
ASSESSING THE IMPACT OF MANDATORY DNA TESTING OF PRISON INMATES IN NSW ON CLEARANCE, CHARGE AND CONVICTION RATES FOR SELECTED CRIME CATEGORIES¹

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EXECUTIVE SUMMARY

OVERVIEW

- 1) This report assesses the association between mandatory DNA testing of NSW prison inmates and clear up, charge and conviction rates for Assault, Sexual Assault, Break and Enter, Robbery, Motor Vehicle Theft and Stealing from Motor Vehicles categories of crime.
- 2) The specific questions of interest are as follows:
 - a) Has the introduction of DNA testing increased the crime clear up rate and, if so, for which crime categories have the clear-up rates increased?
 - b) Has the introduction of DNA testing increased the ratio of charges laid to crimes reported and, if so, for which categories of crime?
 - c) Has DNA testing increased the proportion of charges laid that result in convictions and, if so, for which categories of crime?
- 3) There are 5 outcome series examined in this report covering the periods January 1995 to March 2007 inclusive for the police data on cleared and charged incidents and January 1995 to June 2007 inclusive for court convictions.
 - a) The percentage of cleared incidents within 180 days (Clear Up Rate)
 - b) The percentage of recorded incidents for which charges are laid within 180 days (Charge Rate)
 - c) The percentage of cleared incidents that result in charges laid within 180 days (Charge to Clear Up Rate)
 - d) The percentage of proven cases resulting in a conviction in the Local Courts (Conviction Rate)
 - e) The percentage of proven cases resulting in a conviction in the Higher Courts (Conviction Rate).
- 4) The possible impact on the availability of a growing DNA database on these five series for the various crimes is reviewed. In the absence of any prior studies on this problem the type of impact that might be expected from this intervention on the outcome series of interest is unclear. Our assessment is based on the incorporation of the DNA intervention as a linearly increasing effect commencing no earlier than January 2001 corresponding to the notion that as the DNA database grows the impact on Clear Up, Charge and Conviction Rates is likely to increase in line.
- 5) Because there is potential for lag effects in the impact of DNA testing on crime Clear-up, Charge and Conviction Rates the model allows for a delay in impact which is estimated from the data.
- 6) The model includes a linear trend over the entire series as a baseline against which the impact of the linear growth in available DNA samples is assessed. Appropriate statistical techniques for fitting linear regression models with autocorrelated residuals are applied.
- 7) The assessment of the DNA effect is at best an assessment of association between a change in the slope of a linear trend at or after January 2001 and the outcome series of interest after adjusting for potential covariates and autocorrelation. More

complex responses to the intervention of DNA testing were not attempted here and it is our opinion that alternative functional forms for this would be difficult to justify given the variability and trend patterns observed in the outcome series and in view of the lack of prior studies or knowledge to inform the likely shape of the response to intervention.

- 8) The numbers of crimes in each category were assessed as a proxy for past and present police workloads since this could impact on efficiency of clearing and charging. We could not establish a significant relationship between the numbers of incidents recorded and the outcome series of rates of interest here.
- 9) Covariates that have proved useful in explaining temporal fluctuations in the numbers of high volume property crimes in previous studies were also tested in the course of the modeling but their plausibility has not been established and their impact on the conclusions reached without including them in the modeling was typically quite small. The effects of models with covariates are therefore not presented in this report in detail.

SUMMARY OF FINDINGS

- 10) The results of this study quantify the significance, size and direction of association between the advent of DNA testing and the subsequent growth in the DNA database and the various outcome measures: Clear-up rate, Charge rate, Charge to Clear-up rate and Conviction rates in both court jurisdictions.
 - a) For the police outcome series of Clear-up, Charge and Charge to Clear-up rates, there is consistent evidence of a positive association for 5 of the eight crime categories considered and mixed evidence for the Assault and the two motor vehicle related categories.
 - b) For conviction rates, there is no evidence (apart from a very mild association at an implausibly short lag for Sexual Assault in the higher courts) for a conclusion that the advent of DNA testing has had a positive impact.
- 11) Table 10 of the report provides a detailed summary of our findings concerning the significance of the association between the growth in the DNA database and the five outcome series of interest across the range of crime types assessed.
- 12) For five crimes (Sexual Assault, Robbery with Firearm, Robbery without Firearm, Break and Enter Dwelling and Break and Enter non-Dwelling) there is consistent evidence that the advent of DNA testing is positively associated with an improvement in Clear-up rate, Charge rates and Charge to Clear-up rates relative to prior trends in the monthly series. The lags at which the linear DNA variable is most strongly associated are reasonably consistent across the three outcome measures within each of these five crime categories. This is less so for Break and Enter non-Dwelling and for Robbery With Firearm.
- 13) For Assault the results are mixed. For the Clear-up rate the association with the linear growth in the DNA database is negative while for the Charge and Charge to Clear-up rate series there is a positive association.
- 14) For the two motor vehicle related crimes the results are even more mixed and no consistent impact of the growth of the DNA database on these categories of crimes emerges.
- 15) Apart from Sexual Assault in the Higher Courts, there is no evidence from our analysis that the advent of DNA testing has had any discernible and positive impact

on conviction rates in either court. The introduction of DNA testing in January 2001 is statistically significantly associated with a reduction in conviction rates and this association is immediate or almost immediate in all cases. Given the likelihood of substantial time lags in solving and prosecuting crimes in the courts this immediate association is unlikely to be a causal one. That is, we would rule out the possibility that the advent of DNA testing had an impact on reducing conviction rates.

- 16) For Sexual Assault cases tried in the Higher Courts, the positive association is slight and not mirrored in the corresponding lower court series. Moreover, the effect size is very small. That, and the short lag at which this effect is observed, would suggest that this isolated result is not evidence of a causal link between the advent of DNA testing and the conviction rate for Sexual Assault.
- 17) Table 11 of the report provides an assessment of the impact of inclusion of the linear growth in the DNA database on the modelled level of the three police related outcome series for each crime.
- 18) A summary of the results in this table for the 8 categories of crime is as follows. In this summary the amount of improvement expresses the level of the series with the linear DNA term included (column 6 of Table 11) as a whole number percentage improvement relative to what it would be forecast to be without that term included (column 5 of Table 11). This measures the impact (assuming this is causal) of DNA testing on the level of the series projected 12 months beyond where it is estimated to commence its impact. For example the Charge rate for Assault is predicted to be 36.6% one year after April 2003 without inclusion of a term for DNA database growth. Inclusion of this term leads to a prediction of the Charge rate for Assault to be 38.3%, which is 5% greater than the 36.6%, predicted using prior trends.
 - a) Assault
 - i) Clear-up rate: negative impact.
 - ii) Charge rate: positive impact commencing April 2003 resulting in a 5% improvement 12 months later.
 - iii) Charge to Clear-up rate: positive impact commencing October 2002 resulting in a 6% improvement 12 months later.
 - b) Sexual Assault
 - i) Clear-up rate: positive impact commencing July 2002 resulting in a 18% improvement 12 months later.
 - ii) Charge rate: positive impact commencing August 2002 resulting in a 50% improvement 12 months later.
 - iii) Charge to Clear-up rate: positive impact commencing February 2003 resulting in a 10% improvement 12 months later.
 - c) Robbery with Firearm
 - i) Clear-up rate: positive impact commencing September 2005 resulting in a 53% improvement 12 months later.
 - ii) Charge rate: positive impact commencing July 2005 resulting in a 70% improvement 12 months later.
 - iii) Charge to Clear-up rate: positive impact commencing January 2001 resulting in a 3% improvement 12 months later.

- d) Robbery without Firearm
 - i) Clear-up rate: positive impact commencing December 2004 resulting in a 7% improvement 12 months later.
 - ii) Charge rate: positive impact commencing November 2004 resulting in a 15% improvement 12 months later.
 - iii) Charge to Clear-up rate: positive impact commencing June 2004 resulting in a 4% improvement 12 months later.
 - e) Break and Enter Dwelling
 - i) Clear-up rate: positive impact commencing June 2003 resulting in a 6% improvement 12 months later.
 - ii) Charge rate: positive impact commencing July 2003 resulting in a 9% improvement 12 months later.
 - iii) Charge to Clear-up rate: positive impact commencing February 2004 resulting in a 5% improvement 12 months later.
 - f) Break and Enter Non-Dwelling
 - i) Clear-up rate: positive impact commencing August 2001 resulting in a 9% improvement 12 months later.
 - ii) Charge rate: positive impact commencing November 2001 resulting in an 11% improvement 12 months later.
 - iii) Charge to Clear-up rate: positive impact commencing August 2003 resulting in a 2% improvement 12 months later.
 - g) Motor Theft
 - i) Clear-up rate: negative impact.
 - ii) Charge rate: negative impact.
 - iii) Charge to Clear-up rate: positive impact commencing July 2004 resulting in a 2% improvement 12 months later.
 - h) Stealing from MV
 - i) Clear-up rate: zero impact.
 - ii) Charge rate: positive impact commencing January 2001 resulting in a 4% improvement 12 months later.
 - iii) Charge to Clear-up rate: zero impact.
- 19) The size of the estimated impact may be implausible in some cases. For instance, the clear-up rate for Robbery with Firearm at the point of optimal impact (September 2005) is 14.1%. The impact of the linear DNA terms is estimated to be 7.0%, which as a percentage of the level is almost 50%. On the other hand some of the impacts are modest or small. We know of no way to independently check the plausibility of the effect sizes implied by the results summarised above.
- 20) In relation to the results for the police outcome series, the lags at which the association with the advent of DNA testing and subsequent database growth are quite long and vary across crime categories. Typically the lags tend to be in the order Break and Enter Non Dwelling (shortest lags), Sexual Assault, Break and Enter Dwelling, Robbery without Firearm and Robbery with Firearm (longest lags). It is

possible that these differences in lags across crime categories are due, in part, to differences in average prison sentences for these crimes.

- 21) In order to use the results concerning association into a conclusion of causality in which DNA testing increases the police's effectiveness in solving and prosecuting crime it is necessary to rule out other possible explanations for the observed association.
- 22) It is possible that there are alternative factors at work in the police service that explain the fluctuations in the series and could confound the observed associations with the linear DNA term in the modelling.
- 23) The key assumptions that underpin the analysis and results presented are: that the trend in the outcome measure is linear and that the impact of the growth of the DNA database is linear at a lag determined to optimally fit the model.
- 24) Concerning the outcome measures used in this report, there are two points of caution that should be mentioned. The first concerns the obvious fact that the three police outcome measures of Clear-up rate, Charge rate and Charge to Clear-up rate are not independent of each other. This needs to be kept in mind when considering the overall strength of evidence. The second caution is that the Clear-up and Charge rates are both based on a cut-off for inclusion of 180 days after the recording of a crime. For some, even all, crime categories considered here, this may not be sufficient time to fully capture all cases in which DNA has utility in solving and charging crimes.

FUTURE RESEARCH

- 25) To advance our understanding of the impact of DNA testing on criminal investigation and prosecution future research should direct itself towards:
 - a) Better understanding and quantification of the factors that influence the outcome series considered here.
 - b) Further analysis of data beyond June 2007, particularly for convictions, where there are likely to be long lags.
 - c) Determination of the coverage afforded by 180 clearance rates of crimes in which DNA evidence is likely to play a key role and measurement of the time from location of a DNA sample at a crime scene to prosecution of an offender in a case where DNA evidence is used.
 - d) Further analysis of the conviction rate series to determine historical changes in trends and levels, particular those around 2001, and, to obtain an explanation for why the trend patterns differ between higher and lower court conviction rates for the same crimes.
 - e) A better understanding of the likely time lags for crimes of each type to reach trial in determining plausible lags for the impact of the advent of DNA testing to be noticeable.

Further details concerning recommendations for future research can be found in the final section of the report.

