak, A. & Owens, R. 1996, *Drug Prohibition: A Call for Change*. Sydney: University of New South Wales Press.

Wood, E., Tyndall, M., Spittal, P., Li, K., Anis, A., Hogg, R. 2003, Impact of supply-side policies for control of illicit drugs in the face of the AIDS and overdose epidemics: Investigation of a massive heroin seizure. *Canadian Medical Association Journal*, 168(2): 165-169.

Appendix

Figure A1. UP arrests, ED admissions and Number of seizures for Heroin

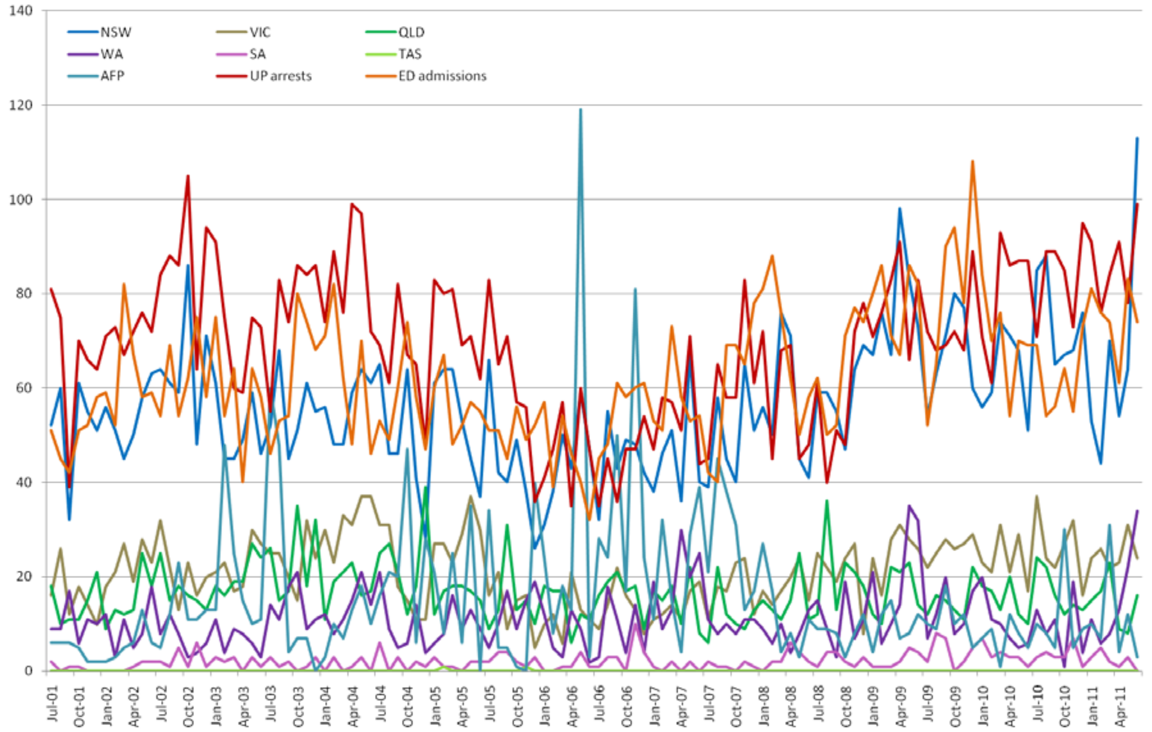
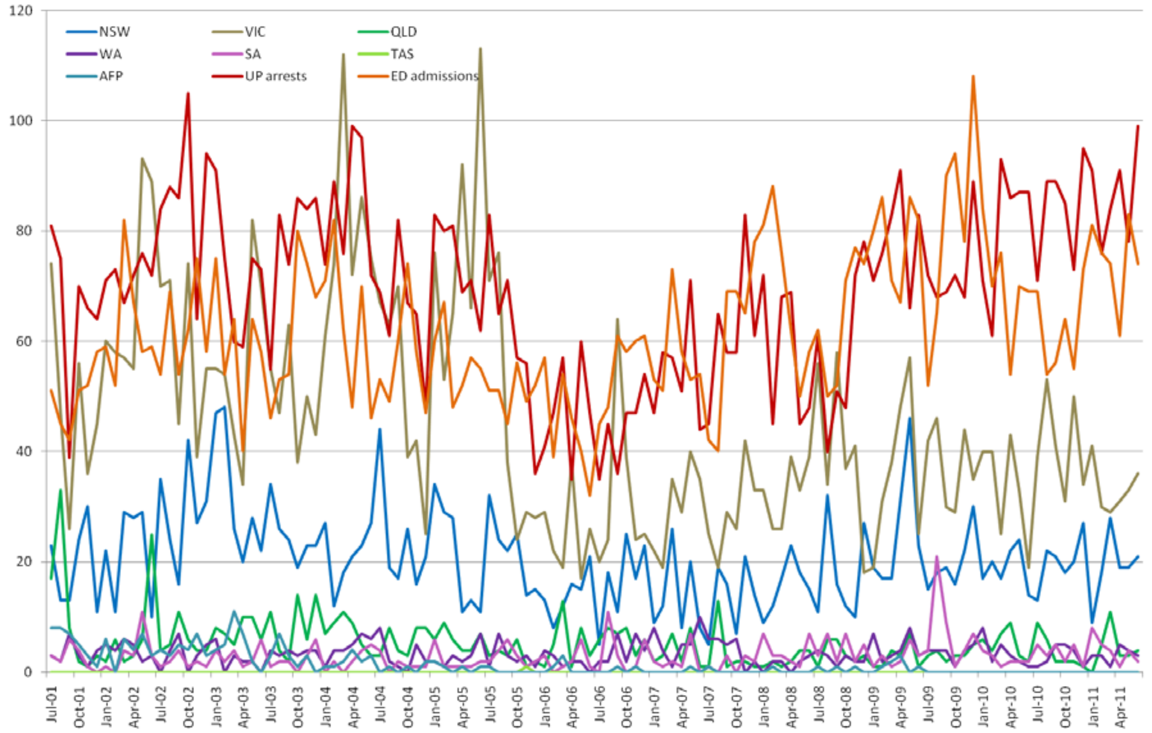


Figure A2. UP arrests, ED admissions and Number of provider arrests for Heroin



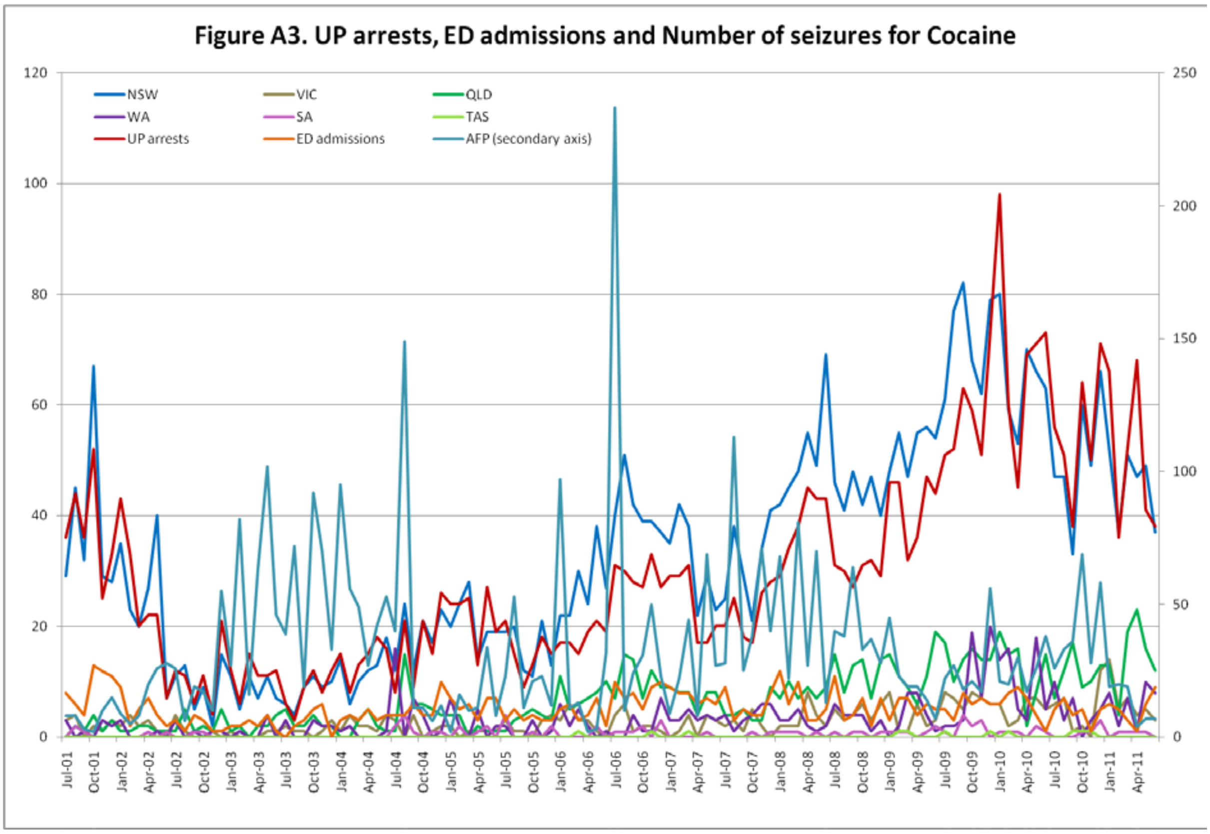


Figure A3. UP arrests, ED admissions and Number of seizures for Cocaine
NSW
VIC
QLD
WA
SA
TAS
UP arrests
ED admissions
AFP (secondary axis)