1. INTRODUCTION

The world's first national DNA database began operation in the United Kingdom (UK) on the 10th of April 1995, following a Royal Commission into the UK Criminal Justice System. By 2000, the database held records on one million individuals, or over a third of the estimated size of the criminal population.¹ The establishment of the database was heralded as a major breakthrough in the fight against crime (Gunn, B. 2001, cited in Briody and Prenzler (2005), and it did not take long for other law enforcement agencies throughout the world to follow suit. In 1998, the FBI set up the National DNA Index System, enabling city, county, state and federal law enforcement agencies throughout the USA to compare DNA profiles electronically.² On July 1, 2000, following a series of cases in which Australian State and Territory Police secured convictions using DNA evidence, the Australian Government established CrimTrac, a Federal Government agency with a national DNA database as its central element.

CrimTrac launched the National Criminal Investigation DNA Database (NCIDD) to allow the nine Australian jurisdictions to match DNA profiles in 2001. State and Territory Governments then began to prepare legislation and Ministerial Arrangements to allow their participation in NCIDD. The NSW contribution to the national database began with the passage of the NSW Crimes (Forensic Procedures) Act (2000). Among other things, this Act gave NSW Police the power to take DNA samples from offenders serving a sentence of imprisonment for a serious indictable offence³ in a correctional centre. From January 2001 onwards, NSW Police began testing inmates serving sentences for serious indictable offences in NSW prisons. By 2007, the inmate DNA database held 25,000 records. The creation of this database gave police a large and growing reservoir of known or suspected offenders whose DNA records could potentially be matched to DNA taken from crime scenes. Since 2002 the database is said to have resulted in 16,322 'cold links' (instances where DNA taken at a crime scene has been linked to the DNA of a known offender in the DNA database). Over the same time period DNA evidence is reported to have contributed to 4,458 criminal convictions (pers comm. David Raper 2008).

The spread of DNA testing at crime scenes and the establishment of DNA databases is widely believed to have improved the capacity of police to identify, arrest and prosecute offenders. There is no doubt that DNA evidence has sometimes been extremely helpful in convicting offenders and in exonerating those who have been wrongly convicted of a crime. To date, however, no rigorous and independent study has been conducted, in Australia or elsewhere, into whether the establishment of a DNA database leads to an increase in the rate at which crimes are cleared and/or offenders are prosecuted and convicted. This purpose of this report is to examine this issue in the context of New South Wales. The specific questions examined in this report are:

1. Has the introduction of DNA testing increased the crime clear up rate and, if so, for which crime categories have the clear-up rates increased?
2. Has the introduction of DNA testing increased the ratio of charges laid to crimes reported and, if so, for which categories of crime?
3. Has DNA testing increased the proportion of charges laid that result in convictions and, if so, for which categories of crime?

These questions addressed are separately examined for a range of offence types. The Australian Standard Offence Classification (ASOC) classifications considered were:

- assault
- sexual assault
- robbery with a firearm
- robbery without a weapon and with a weapon not a firearm combined
- break and enter – dwelling
- break and enter - non-dwelling
- motor vehicle theft
- steal from motor vehicle.

The next section of this report briefly reviews past research on the utility of DNA evidence in identifying and prosecuting offenders. We then describe the current study in more detail.

2. PAST RESEARCH

Numerous claims have been made about the effectiveness or otherwise of DNA evidence in criminal investigation and prosecution. Few of these claims, however, have been backed up by rigorous published research. Alaster Smith (2004), for example, reported that:

“Overall, the national (UK) detection rate for the police is 23% of recorded crime. When useable DNA is recovered and loaded onto the DNA database, this detection rate rises to 43%....In domestic burglary....the detection rate rises from 15 to 46%; theft from a vehicle rises from 7 to 61%; and criminal damage increases from 13 to 52%.”(Smith 2004, p. 14).

Unfortunately, Smith does not provide enough detail on the analysis that led to these conclusions to be confident in their veracity. It is impossible, for example, to tell whether the cases in his analysis where DNA was present were identical in all other relevant respects to cases in which it was absent. The difference in clear-up rates might be therefore be attributable to factors other than the presence or absence of DNA evidence.

Bradbury and Feist (2005) recently reviewed research on the general utility of forensic evidence⁴ in volume crime (e.g. burglary, car theft, stealing from a motor vehicle) investigation in Britain. The main findings to emerge from their review were that:

1. Although the proportion of volume crime offender identified through forensic evidence has historically been low, forensic evidence (in the UK) is now the main evidence supporting detection of an offender in more than a quarter of volume crime cases.
2. Forensic evidence is principally used to corroborate other evidence against known suspects, rather than to identify unknown offenders.
3. The presence of forensic evidence greatly increases the odds of [offender] detection where other types of evidence are not available.
4. The overall conviction rate for cases with forensic evidence is not significantly higher than for those without such evidence. There are significant differences (favouring cases where forensic evidence exists), however, when individual crime types such as murder, burglary and theft cases are examined.

Two of the studies reviewed by Bradbury and Feist (2005) looked at the role of DNA evidence in Australian court proceedings. Briody (2002)⁵ examined a sample of 200 sexual offence cases in Queensland, Australia, 102 of which involved DNA evidence and 98 of which did not. Importantly, cases where the suspect had admitted intercourse (i.e. cases where the only issue was whether consent had been given) were not included in the samples. Briody found that the presence of DNA evidence did not influence the likelihood of a guilty plea. Cases where DNA was present, however, were more likely to reach court and more likely to end in a guilty verdict if they went to trial. In a later study (Briody 2004)⁶, Briody examined a sample of 150 completed Queensland homicide cases, 75 of which used DNA evidence to link the offender to the crime scene and 75 of which contained no DNA evidence. As with the study on sexual assault, the presence of DNA evidence had no effect on the likelihood of a guilty plea but a strong effect on the likelihood of conviction among cases that went to trial.

The strongest evidence to date that DNA testing increases the capacity of the police to identify and arrest offenders comes from a study published earlier this year by Roman, Reid, Reid, Chalfin, Adams and Knight (2008). They conducted a prospective randomised experiment of the cost-effectiveness of DNA in investigating high-volume crimes, including residential burglary, commercial burglary, and theft from automobiles. Biological evidence was gathered from 500 crime scenes in five different communities and the cases in respect of which this evidence was gathered were then randomly assigned to treatment and control conditions so as to produce a roughly equal split of cases at each site. In the treatment group, DNA processing as well as traditional methods were used to investigate the case. In the control group, biological evidence was not initially tested, and case outcomes were due only to traditional investigation. The study found that property crime cases where DNA evidence was processed had more than twice as many suspects identified, twice as many suspects arrested and more than twice as many cases accepted for prosecution compared with traditional investigation.

These studies show that DNA evidence has the potential to increase clear up and conviction rates but they do not tell us whether the creation of a DNA database has in fact had any effect on the rate at which crimes are cleared and offenders convicted. The impact of a DNA database on criminal investigation and prosecution depends upon a great deal more than the effectiveness of DNA as a means of identifying persons who might have been at the scene of a crime. It will depend, for example, upon the proportion of crime scenes attended by police, the proportion of police attendances that lead to the recovery of DNA and the proportion of recovered DNA samples that result in the arrest and conviction of someone. Briody and Prenzler (2005) examined the influence of these variables on the overall impact of DNA on burglary conviction in Britain. On the basis of data obtained from various public reports in Britain, they estimated that:

- 85 per cent of burglaries were attended by scenes of crime officers (SOCOs)
- Only five per cent of those attended resulted in the recovery of DNA
- 44 per cent of cases where DNA was recovered led to the detection of an offender
- Each detection led to the solution of 0.8 additional burglaries
- Only half the detections resulted in a conviction

This led them to conclude that the DNA database in the United Kingdom was instrumental in achieving burglary convictions in less than 1.7 per cent ($0.85 \times 0.5 \times 0.44 \times 1.8 \times 0.5 = 0.016832$) of reported burglaries.

Such calculations highlight the extent to which the impact of DNA testing depends upon a range of factors other than the reliability of DNA as a means of identifying offenders. It would be unwise, nonetheless, to take the calculations given above as a demonstration of the impossibility of influencing criminal investigation and prosecution outcomes via the use of DNA. There are two reasons for this. One is that the assumptions on which the calculations are based may change over time in a given jurisdiction or differ markedly at a particular point in time from one jurisdiction to another. It is well within the power of police, for example, to increase the rate of attendance at crime scenes, the recovery rate of DNA from crime scenes, the percentage of identified offenders apprehended and brought before the courts and the additional crimes solved as a result of apprehension.⁷ Secondly, the contribution of DNA testing to burglary investigation is not limited to DNA testing at burglary scenes of crime. Offenders picked up for offences other than burglary may provide DNA that can be matched to previous burglaries.

The Briody and Prenzler (2005) calculations therefore probably underestimate the percentage of cases whose outcomes are influenced by DNA.

Rather than try and estimate the number of cases that could be influenced by DNA testing, it would be wiser to actually measure the impact of DNA testing on clear up and conviction rates before and after the advent of DNA testing in a particular location (preferably comparing outcomes in another similar location where DNA testing does not exist). One of the difficulties in pursuing such research, however, is that the size and timing of any effect stemming from the construction or expansion of a DNA database is likely to depend on a wide range of factors, including:

1. The size of the DNA database, relative to the active criminal population
2. The proportion of crime scenes from which DNA evidence is taken
3. The speed with which DNA evidence is analysed and compared to DNA evidence on the database
4. The speed with which identified offenders are apprehended
5. The rate of turnover in the criminal population
6. The average length of stay of offenders in prison

The smaller the size of the DNA database (relative to the active offender population) and the lower the proportion of crime scenes from which DNA evidence is taken, the lower the chance of a DNA match between crime scene and offender. The longer it takes to process DNA evidence, the smaller the chance of apprehending the offender and the longer it takes for the effect of increases in the size of the DNA database to show through. The turnover rate in the criminal population and the average length of stay in prison are important for slightly different reasons. If turnover in the criminal population is high (i.e. offenders quit crime very quickly), then increasing the size of the DNA database past a certain point may not confer much additional benefit (because new offenders are not on the database and old offenders have already quit crime). If the average length of stay in prison is long, the benefits of increasing the size of the DNA database may take a long time to be felt.

There is very little evidence bearing on these matters. Estimates of the size of the offender population vary widely, depending upon the method used (Blumstein et al. 1986). Few jurisdictions publish information on the proportion of crime scenes from which usable DNA evidence is taken, the speed with which it is processed and the speed with which identified offenders are apprehended. The average length of stay in crime is known to be around five years (Blumstein et al. 1986; Weatherburn et al. 2006) but the distribution of time spent as an active offender is very highly skewed; with most offenders quitting crime early but a significant percentage remaining in crime for a substantial proportion of their lives. The distribution of sentence lengths also tends to be highly skewed, with most prison sentences averaging about a year but a substantial proportion being over five years in length (Australian Bureau of Statistics 2007). These considerations make it difficult to determine, a priori, how and when changes in the size of a DNA database will influence the process of criminal investigation and prosecution.

The only study, to date, which seems to have considered these issues in any depth is that conducted by Roach and Pease (2006). They examined submissions of crime scene DNA samples by the West Midlands police and the number of matches with criminal justice samples on the National DNA Database (NDNADB) between April 2000 and October 2001. Over this period there were a total of 6,878 submissions and 3,982 matches, with

the number of submissions growing at an average rate of about 19 per month. Leary and Pease found that the proportion matched remained constant over the period in which the number of samples submitted increased. They also found evidence (albeit tentative) that the proportion of matches in any given month was a constant fraction of the number of DNA submissions made in that month. They interpreted their findings as evidence against the hypothesis that increases in the number of DNA submissions brought diminishing returns (in terms of matches on the NDNADB).

3. THE PRESENT STUDY

The aim of the present investigation is to examine the impact on clear-up prosecution and conviction rates of NSW legislation passed in 2000, permitting police to take DNA samples from any offender serving a sentence of imprisonment for a serious indictable offence.

Five outcome measures are used to obtain an answer to questions (1) to (3) of Section 1.

- I. The percentage of cleared incidents within 180 days (clear-up rate)
- II. The percentage of recorded incidents for which charges are laid within 180 days (charge rate)
- III. The percentage of cleared incidents that results in charges laid within 180 days (charge to clear-up rate)
- IV. The percentage of charges proven in the Local Courts (LC conviction rate)
- V. The percentage of charges proven in the Higher Courts (HC conviction rate)

A series of statistical regression models is used to assess if there is any association between the implementation of DNA testing of prisoners and the clear up, charge and conviction rates for various categories of crime. In order to understand the development of these models it is necessary to describe the pattern of the growth in the numbers of prisoners tested and estimate the numbers of prisoners released from prison who have been tested.

3.1 NUMBERS IN THE DNA DATABASE

Data on the number of inmates tested each month from January 2001 to June 2007. These are shown in Figure 1. Accumulation of monthly numbers of those tested gives size of the DNA database for each month since the program of testing started. These are shown in Figure 2. There was a relatively higher level of testing in 2001-2002 due to the "initial" back-capture requirements. [personal communication, David Raper, NSW Police]. After the initial two years of back capture of existing prisoners the monthly average numbers of prisoners tested was around 225 per month.

It is assumed for this report that there are no duplicates in the DNA database; that is, a reoffending prisoner for whom a valid DNA test results was taken previously, was not retested upon readmission to prison.

Figure 1: Monthly Counts of DNA Inmate Tests

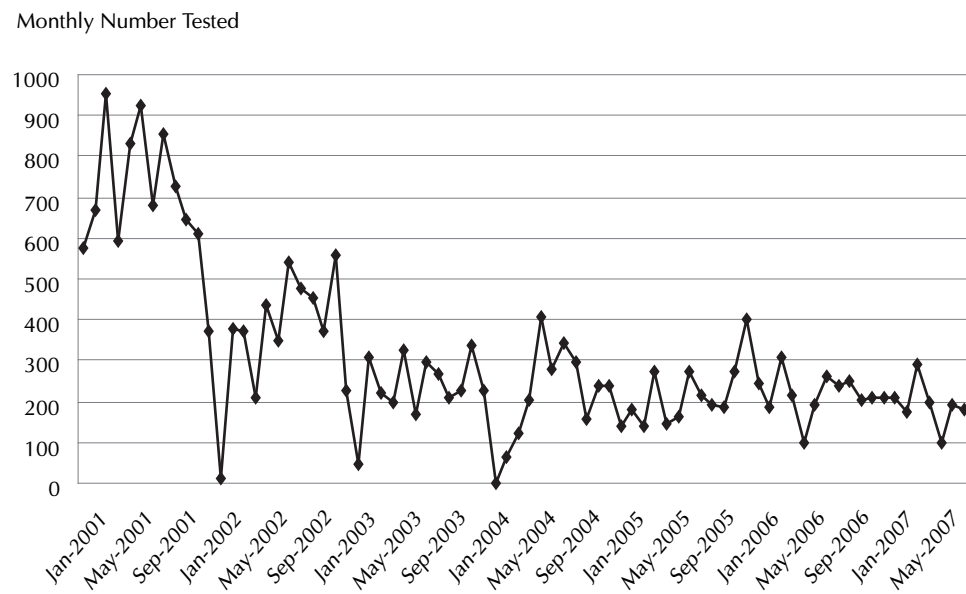
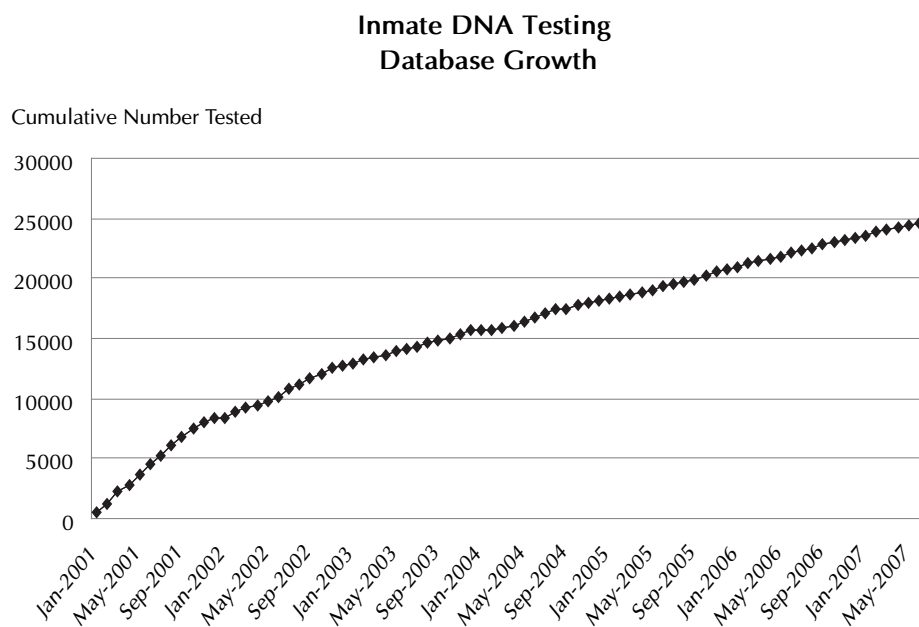


Figure 2: Size of DNA Inmate Database through time



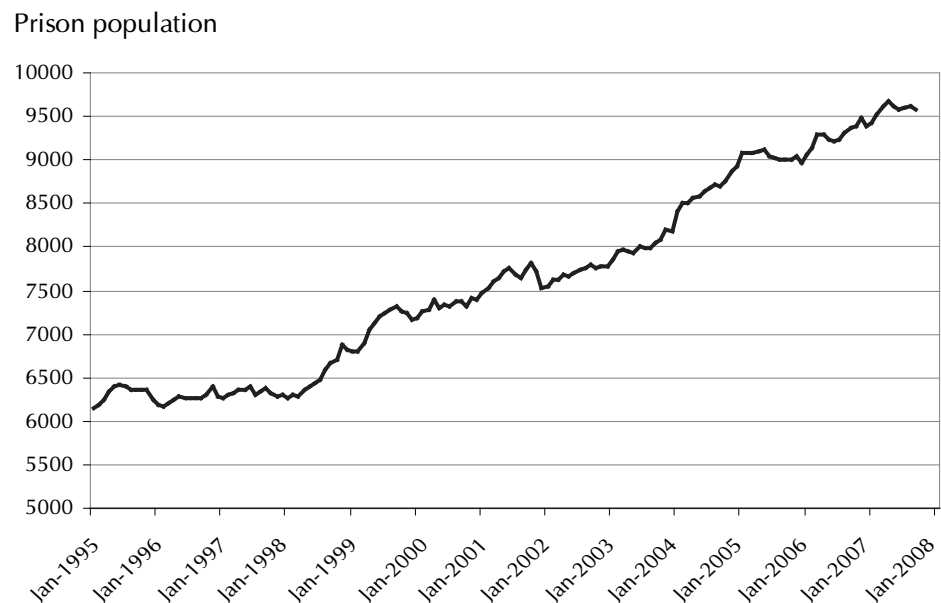
3.2 GROWTH IN NUMBERS OF DNA TESTED CRIMINALS IN CIVILIAN POPULATION.

Figure 2 shows the growth in the DNA inmate database. Obviously, as the number of individuals released after testing grows, the number of individual DNA results available to match against DNA evidence collected as a result of a crime will also increase. The existence of test results for prisoners remaining in prison is, of course, relevant to assisting in solving old cases. However this study is concerned with the impact of DNA testing on cases that are cleared or in which charges are laid within 180 days of their recording.

It has not been possible to obtain a time series of the numbers of people outside of prison who have been DNA tested. Here we will attempt, albeit crudely, to construct such a time series.

Figure 3 shows the prison population of NSW over the period of this study.

Figure 3: Prison Population, NSW, 1995-2008



Note on series: There was a change in definition of the NSW prison population in January 2004. Prior to January 2004 the prison population was based on the population of gazetted correctional centres only. Since January 2004, the prison population includes persons held in gazetted correctional centres, transitional centres and police/court cells managed by NSW DCS. As an indicator of the impact of this change in series, the daily average population of transitional centres in 2004-05 was 29 and the daily average population of police/court cells was 102.

Note that, after a stable period until January 1998, the prison population continued to grow along a more or less linear path. This trend is largely due to a growth in the proportions of offenders refused bail and given a prison sentence.

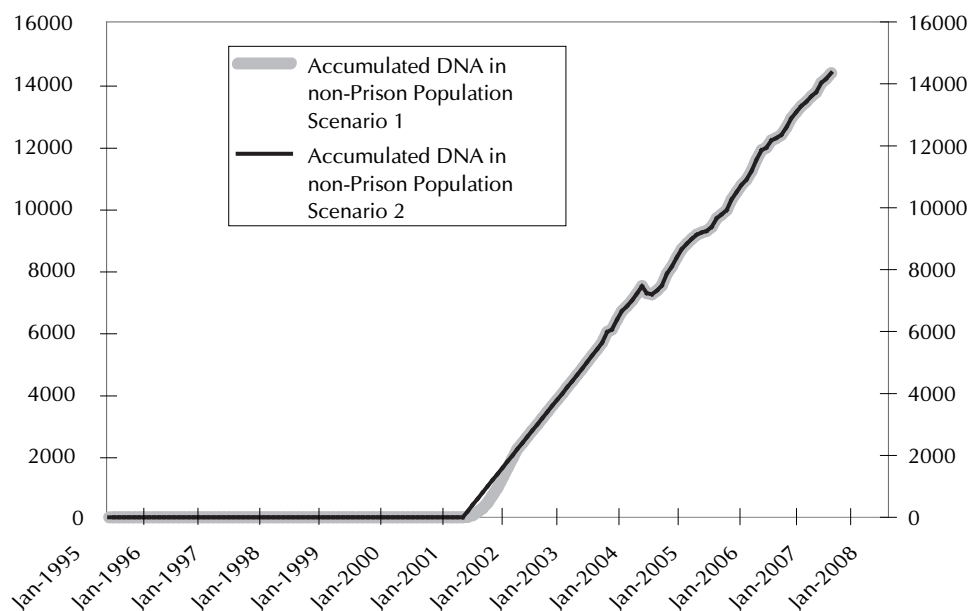
In June 2007 there were 9,585 inmates most of whom, it is safe to assume, had been tested. A total of 24,548 individuals had been DNA tested while incarcerated since DNA testing began. Hence in June 2007 there were approximately 15,000 individuals who had served time in prison had been released and for whom DNA test data was available. This represents approximately 285 individuals per 100,000 people from the approximate total population of NSW of 5.3 million in June 2007.

We have estimated the numbers of ex-prisoners with DNA tests in the database for each month starting in January 2001 in two ways. Both assume that the numbers of such individuals from January 2003 (two years after the onset of DNA testing and considered to be the end of the “back-capture” period) is obtained monthly by subtracting the prison population in that month from the numbers of DNA samples in the database. For the initial two-year period two alternative methods are used:

1. Scenario 1: Assumes that the existing prisoners tested are selected at random and the proportion of prisoners tested to date is applied to the constant release rate of 225.
2. Scenario 2: Assumes that the prisoners soon to be released will be tested with higher priority and that the number of prisoners released per month is a constant 225.

The two scenarios are compared in Figure 4. The first Scenario coincides with the second scenario from the start of 2004. The main difference is that Scenario 1 has a delay in the numbers of individuals who are tested who have been released.

Figure 4: Two Scenarios for Growth in Released Prisoners with DNA Test Results



Bearing in mind that the initial period constitutes a small fraction of the total numbers of DNA samples accumulated by the end of the period (about 1 in 7) or by the middle of the period from 2001 to 2007 (about 1 in 4) and, given the level of variability evident in the outcome series, it is unlikely that it will be possible to determine which of these two scenarios is the more likely. Because of this we use a straight line starting in January 2001 to model the increase in numbers of ex-prisoners in the DNA database. The slope (or rate of increase) is determined by the regression or other time series procedures we adopt.

Note that in the above analysis we did not attempt to take into account recidivism where a previously tested inmate who is released is then imprisoned again. Some of the prison population will be those who had been tested in a previous period of incarceration. If the rate of incarceration has been reasonably constant over the period then the straight line model for growth in numbers of released prisoners with DNA test results would remain a reasonable first approximation.