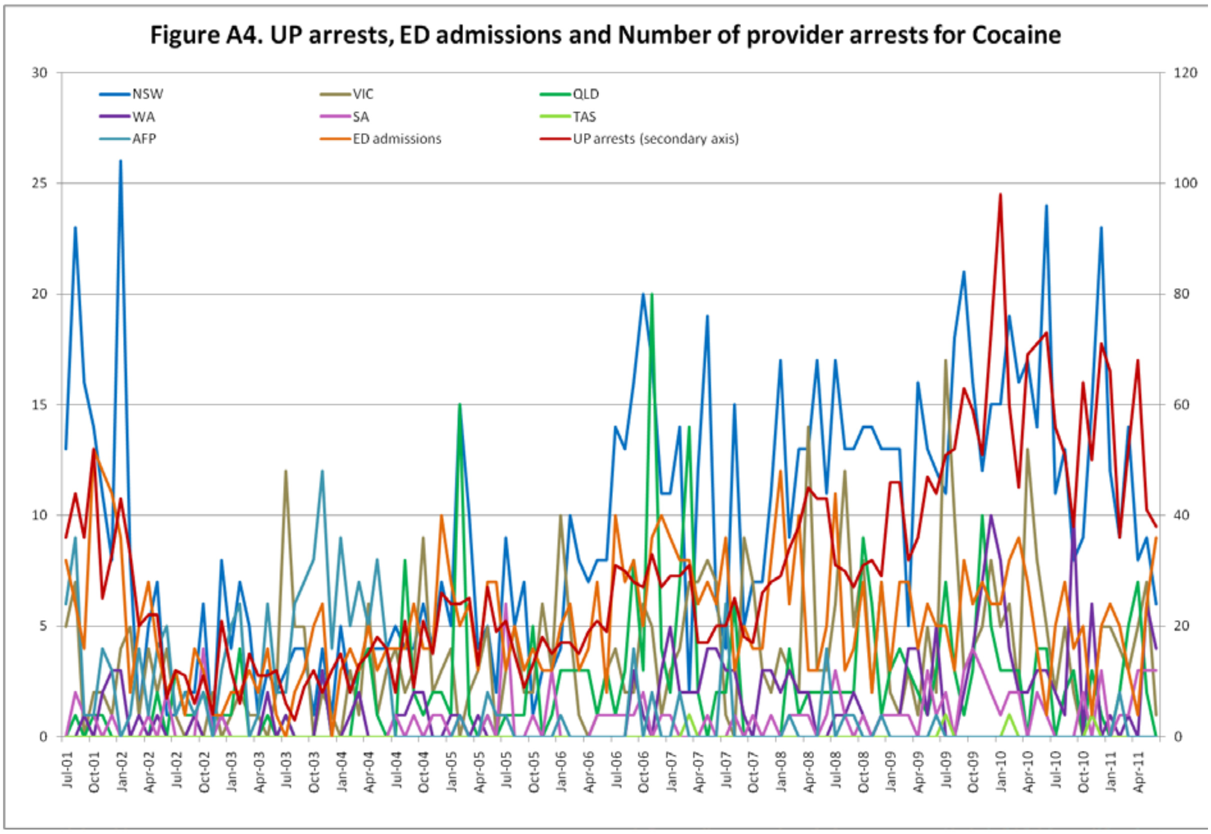


Figure A4. UP arrests, ED admissions and Number of provider arrests for Cocaine
NSW
VIC
QLD
WA
SA
TAS
AFP
ED admissions
UP arrests (secondary axis)