Factors that could be important in assessing the impact of the numbers of DNA samples in the population of released offenders include:

1. Offenders in various categories of crime will tend to have prison terms that increase with the seriousness of the offence. If they reoffend they may also tend to reoffend in the same category as the crime they were imprisoned for when DNA tested. This would suggest that there would be differential delay effects in the impact of DNA on detection, prosecution and conviction rates across the range of offences we have been asked to examine.
2. The time from release of to reoffending and from re-offending to detection (bearing in mind the low detection rates for many crimes) will lead to a delay in the impact of the DNA database.

It is not possible, with the data and information that we have, to determine a priori, either overall or for individual crime categories, what the likely delays in the impact of DNA database size on detection, prosecution and conviction for various crimes. Accordingly we will attempt in our analysis to estimate any time delays in the impact and we will do this separately for each category of crime under study.

3.3 POSSIBLE IMPACT OF DNA TESTING

As noted earlier, we know of no other studies in existence assessing the impact of implementation of DNA testing on trends in crime, clear up, charge or conviction rates. The comments that follow, being based on 'common sense', are necessarily limited and speculative. Some background to the DNA testing intervention and its possible impacts can be found in Haesler (2003).

The potential impacts on crime include:

Enhanced Detection: Police have a better net to catch criminals, either those who have already offended or those who offend in the future. The impact of DNA testing on clear up and charge rates for crimes committed prior to January 2001 will likely be quite low. The series we are examining are clear up and charge rates within 180 days of the incident being recorded – any crimes committed in the last 6 months of 2000 are unlikely to be related to someone who has been DNA tested within 180 days of committing these crimes. DNA testing could, however, increase the likelihood of obtaining convictions post introduction for crimes that were committed pre-introduction.

For new cases there will be gradual increase in the ability of police to solve and successfully prosecute crimes because the number of released and DNA tested criminals in the database has grown gradually since the start of 2001. This study is concerned with clear up, charge and conviction rates for new crimes committed and therefore any impact of DNA testing on these outcome measures is likely to be gradual and more or less in line with the growth in the numbers of released prisoners who have been DNA tested.

Increased Caution: Balanced against the increased ability of police to solve crimes in which DNA evidence is available, and for which there is potential for a match with the growing database of ex-prisoners, there is the potential for enhanced awareness by criminals of the need to cover their tracks – this may tend to reduce evidence available from crime scenes, property or victims and therefore lead to a lowering of the detection rate.

Increased Deterrence: Criminals may be deterred by the perception that the likelihood of being caught is increased by DNA testing. Ex prisoners who have been tested may be deterred from re-offending after release believing that their chances of being caught will be substantially increased. Similarly criminals who have not been tested previously, if caught and incarcerated, may be DNA tested and this will increase the likelihood that they will be charged with any crimes committed since release from prison.

3.4 SUMMARY: LIKELY IMPACT OF DNA TESTING ON CLEAR-UP, CHARGE AND CONVICTION RATES

In view of the above discussion:

- The implementation of DNA testing could conceivably have an immediate impact in these outcome measures and show itself as a step change. However we believe that this response is unlikely. Also we cannot observe such an impact in the time series of outcomes themselves.
- It is more likely, given the nature of the growth in the database of released prisoners with DNA tests that the response to the intervention will be gradual and increase monotonically in line with the increase in the database. The simplest such representation is a straight-line increase as the numbers of available DNA samples for released criminals grows. Of course, this ignores more subtle dynamic relationships that could develop through time, such as arise from changing behaviour of criminals as time passes from the onset of the DNA testing regime.

As a result of these considerations we decided to model the impact of the DNA testing intervention with a linear increasing function. To allow for delays in the response to this we have also examined whether this linear increase is better modelled with a lag delay where the lag is selected to minimize residual deviation of the observed time series around the fitted linear trends and intervention effects.

3.5 DATA SOURCES: OUTCOME MEASURES

Data comes from two sources:

Police Statistics on Clearances and Commencement of Legal Proceedings : The spreadsheet **Data Source Dg08/6102** (supplied by the NSW Bureau of Crime Statistics and Research) contains monthly values of NSW Recorded Crime Statistics for the period January 1995 to March 2007 inclusive. The five series provided for selected offences are:

- number of recorded incidents ("Total number recorded");
- number and percentage of cleared incidents within 180 days;
- number and percentage of incidents that have legal proceedings commenced within 180 days.

The selected ASOC categories are

- assault
- sexual assault
- robbery with a firearm
- robbery without a weapon and with a weapon not a firearm combined
- break and enter – dwelling
- break and enter - non-dwelling
- motor vehicle theft
- steal from motor vehicle.

Court Statistics on Convictions: The spreadsheet **Data Source HcLc086251dg** (supplied by the NSW Bureau of Crime Statistics and Research) provides the number of charges, the number of proven charges and the percentage of proven charges for six selected ASOC categories by finalisation month for the period January 1995 to June 2007 inclusive. The selected ASOC Categories are:

- assault
- sexual assault
- robbery
- unlawful entry with intent/burglary
- break and enter
- motor vehicle and related offences
- theft (except motor vehicle) and other.

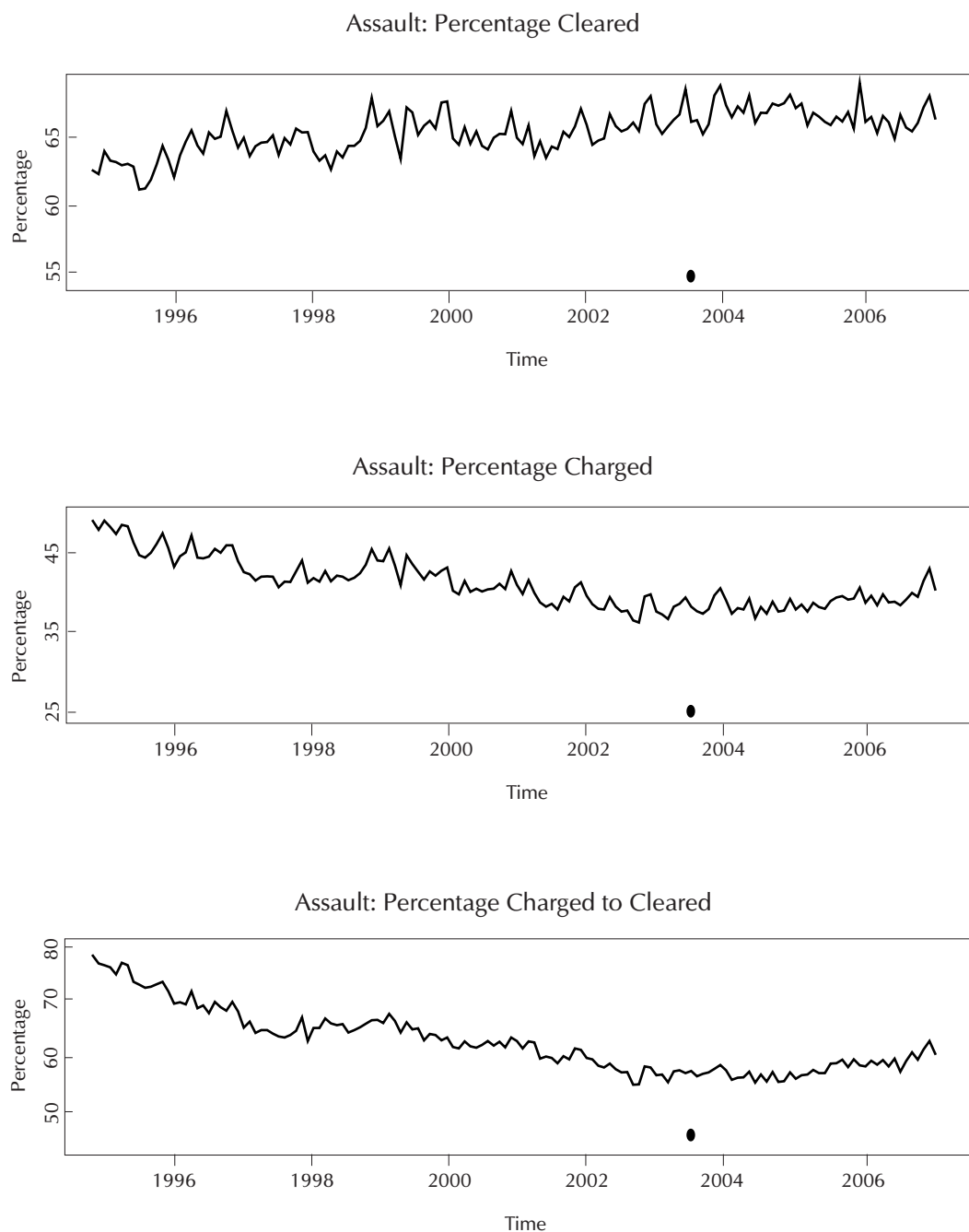
Data are available for NSW Local Criminal Courts and NSW Higher Criminal Courts January 1995-June 2007 separately.

Note that the categories of crime in these proven charge series differ from those for the clearance rates and legal proceedings in the previous data set. Also, there will be unknown delays between when the offence is recorded and when any court proceedings relating to that offence are finalized. In view of these two difficulties we will not attempt to relate the numbers of cases finalized in court (from the Court Statistics) to the number of cases for which court proceedings commenced within 180 days from the Police Statistics.

3.6 SOME EXAMPLES OF CLEAR UP AND CHARGE RATE TIME SERIES

To focus later discussion of the issues involved in developing statistical models for the purposes of assessing any impact of DNA testing, we review the basic features of the time series for two of the crime categories: Assault and Robbery Without Firearm. Similar graphs for all of the series are given in Appendix A with some qualitative discussion of the main features of the underlying series. Figure 5 show the three outcome series for Assaults.

Figure 5: Assault - Percentage Cleared, Charged and Charged to Cleared



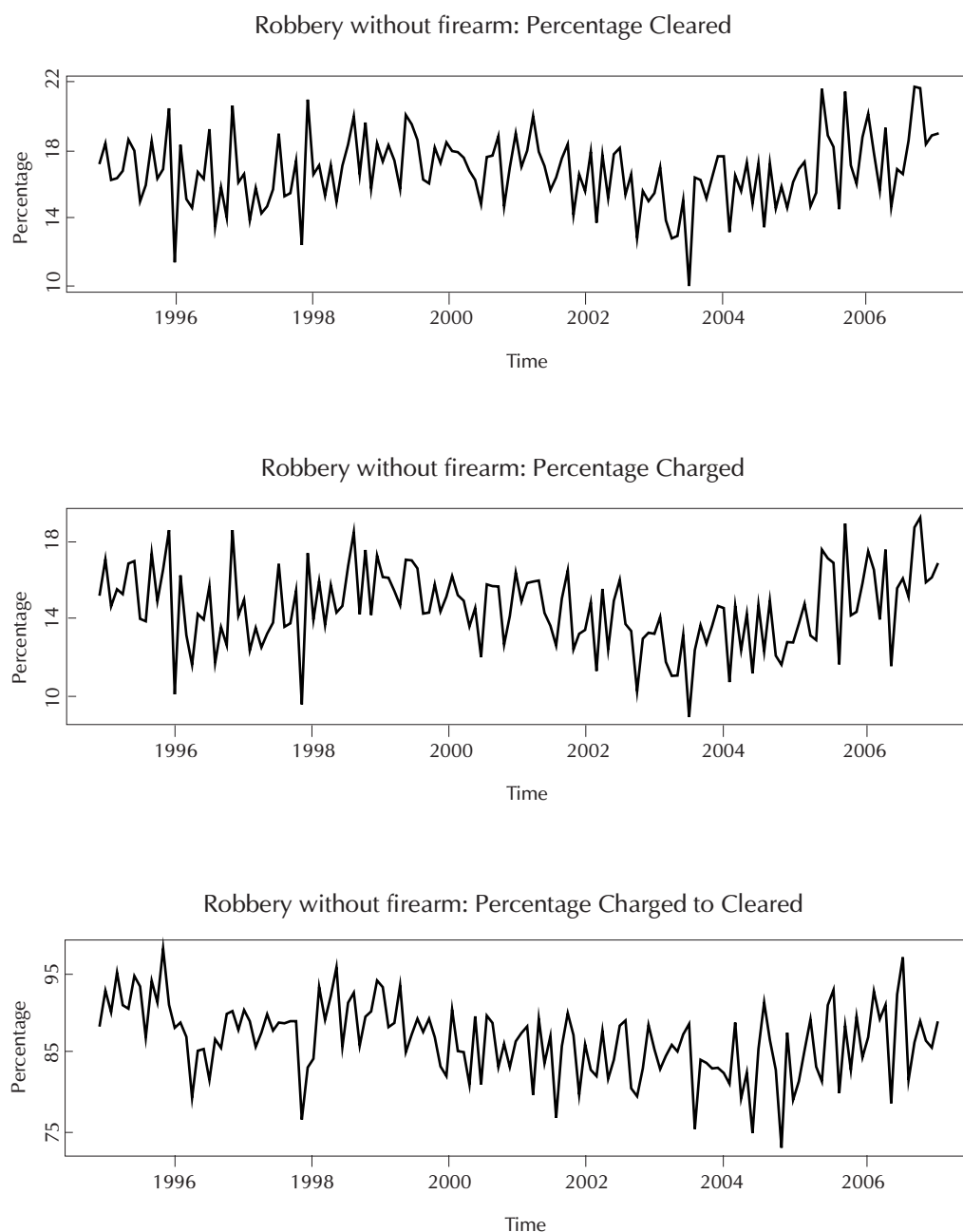
Note that there is a substantial outlier due to a temporary change in Police recording practices in July 2003. There is the possibility of seasonal patterns in the series of percent cleared which is found in the modelling. For the percentage cleared series there is an upward trend until about 2004 and thereafter a slight downward trend towards the latter part of the record and for the other two series there is a downward trend until about 2003 and thereafter a slight upward trend. There are seasonal patterns associated with summer months easily observed in the percentage cleared time series. Seasonality in the other series is not as obvious. Note also that if DNA testing has had an impact on these series it would appear to be acting in different directions.

In addition to the broad upward and downward linear trends observed there are shorter-term variations around these. These could be due to a host of factors impacting the series. In Section 4 we discuss some of the possibilities. In some cases none of the potential covariates that we selected to include in the models was significant and the variations around a linear trend were either uncorrelated or, if indicating autocorrelation, were modelled using autoregressive time series models.

Looking at Figure 5, one possible approach to modelling the underlying trend would be to represent it as a series of segments, each of which could be modelled using linear (or more complex) trend lines. In particular, the trend in the time series Percentage Charged to Cleared, would be well represented by 3 line segments joined in mid-1997, the start of 1999 and the start of 2003. Alternatively spline regressions with suitably chosen knots (times where the segments join in a smooth way) might be considered. While this general approach, if refined and appropriately implemented, could give a good characterisation of the trends in the series, the trend established might not provide a sound basis on which to assess the intervention of interest or it may be confounded with the intervention.

Figure 6 shows the time series of clear up, charge and charge to clear up rates for the crime of Robbery Without Firearm. Note that the trend patterns for this crime are more complex than a linear downward trend. After 2003 the three series show an increasing trend – this is modelled by the linear DNA term in the model.

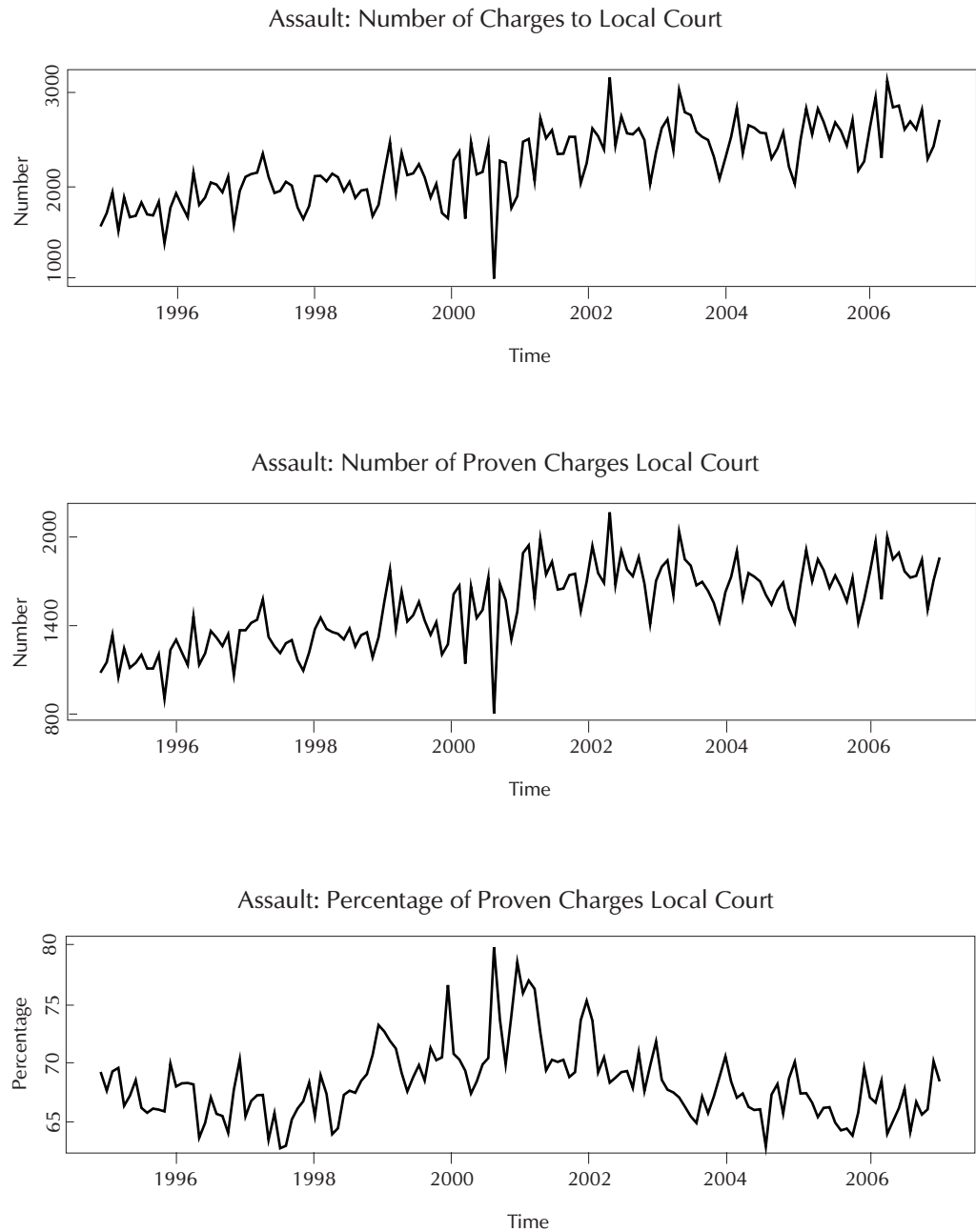
Figure 6: Robbery Without Firearm – Percentage Cleared, Charged and Charged to Cleared



3.7 SOME EXAMPLES OF CONVICTION RATE TIME SERIES

We provide an example from the Lower Court series and an example from the Higher Court series. Similar graphs for all of the court conviction time series are given in Appendix B, along with a qualitative description of their main features.

Figure 7: Assault – Numbers of Charges and Convictions in Local Courts

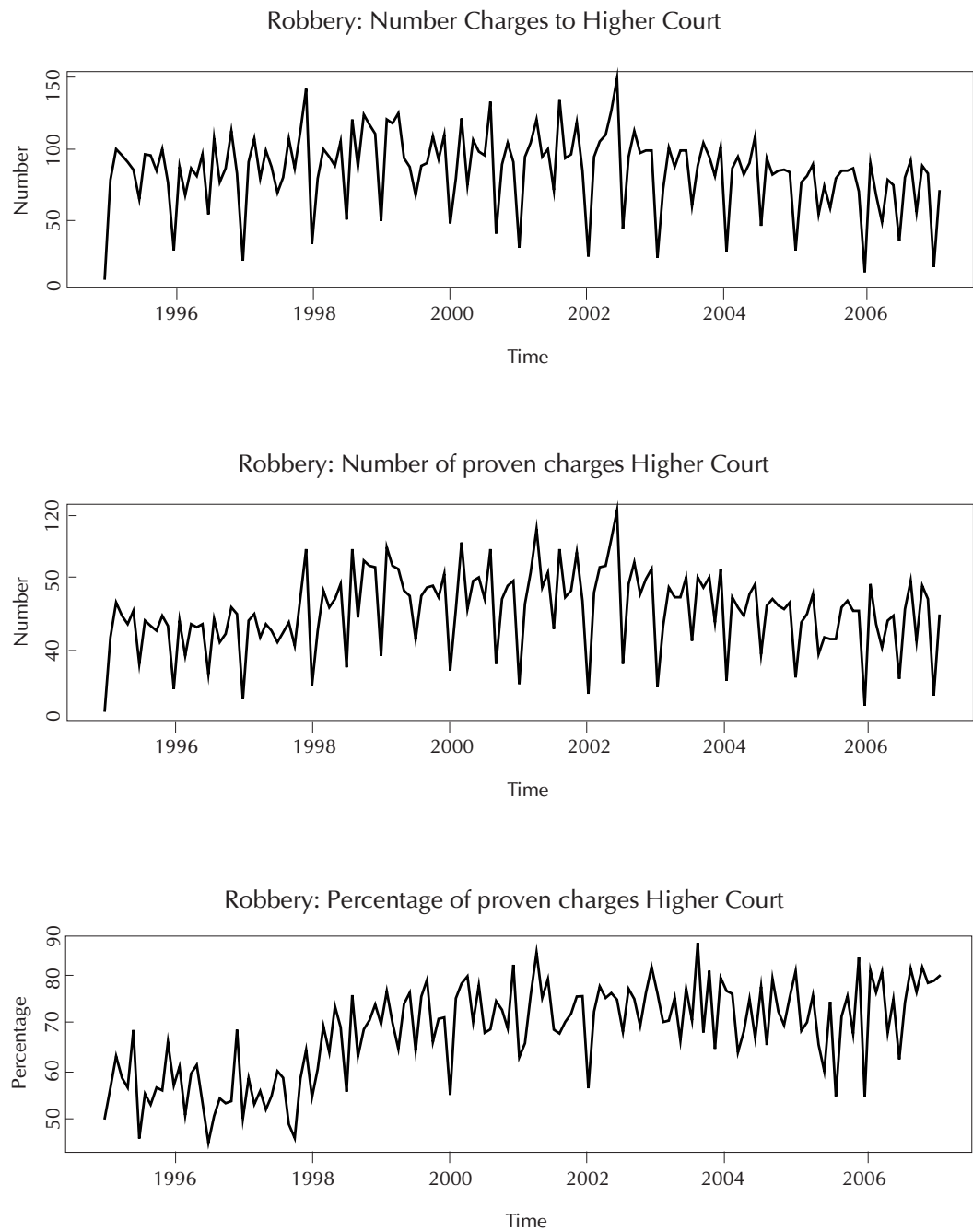


For the percentage of proven charges for Local Court shown in Figure 7, the trend patterns are complex. After 1998 there is tendency for the series to increase up to 2001 and thereafter decrease until mid 2003 when it then flattens out. If DNA testing has had an impact on this series it would be to cause a decline in percentage of proven charges, or, if the view was taken that the DNA effect was delayed until mid 2003, then its impact would appear to have been to arrest a downward trend established over the period 2001 to 2003. We have no additional information that can be relied upon to decide this issue.

Figure 8 shows the time series for the Higher Court data for the Robbery crime category. Note that the number of cases presented to the court and the number of cases successfully convicted is not very large. In some months the numbers of cases are below 10. Low to moderate counts were encountered in most of the Higher Court series and as a result the method of modelling the data differed from that for the other series from the Lower Court and from the Police Data – logistic regression for binomial observations in each month was used – see Section 5 for details.

Note that the percentage of cases convicted shows a generally flat level around 75% from 1999 onward. Any impact of DNA testing is difficult to discern from this graph.