Figure A5. UP arrests, ED admissions and Number of seizures for ATS

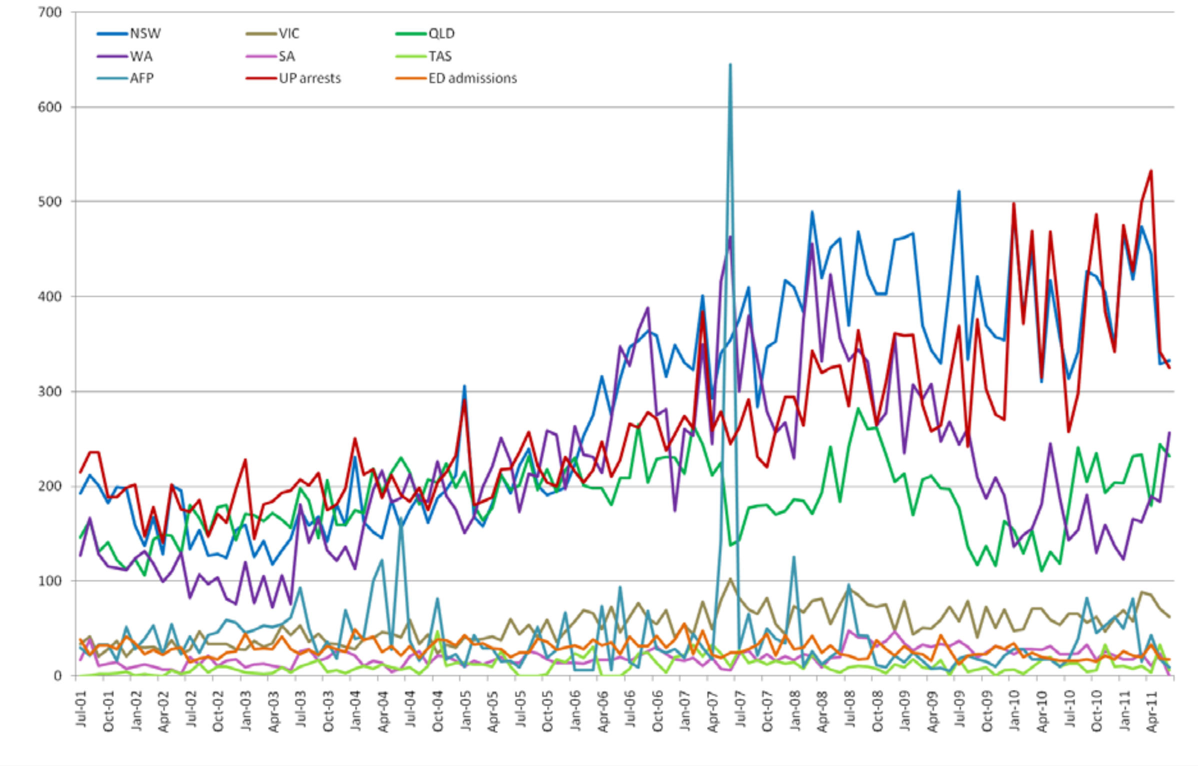
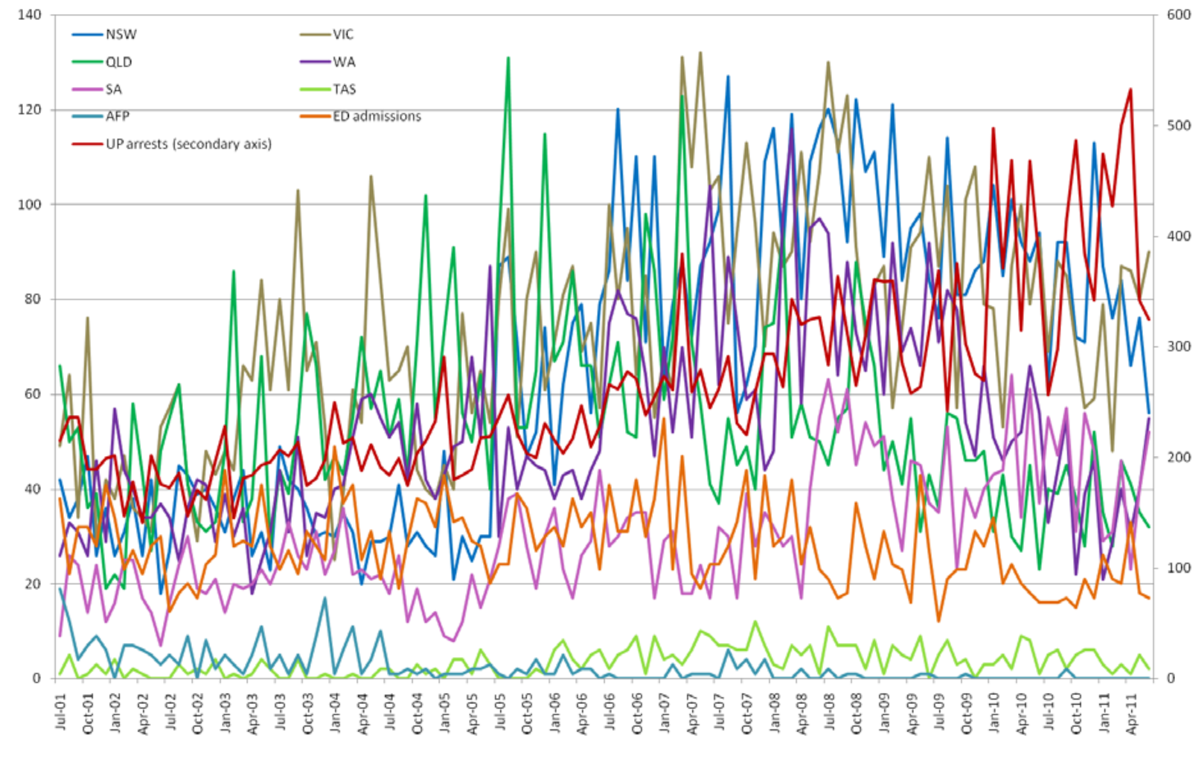