Figure 8: Robbery – Numbers Charged and Convicted in Higher Courts



4. ISSUES IN IDENTIFYING SUITABLE CONTROL SERIES OR COVARIATES SERIES

In studies of this type, in which the impact of an intervention is being estimated, it is necessary to establish the underlying average level that the series has taken historically and the likely level it would have taken had the intervention not occurred. This provides the baseline against which the impact of the intervention is estimated.

Establishing the likely levels of the series, post intervention, would be greatly assisted by use of a control series, a series that would, all things being equal, follow levels and trends similar to the series of interest yet is free of any intervention effects. For example series from similar jurisdictions, policing and court practices such as neighbouring states are sometimes useful as control series. However such control series are not available for this study. Other Australian States cannot be used as a control series because they passed similar DNA legislation around the same time [personal communication, Mr David Raper, NSW Police]. Hence, examination of the trend levels in those States would not be free of any impacts of the intervention of DNA testing. Within NSW we are not aware of any other suitable control series for any of the clear up, charge or conviction rate series in any of the crimes being considered here.

Hence the historical data prior to intervention is all that can be relied upon to establish historical levels and trends against which the impact of the intervention can be assessed. Modelling these trends consists of two main components:

1. Broad trends such as linear or other smooth patterns through time. Options include extensions of linear trends to other smooth functions of time such as polynomials, splines and regression splines.
2. Impacts of any relevant covariates on the series, either directly or as deviations around overall trends.

Often, these two components do not fully capture the smooth behaviour of the time series and the use of models for autocorrelated time series is often required. Examples include the autoregressive time series models – see below.

We know of no literature that would provide direct guidance on suitable covariates that are temporally related to the clear up, charge and conviction rate time series of interest for this study. We have examined the recent report of Moffatt, Weatherburn and Donnelly (2005), which suggests appropriate covariates for studying the incidence of crime in various property crime categories. We review this in Subsection 4.2 below. We decided to include similar covariates in the modelling of clear up, charge and conviction rates (not numbers of incidents) but are fully aware that their use in this context has not yet been justified.

One possible covariate that could impact the capacity of the police to solve and prosecute crimes is the actual caseload the NSW Police Service faces. We discuss this possibility in the next subsection.

4.1 DOES POLICE CASE WORKLOAD INFLUENCE CLEAR UP RATES?

The advent of DNA testing is intended to make solving and prosecuting crimes easier. As a result clear up rates in particular should tend to increase as the size of the DNA database increases. Thus the police may be able to more efficiently identify a criminal at least in cases where DNA has been left. On the other hand if the number of incidents of a particular crime is increasing it might be expected that, unless police resources allocated to solving that type of crimes are increased then the clear up rate should decline.

We have not been provided with data on the temporal changes in the allocation of policing resources to the solution and prosecution of various types of crimes. Such data are likely to be unobtainable. How does the Police Service allocate resources to solving and prosecuting crimes in face of temporal variation in numbers of incidents of each type? This information might provide a way of standardising the series to remove various trends.

Since we have no data on the allocation of policing resources to solving the crimes recorded in the various categories of crimes being examined in this study it is difficult to determine the answer to this question. At best we can examine the relationship between the clear up, charge and conviction rates and the numbers of cases (crimes recorded or numbers of cases before the courts).

Appendix A also presents scatter plots of the numbers of crimes recorded against the monthly values of the three response variables in the same month (see Figures 17, 18 & 19 respectively). Obvious outliers have been removed in the graphs. Also presented with the graphs in each Figure are the Pearson correlation coefficients that provide an informal assessment of the strength of relationship between these variables within the same month. Note that no assessment of the significance of these values is presented since they are constructed from trending or autocorrelated bivariate time series.

However we can observe, at least in some of the crime types, a broad correlation between clear up rates and number of recorded incidents. In some cases this correlation is positive, which runs counter to the notion that clear up rates should decrease with increasing workload. However in many cases the correlation is negative; which is consistent with the notion that increased workloads lower clear up rates and rates of charges laid.

In view of the potential for workload to impact clear up and charge rates, we have assessed the use of numbers of recorded incidents in each category of crime separately in the regression analysis. In almost every case, despite the sometimes strong correlation indicated in Figures 17, 18 & 19 of Appendix A, the monthly numbers of recorded incidents was not a significant explanatory variable once an overall trend was included in the model.

This observation was consistent with the results of cross correlation analysis between the number of crimes reported (the input) with three output series: the percentage of crimes cleared, for which charges were laid or percentage of charges laid to cleared. Cross correlation analysis seeks to determine any significant correlations between the input series (here numbers of crimes reported) and the output series (percentage cleared etc) at different time lags. The possibility of a 'backlog' in unsolved crimes leading to a lower capacity to clear crimes reported in a particular month can be examined in this way. If

there is significant negative correlation between the clearance rate for the current month and the numbers of incidents recorded in a previous month, then this could lend support to the notion that prior caseloads lead to lower efficiency of solving current caseloads.

Overall, once the input series was pre-whitened using the methods of Box and Jenkins (1976, Chapter 11), which was typically achieved using an ARIMA (0,1,1)(0,1,1)₁₂ model, we detected no substantial or consistent support for the hypothesis that volume of crime (as measured by number of incidents recorded) in the same or preceding months was associated with clear up rate or charge rates. This was true for all categories of crimes. Thus any substantial positive or negative association observed in the marginal scatter plots of Figures 17, 18 & 19 of Appendix A are likely the result of trends in the numbers recorded and the percentages cleared or charged. Any such trends may be due to other factors that we are not aware of.

These conclusions are also supported in the court data by the obvious lack of any tendency for temporal patterns in the rate of convictions in both the Local and Higher courts to relate to the temporal patterns of the numbers of charges put before the courts – see Appendix B.

It should be noted that the above cross correlation analysis was directed at volumes of crime and clear up rates in the same category of crime. Of course, total caseload (across all crimes or across subsets of similar crimes) might be more relevant. To pursue this line of analysis would require an understanding of police procedures in allocating resources to the various categories of crime, data on which, as noted above, are not available.

4.2 OTHER POTENTIAL EXPLANATORY VARIABLES

In Moffatt, Weatherburn and Donnelly (2005) various factors that were thought to cause the drop in property crime around 2001 were assessed. Their analysis was concerned with assessing the impact of various covariates on the trends in robbery and theft incidents in NSW over the period January 1995 to September 2004. They considered the following factors:

- (Reregphar) Drug Treatment – using the series of re-registrations for pharmacotherapy for persons aged 15-34.
- (NLTU) Unemployment – using the number of 15-34 years old males unemployed for more than 52 weeks in NSW – obtained from the Australian Bureau of Statistics.
- (CSI) Consumer sentiment index (as a proxy for quarterly Average weekly earnings Australia wide).
- (PrisSentB) Trends in arrest and imprisonment – represented by aggregate prison time given for burglary offences or robbery offences being a composite measure that ‘reflects both the number of offenders imprisoned and the average sentence length’.
- (CocCh) Cocaine arrests – monthly number of police recorded incidents for cocaine use/possession.
- (OD) Monthly numbers of non-fatal heroin overdoses as a proxy measure of heroin use obtained from the NSW Department of Health.

Moving average models with coefficients at lags 1 and 2 were used to account for autocorrelation in the error terms in the linear regression models to account for omitted covariates and local behaviour of the outcome variable. The two models, one for burglary counts and the other for robbery counts, obtained good measures of fit and residuals conformed to the usual assumptions. The study concluded that:

1. In the model for recorded incidents of break and enter (dwelling) the significant factors (P-value < 0.05) were OD (at lag 3), Reregphar (at lag 4), NLTU and CSI (lag 1). PrisSentB had a P-value = 0.056. Signs of regression coefficients were in the anticipated direction.
2. In the model for recorded incidents of robbery the significant factors (P-value < 0.05) were OD (at lag 3), Reregphar (at lag 4), CocCH and CSI (lag 1). The variables PrisSentB (P-value = 0.116) and NLTU (P-value = 0.598) were not significant. Signs of regression coefficients were in the anticipated direction.

For Assault and Sexual Assault it is not obvious that these covariates would impact the number of recorded instances of these crimes. Similarly we have not seen any literature to suggest that these factors would impact on the numbers of motor vehicle related crimes. Theft from a motor vehicle, which possibly bears similarities to other property crimes, might be impacted by these variables,

This report is concerned with examining the question of the impact of DNA testing on clearance rates and conviction rates and not with absolute levels of crimes directly. The Moffatt et al (2005) report was concerned with the impact of various temporal covariates on levels of recorded crimes. The relevance of such findings for clear up, charge and conviction rate time series is not at all clear and we have seen not literature to suggest that they would be.

However, because these use the number of incidents of crimes reported in each month as a denominator, it is conceivable that they will also show dependence on the factors identified in the Moffatt et al (2005); this is likely to be more reasonable under an assumption that the numbers of crimes cleared is rather constant and more reflects policing capacity than the numbers of crimes reported. We have discussed this issue in Subsection 4.1 above.

In spite of these misgivings about the relevance of these series we assessed them in our regression modelling because they point to general factors (the economy, drug use and imprisonment) that have found to be significant in investigating time series derived from incidence of crime. It is possible that their influence on the clear up, charge or conviction rates was statistically significant. In such cases possible explanations include:

1. Any significant covariates are in fact meaningfully impacting on the rate series but in as yet not understood ways.
2. Any significant covariates, while not directly impacting on the rates might be acting as proxies for other factors that do directly impact them.

In either case, knowledge of their significance could provide stimuli for generating useful hypotheses that might be testable in future research. Some of the variables used in the above study were not available for us to incorporate in our model. The covariates that we obtained (which cover similar general areas similar to those listed above) for assessment in the modelling are:

- (Cocaine) Cocaine arrests, monthly number of police recorded incidents for cocaine use/possession
- (NFHOD) Monthly numbers of non-fatal heroin overdoses as a proxy measure of heroin use obtained from the NSW Department of
- (MaleUnem) Unemployment Male unemployment in NSW obtained from the Australian Bureau of Statistics
- (CSI) Consumer sentiment index , Westpac-Melbourne Institute consumer sentiment index obtained from the Reserve Bank of Australia
- (PrisonRate) The numbers of prisoners in NSW expressed per 100,000 people – see Figure 12.

The regression modelling indicated that some of these covariates were significant in some of the models. However there were inconsistencies across series of similar crimes as to which covariates were significant and the plausibility of the covariates that were statistically significant cannot be established. Overall a strong causal case could not be made for inclusion of the covariates and discussions with police service personnel could not suggest explanations for the significant factors obtained. In view of this we will not report in detail the results including covariates in what follows.

5. STATISTICAL MODELS AND METHODS

5.1 MODELLING LEVELS OR DIFFERENCES?

In regression modelling of time series it can be expected that we may encounter serial dependence; this can occur in the series themselves or in the residuals after regression of the response or dependent series on the covariate or independent series.

A decision has to be made between modelling the series themselves (that is on the scale of the levels of the response variable series) or to model changes in level of the series, the changes being from the current month to the last or the that 12 months prior, and in some cases a combination of seasonal and month to month changes.

Commonly, if there is substantial autocorrelation then differencing at lag 1 or at the seasonal lag 12 or both is suggested. That is the modelling of the relationship between the independent variables and the dependent variables is done on the changes in levels. If the serial dependence is not too high then use of regression on levels is usually preferred with serial dependence being modelled by stationary time series models such as autoregressions. A recent discussion of these issues relevant to modelling crime series is given in Spelman (2008).

The approach based on levels uses regression methods to relate the various factors at appropriate lag values including the DNA impact variable to the outcome series of interest. The residuals in this regression are tested for autocorrelation and, if present, appropriate terms are included in the model to adjust for these. In all cases autoregressive error models were found to adequately capture the autocorrelation effects. The alternative approach is that of transfer function modelling in which the explanatory variable series and the outcome series are assessed for cross correlation indicative of the time lags at which the regression variables are impacting the outcome variable. This approach often requires lag one differencing of the time series to achieve estimation of the cross correlation functions.

Spelman (2008) provides a useful, recent discussion of these issues in the context of specifying the relationship between crime and imprisonment using panel data. He also discusses various statistical tests that can be applied to help decide between the two approaches. In particular the Augmented Dickey-Fuller test for the existence of a unit root in the original series and the KPSS test for stationarity of residuals around a linear trend regression.

All outcome time series were assessed for the existence of a unit root using the augmented Dickey-Fuller and the Phillips-Perron test statistics. In almost all cases these tests (when an intercept or trend term was included in the model) rejected the existence of a unit root indicating that the differencing methodology was inappropriate compared with the first approach of regression modelling. The results of applying the KPSS statistic to the various series, in all but a few cases, also confirmed that the residuals around an overall linear trend were stationary. In the few cases where the tests for a unit root were significant, the stationarity of the series around a linear trend was typically not rejected giving inconsistent results, something that was also noted in Spelman (2008).

Since the evidence from applying these tests overwhelmingly pointed towards modelling the original levels it was decided to use, as the starting point at least, a regression model

with autocorrelated errors for the level series. The results of this modelling did not result in any residual time series having autocorrelation that indicated unit root or other non-stationary behaviour. Hence the outcome from modelling the level series across the board resulted in no instance where the alternative approach based on modelling the differences was justified after the fact.

There are other reasons why modelling the levels was used. One is that interpretation of results is often simpler when levels are modelled – there is no need to unwind the differencing process to determine any long-term effects of an intervention for example. A second reason relates to the Higher Court series in which the numbers of cases was sufficiently small as to lead us to using recently developed time series models for binomial counts which extend logistic regression to include serial dependence. The concept of lag 1 differences is difficult to formulate for binomial counts where the response is really a combination of the numbers of trials (here the number of charges brought to court) and the number of successes (here the number of convictions for each month). To date similar concepts to differencing for stationarity are not developed for time series of counts.

5.2 REGRESSION MODELLING OF LEVELS

To summarize, in this study, the approach we took followed these lines:

1. A linear trend was used to establish the overall trend over the whole length of the series. The linear trend variable was scaled so that its regression model coefficient was directly interpretable as the annual change in level.
2. A linear trend was added commencing at January 2001 (or at a later time point selected to minimize error of fit) to capture any impact of the growth in the numbers of released prisoners who have been DNA tested. The Linear DNA variable was also scaled so that its regression model coefficient was directly interpretable as the annual change in level.
3. Terms for seasonal factors and identified outliers.
4. Any other unexplained smooth deviations around the fitted trend modelled by autoregressive or moving average time series models (see Box and Jenkins, 1976, for details of these) whenever required.

More complex trend patterns than the linear trend used here could be considered. However, extrapolation beyond January 2001 to establish a level against which to compare any intervention effect is problematical. For example, a quadratic trend or a spline with several knots or a segmented line regression with several join points could easily be confounded with the intervention effect. More complex intervention impacts than linear could also be considered. However, the data series do not generally suggest an appropriate functional shape that these could take.

The data we seek to model are time series of percentages: percentage cleared, percentage charged, percentage convicted. For instance the time series of percentage of crimes cleared are calculated by taking the ratio of the counts of cases cleared to the counts of incidents for each category of crime in each month. These percentages are, for each month, the sample estimate of the probability that an individual crime committed will be cleared. Models with binomially distributed outcomes provide a natural way to model these percentages.. This would suggest that generalized linear models (McCullough and Nelder 1989) would be appropriate with, for example, the

logit link function. If all the crimes in a month are assumed to be independent, then this is straightforward. However here we anticipate that there will be serial dependence, in which case this will need to be accounted for in the modelling.

The theory and application of generalized linear models when there is potential serial correlation is not nearly as well developed as that for time series with normally distributed outcomes using maximum likelihood for regression with autocorrelated errors. The results are accordingly more difficult to interpret.

For many of the series under consideration, the binomial distribution can be approximated very well by the normal distribution for the percentages. This results from the substantial numbers of counts used in creating these percentages, even when the percentage itself is small or moderate.

For almost all the clear up and charge rate series, use of standard time series regression methods with normally distributed error terms was considered to be appropriate. The only exception to this was Robbery with Firearm, for which the counts were particularly small. For this series we repeated the linear regression analysis using logistic regression methods extended to allow for assessment of autocorrelation – and obtained comparable results.

For Local Court conviction rate series we also considered the numbers of cases presented monthly were sufficiently large, especially in view of the moderate to high conviction rates obtained, to allow the standard regression techniques to be used. However for Higher Court conviction rate series we analysed all of the series using extended logistic regression described below. In fact, although use of normal distribution based regression methods was not considered appropriate here, we found that the results were similar. In the remainder of this section we describe the modelling approach used to fit the time series by standard time series regression methods and then discuss the use of logistic regression.

5.2.1 LINEAR REGRESSION WITH AUTOCORRELATED RESIDUALS

For the majority of the series considered here, the denominator count used in calculating the various outcome measure percentages was sufficiently large so that we could safely assume the use of standard normal distribution theory. Overall the use of the normal distribution for the outcome variables was very reasonable – the model residuals were assessed for normality. All of the potential regression factors were initially included in the regression model, along with an overall trend variable and the DNA Impact variable. Any obvious outliers were handled by including a dummy variable in the model for that outlier. This was found to be a more reliable adjustment method than replacing the outliers by imputation based on neighbouring values.

Autocorrelation effects at the first few lags and the seasonal lag were included initially. Non-significant variables (including the autoregression terms) were removed from the model but the trend; DNA impact variable and outlier or seasonal dummy variables were retained when they were required. The model was then refit. Residuals from the final model were assessed for normality and absence of serial correlation as well as for obvious departures from heteroscedasticity.

The form of the model reported in later sections is

$$Y_t = \mu_t + W_t$$

$$\mu_t = \beta_0 + \beta_1 T_t + \beta_2 DNA_{t-L} + \beta_{SD} X_{SD,t}$$

where:

- Y_t is the value of the response variable being modelled in month $t = 1, \dots$, covering the period January 1995 to March 2007 inclusive.
- $T_t = t / 12$ is the time trend standardized to annual units where t is the month since January 1995;
- $DNA_{t-L} = \max(t - L - 73, 0)$ is the linear DNA variable standardized to annual units which represents a linear increase in effect starting with a value of 0 in January 2001 (when $t = 73$) and L is the lag effect;
- $\beta_{SD} X_{SD,t}$ represents any seasonal dummies (for months showing seasonal effects) and any dummies for outliers.
- $W_t = \sum_{j=1}^p \phi_j W_{t-j} + e_t$ is the residual variation, which is represented by an autoregression of degree, p , and the $e_t \sim N(0, \sigma^2)$ are assumed to be independent normally distributed random errors. The degree of autoregression was chosen by examining the residual autocorrelation or partial autocorrelation from the least squares regression fit, testing the significance of any such terms and checking the residual autocorrelation for the maximum likelihood fit of the above model including the autoregressive error parameters.

The model was fit with the optimal lag found by minimizing RMSE. This is equivalent to maximizing the log likelihood for the model.

5.2.2 EXTENDED LOGISTIC REGRESSION

In this method it is assumed that the number of crimes cleared in a given month Y_t is the outcome of a binomial random process in which the probability of success (i.e. clearing the crime) in that month is p_t (depending on the month through values of trends and other covariates for that month) and the number of trials in the binomial is n_t , the number of incidents recorded in that month.

Under this assumption, and under the additional assumption that the outcomes from month to month are independent, the standard way to model the probability of success, p_t , in any month is via a logistic regression on the covariates of interest. Here, given the covariates, the numbers cleared Y_t , are independent with Binomial distribution and success probability given by

$$p_t = \frac{e^{\mu_t}}{1 + e^{\mu_t}}$$

where

$$\mu_t = \beta_0 + \beta_1 T_t + \beta_2 DNA_{t-L} + \beta_{SD} X_{SD,t}$$

is as previously in the linear regression model. This is the same as modelling the logits, or log (odds) of success:

$$\log \left(\frac{p_t}{1 - p_t} \right) = \mu_t = \beta_0 + \beta_1 T_t + \beta_2 DNA_{t-L} + \beta_{SD} X_{SD,t}$$

as a linear function of the regression terms. Fitting such models is easily done using logistic regression a special case of generalized linear models (see McCullough and Nelder, 1989).

When there is likely to be dependence from month to month in the counts Y_t , extensions of the GLARMA models of Davis et al (2003) from the Poisson to the Binomial case are useful. In these models serial dependence is modelled by including past standardised deviations in the counts thus:

$$\log \left(\frac{p_t}{1 - p_t} \right) = \mu_t = \beta_0 + \beta_1 T_t + \beta_2 DNA_{t-L} + \beta_{SD} X_{SD,t} + W_t$$

where

$$W_t = \theta_1 e_{t-1} + \dots + \theta_q e_{t-q}$$

is a linear combination of past standardised or Pearson residuals

$$e_{t-j} = \frac{Y_{t-j} - n_{t-j} p_{t-j}}{\sqrt{n_{t-j} p_{t-j} (1 - p_{t-j})}}$$

We found that the lag of at most 3 was adequate for all the series considered.

6. ANALYSIS OF POLICE DATA ON CLEAR UP AND CHARGES LAID RATES

In this section we address the question: Is the introduction of DNA testing associated with an increase in:

1. the crime clear-up rate and, if so, for which crime categories have the clear-up rates increased?;
2. the ratio of charges laid to crimes reported and, if so, for which categories of crime?; and,
3. the ratio of charges laid to crimes cleared and, if so, for which categories of crime?.

The three response variables relevant to the objectives of this study are:

Clear-up rate – Percentage of reported incidents that are cleared within 180 days.

Charge rate – Percentage of recorded incidents that for which charges are laid within 180 days.

Charge to Clear-up rate – Percentage of charges laid within 180 days to numbers cleared within 180 days. This is equivalent to the ratio, expressed as a percentage, of the Percentage of Legal Proceedings to Percentage Cleared.

Appendix A presents graphs of the monthly time series for each crime category over the period January 1995 to March 2007 of:

- Number of incidents recorded, number of incidents cleared within 180 days and number of incidents for which charges are laid within 180 days.
- Clear-up rate, Charge rate and Charge to Clear-up rate.

Appendix A also contains a brief summary of the main features of each of the above series separately for each category of crime. A review of that material indicates that overall trends are often complex, any response to the intervention may be delayed and in some case may be in the opposite direction to that anticipated leading to a reduction in these series of clear up and charge rates or a slowing of a general upward trend, there may be seasonal effects and outliers to deal with in the modelling, and, there is the possibility of the impact of other covariates or autocovariance due to omitted covariates.

6.1 CLEAR-UP RATE

6.1.1 OVERALL REGRESSION MODEL RESULTS

In this section we summarize the results of fitting the regression models defined in Subsection 5.2 to the time series of the Clear-up rate for each category or crime.

Table 1 gives an overall summary of the results pertaining to the impact of the linear DNA term in models that include the linear trend, the linear DNA term, any outliers and seasonal factors as well as any autoregressive models required for serial correlation in the model residuals. The columns in Table 1 are:

Column 1: Crime Category

Column 2: Lag at which linear DNA term is set in the model.

Column 3: Regression coefficient of the Linear DNA term and 95% confidence interval

Column 4: List of seasonal and outlier model terms found to be significant; if trend prior to impact of Linear DNA term is not significant this is noted.

Column 5: The root mean square error of the residuals in the model (or innovations in the case of autoregression models.)

Column 6: Total R-squared (which includes the contribution from autoregression effects).

Column 7: Degree of autoregression model fit.

Table 1: Summary of model results for Clear-up rate

<i>Crime Category</i>	<i>DNA Term Lag</i>	<i>DNA Term</i>	<i>Other Model Terms</i>	<i>RMSE</i>	<i>R-Sq Total</i>	<i>AR degree</i>
Assault	45	-0.90 [-1.57, -0.22]	Outlier: July 2003 Seasonals: Dec, Jan, Feb	0.82	77%	3
Sexual Assault	18	4.15 [3.25, 5.05]		4.55	88%	0
Robbery with Firearm	56	6.99 [3.56, 10.43]		6.63	15%	0
Robbery without Firearm	47	1.21 [0.63, 1.79]	Outlier: July 2003 Trend Not Significant	1.91	17%	0
Break and Enter Dwelling	29	0.39 [0.20, 0.57]	Trend Not Significant	0.52	50%	3
Break and Enter Non-Dwelling	7	0.50 [0.30, 0.69]		0.73	30%	2
Motor Theft	1	-0.64 [-0.74, -0.54]		0.55	61%	0
Stealing from MV	-	NS	Outlier: April 1995	0.38	61%	2

Figure 9 contains monthly time series graphs of the observed clearance rates for each category of crime along with fitted regression lines. For some of the crimes there are two fitted lines: the first corresponds to the fixed effects component of the model (i.e. the regression terms) and the second corresponds to the fixed effects plus the autoregression model effects when this is significant.