Figure A6. UP arrests, ED admissions and Number of provider arrests for ATS



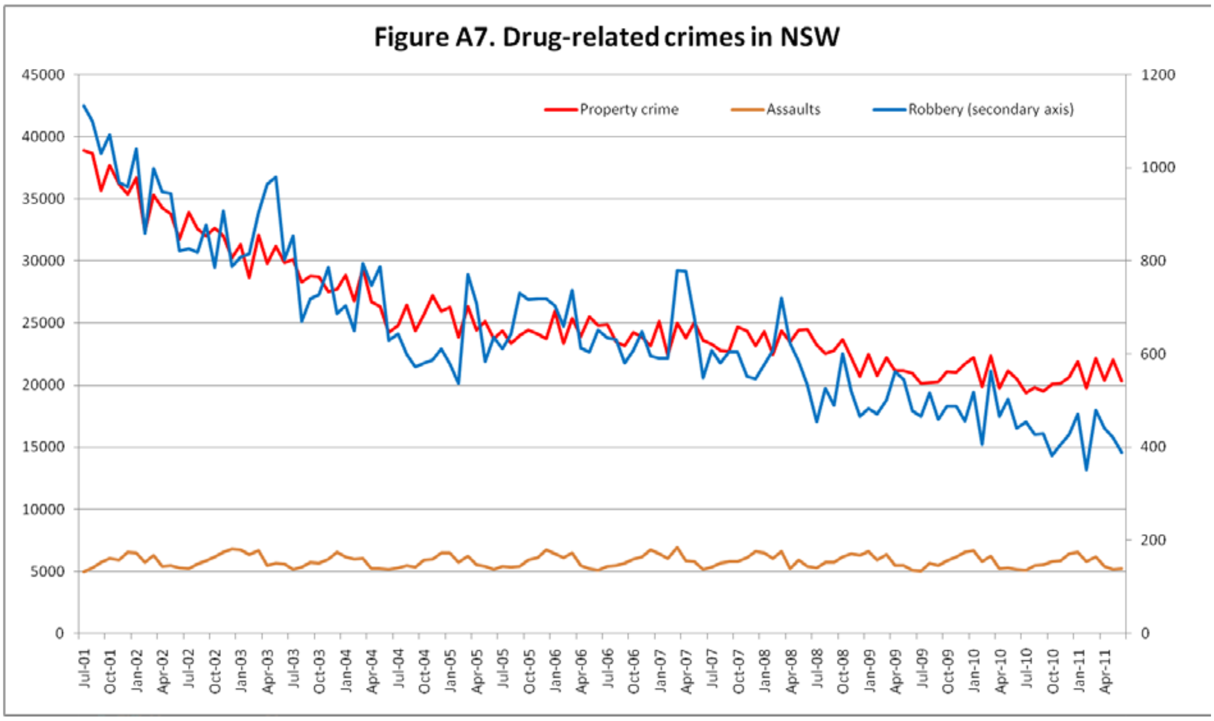


Figure A7. Drug-related crimes in NSW
Property crime
Assaults
Robbery (secondary axis)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
1200
1000
800
600
400
200
0
Jul-01
Oct-01
Jan-02
Apr-02
Jul-02
Oct-02
Jan-03
Apr-03
Jul-03
Oct-03
Jan-04
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Jul-08
Oct-08
Jan-09
Apr-09
Jul-09
Oct-09
Jan-10
Apr-10
Jul-10
Oct-10
Jan-11
Apr-11

Table A1. Summary of ARDL model results for heroin

State	Independent variables	Dependent variables									
		UP arrests					ED admissions				
		Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4
NSW	Number of seizures	+	-					+		+	
	Weight of seizures	-		+			+				
	Number of supplier arrests	+						+	-		
VIC	Number of seizures				+						
	Weight of seizures		+				-				-
	Number of supplier arrests										
QLD	Number of seizures			+							
	Weight of seizures										
	Number of supplier arrests										
WA	Number of seizures	-								+	
	Weight of seizures	+							-		
	Number of supplier arrests										
SA	Number of seizures							-			
	Weight of seizures										
	Number of supplier arrests					+	+			+	+
TAS	Number of seizures										
	Weight of seizures										
	Number of supplier arrests										
AFP	Number of seizures						-				+
	Weight of seizures					+					
	Number of supplier arrests										

Note: Blank cell means statistically insignificant coefficients; light grey cell with + means significant positive coefficients; and dark grey cell with - means significantly negative coefficients.

Table A2. Summary of ARDL model results for cocaine

State	Independent variables	Dependent variables									
		UP arrests					ED admissions				
		Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4
NSW	Number of seizures	+	-		+						
	Weight of seizures										
	Number of supplier arrests	+							+		
VIC	Number of seizures		+	-							
	Weight of seizures										
	Number of supplier arrests							-			
QLD	Number of seizures			-							
	Weight of seizures										
	Number of supplier arrests									+	+
WA	Number of seizures				+						
	Weight of seizures		+					-			
	Number of supplier arrests		+								
SA	Number of seizures				+						
	Weight of seizures										
	Number of supplier arrests										
TAS	Number of seizures										
	Weight of seizures										
	Number of supplier arrests										
AFP	Number of seizures										
	Weight of seizures				-						+
	Number of supplier arrests										

Note: Blank cell means statistically insignificant coefficients; + means significant positive coefficients; and S- means significantly negative coefficients.

Table A3. Summary of ARDL model results for ATS

State	Independent variables	Dependent variables									
		UP arrests					ED admissions				
		Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4
NSW	Number of seizures	+	-								
	Weight of seizures	-									
	Number of supplier arrests	+									
VIC	Number of seizures										
	Weight of seizures										
	Number of supplier arrests										+
QLD	Number of seizures							+			
	Weight of seizures										
	Number of supplier arrests										
WA	Number of seizures				-						
	Weight of seizures	-	-								
	Number of supplier arrests										
SA	Number of seizures										
	Weight of seizures										
	Number of supplier arrests						-				
TAS	Number of seizures										
	Weight of seizures										
	Number of supplier arrests										
AFP	Number of seizures										+
	Weight of seizures				+						
	Number of supplier arrests										

Note: Blank cell means statistically insignificant coefficients; + means significant positive coefficients; and S- means significantly negative coefficients.

Table A4. Summary of reduced ARDL model results for heroin

Independent variables	Dependent variables														
	Property crime					Assault					Robbery				
	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4
Number of seizures															
Weight of seizures		+			-	-		+	-	-	+				-
Number of supplier arrests															
Diagnostic checking	**p-value**					**p-value**					**p-value**				
	M1	**M2**				**M1**	**M2**				**M1**	**M2**			
Ljung-Box test (up to lag 24)	.326					.508					.272				
Engle's LM test	.966					.274					.860				
Granger causality test						**p-value**					**p-value**				
Weight of seizures						.163					.414				

Note: M1 refers the ARDL model using number and weight of seizures as independent variables; M2 refers to the model with number of supplier arrests as independent variable.

Table A5. Summary of reduced ARDL model results for cocaine

Independent variables	Dependent variables														
	Property crime					Assault					Robbery				
	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4
Number of seizures		-	+												
Weight of seizures							+							+	
Number of supplier arrests		-													
Diagnostic checking	**p-value**					**p-value**					**p-value**				
	M1	**M2**				**M1**	**M2**				**M1**	**M2**			
Ljung-Box test (up to lag 24)	.134	.235				.317					.794				
Engle's LM test	.680	.691				.330					.915				

Table A6. Summary of reduced ARDL model results for ATS

Independent variables	Dependent variables														
	Property crime					Assault					Robbery				
	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4
Number of seizures															
Weight of seizures															
Number of supplier arrests						+	-					-			-
Diagnostic checking	**p-value**					**p-value**					**p-value**				
	M1	**M2**				**M1**	**M2**				**M1**	**M2**			
Ljung-Box test (up to lag 24)							.455					.616			
Engle's LM test							.454					.854			
Granger causality test						**p-value**									
Number of supplier arrests						.248									

[i]Supply-reduction' in this context refers to policies designed to reduce the supply or increase the cost of illegal drugs (e.g. crop eradication, drug seizures, arresting drug importers and distributors). 'Demand reduction' refers to policies designed to discourage people from using illegal drugs or encourage them to consume smaller quantities (e.g. drug education and treatment). 'Harm reduction' refers to policies designed to reduce the harms associated with illegal drugs (e.g. needle and syringe programs).