Notes on results in Table 1:

1. Other than for Stealing from MV, the P-values associated with the DNA terms are less than 0.01 and in many cases are substantially smaller than that. The 95% confidence interval for the significant Linear DNA terms is well clear of zero.
2. The trends prior to the onset of the linear DNA term are statistically significant in all cases except Robbery Without Firearm and Break and Enter Dwelling.
3. In cases where an autoregressive model was required to account for residual autocorrelation, the model was well within the stationarity region for the autoregressive parameters.

4. The degree of fit as measured by R-Sq Total is very high in some cases, especially in view of the simplicity of the regression model used. However in some cases the variability explained by the model is quite low – for example for the two categories of Robbery.
5. The optimal lag for the linear DNA term varies substantially across the crime categories. However as discussed below, there is considerable uncertainty in determining the lag.
6. Inclusion of the covariates discussed earlier in the report does not improve model fit except for the Robbery Without Firearm category. For this crime, the Cocaine Arrest series (with a positive coefficient) and Male Unemployment (with a negative coefficient) were significant. When these were included in the model, the optimal lag shortened to 43 months and the Linear DNA coefficient increased from 1.15 to 1.59, indicating an even stronger impact. Model fit improved with a total R-Square value increasing from 17% to 29%.

Figure 9 provides time series graphs of monthly clearance rates for eight categories of crime. Also shown (in grey) is the fitted regression model consisting of any significant trends, Linear DNA term, seasonal factors and outliers. When the residuals are autocorrelated, an extra (black) line is shown on the graphs, which shows the additional variation captured by the fitted autoregressive model.

There are four types of trend patterns observable in Figure 9:

1. An upward trend followed by downward trend, associated with the linear DNA component: Assault and Motor Theft. In these cases the linear DNA component is associated with a lowering of clearance rates relative to previously established trends.
2. A downward trend followed by a positive impact of the linear DNA component: Sexual Assault, Robbery with Firearm, Break and Enter non-Dwelling. In these cases the linear DNA component is associated with an improvement in clearance rates relative to previously established trends.
3. No prior trend (i.e. clearance rates were constant on average, followed by an upward trend associated with the linear DNA component: Robbery Without Firearm, Break and Enter Dwelling. In these cases the linear DNA component is associated with a positive impact on clearance rates.
4. A downward trend with no significant impact of DNA: Stealing from MV.

Table 2 gives 95% confidence intervals on the lag at which the Linear DNA term is estimated to act at. The determination of the optimal lag was achieved by minimizing the residual mean square. This is equivalent to maximising the likelihood function and hence minimizing the Akaike information criterion, since the number of parameters was the same across all lags. Confidence intervals on the optimal lag were constructed by finding the values of lags at which the maximised log-likelihood was reduced by an amount sufficient to give 95% coverage, based on the Chi-squared distribution with 1 degree of freedom.

Figure 9: Model fits to Clear-up rates for eight crimes

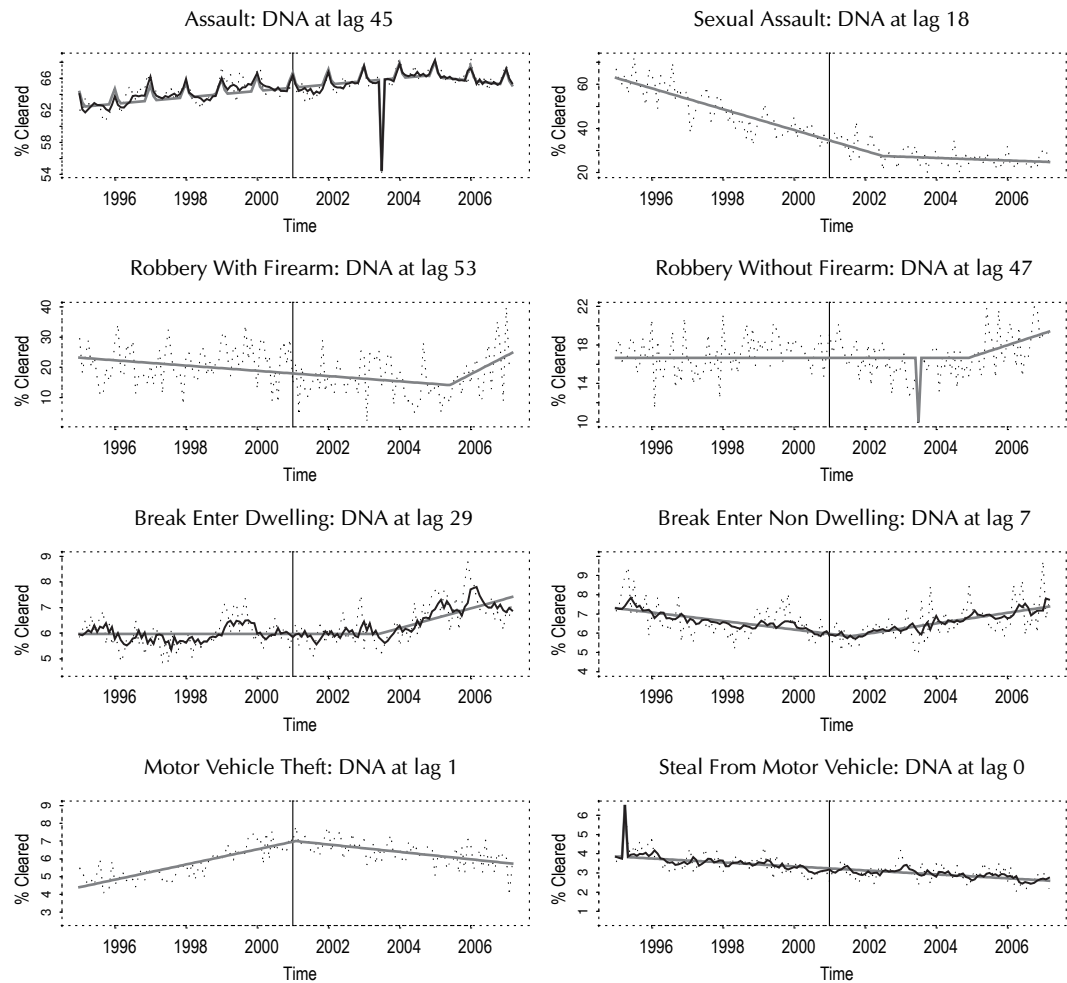


Table 2: Confidence intervals (95%) on lag at which Linear DNA is estimated to take effect on Clear-up rates

<i>Crime Category</i>	<i>DNA Term Lag</i>	<i>95% Confidence Interval on Lag</i>
Assault	45	Indefinite (likelihood very flat)
Sexual Assault	18	[1,28]
Robbery with Firearm	56	[47, 65]
Robbery without Firearm	47	[36, 60]
Break and Enter Dwelling	29	[4, 34]
Break and Enter Non-Dwelling	7	[-2,21]
Motor Theft	1	[-3,10]
Stealing from MV	-	NA

6.1.2 ADDITIONAL COMMENTS ON SPECIFIC CRIMES

Sexual Assault

The linear DNA model term captures the noticeable change in downward trend prior to 2001. The explanation for the downward trend in the clear-up rate for sexual assault is unclear. The change in this trend around the time at which DNA testing is introduced, however, may be a natural levelling off in the clear up rate rather than a result of the introduction of DNA testing.

Robbery with Firearm

The optimized lag for the linear DNA term is rather long at 56 months and this may be implausible. At this lag the linear DNA term is significant and positive and the prior trend is also significant.

The results presented in Table 1 above and in Appendix A.2 are obtained using ordinary least squares regression. Since the number of incidents recorded is quite small, particularly towards the end of the series, logistic regression, which is more appropriate in these circumstances, was also tried. In view of the potential for serial dependence we repeated the analysis using extended logistic regression based on GLARMA models of Davis et al (2003) for binomial count series. When the linear DNA effect is included at a lag of 56 months it is significant and positive and the conclusions from the least squares regression discussed above are confirmed using logistic regression.

Stealing from MV

A very large positive outlier in April 1995 has been adjusted for in this analysis – no explanation has been found for this outlier but it was removed in order to lessen its influence, which would serve to make the trend prior to 2001 even more negative.

6.1.3 IMPACT OF LINEAR DNA TERM ON CLEAR-UP RATES

Table 3 provides an overall summary of the trend prior to any impact of the Linear DNA term in the model, the level of Clearance Rate at the optimal lag for inclusion of the Linear DNA term (that is the base from which any impact of the linear DNA term can be assessed) and the impact in annual increase in Percent Cleared. For example, for Break and Enter Dwelling the optimal lag is 29 months after January 2001, which corresponds to June 2003. At June 2003 the average monthly clearance rate estimated using the fitted regression model is 6.0%. There is no trend in the clearance rate prior to this time. From that point onwards there is an increasing upward trend in Clearance Rate equivalent to an additional 0.39% per year – after 1 year the Clearance Rate is estimated to be 6.39%, after 2 years to be 6.78% and so on.

As a second example consider Sexual Assault. The optimal lag for the impact of the Linear DNA term is estimated to be 18 months, at July 2002 (18 months after January 2001) the estimated Clearance rate is 27.5%, prior to which the Clearance Rates reduced by 4.72% per annum and after July 2002 the Clearance Rate increased by 4.15% per annum. The net effect is that after July 2002 the previous downward trend of 4.72% decrease per annum remains slightly negative at 0.57% decrease per annum.

Table 3: Impact of Linear DNA variable on Clear-up rates

<i>Crime</i>	<i>DNA Term Lag (months)</i>	<i>Clearance rate at change point</i>	<i>Annual Trend prior to change point</i>	<i>Annual DNA impact</i>	<i>Annual Trend post change</i>
Assault	45	66.30%	0.40%	-0.90%	-0.50%
Sexual Assault	18	27.50%	-4.72%	4.15%	-0.57%
Robbery with Firearm	56	14.10%	-0.87%	6.99%	6.11%
Robbery without Firearm	47	16.70%	0	1.21%	1.21%
Break and Enter Dwelling	29	6.00%	0	0.39%	0.39%
Break and Enter Non-Dwelling	7	5.80%	-0.22%	0.50%	0.28%
Motor Theft	1	7.00%	0.43%	-0.64%	-0.21%
Stealing from MV	-	3.20%	-0.10%	-	-0.10%

6.2 CHARGE RATE

6.2.1 OVERALL REGRESSION MODEL RESULTS

Summary results are given in Table 4 using the same format as Table 1. In particular:

1. The trends prior to the onset of the linear DNA term are statistically significant.
2. In cases where an autoregressive model was required to account for residual autocorrelation the model was well within the stationarity region for the autoregressive parameters.
3. The degree of fit, as measured by R-Sq Total, is very high in some cases, especially in view of the simplicity of the regression model used. However in some cases the variability explained by the model is quite low – for example for the two categories of Robbery.
4. A negative outlier in July 2003 (due to a temporary change in police recording of crimes) which impacted the Assault, Robbery without Firearm, Motor Theft and Stealing from MV series. A substantial positive outlier in April 1995 was also modelled for the Stealing from MV series. These outliers can contribute a reasonable amount of the overall R-Squared measure of fit.
5. Seasonal factors for the increase in clearance rates in the months of December, January and February for the Assault series were also included. No other series demonstrated significant seasonal patterns.
6. All P-values are less than 0.0005 except for Stealing from MV with P-value = 0.047 and Break and Enter Non-dwelling with P-value = 0.0006. The 95% confidence intervals for the significant Linear DNA terms reflect these P-values.
7. The optimal lag for the linear DNA term varies substantially across the crime categories. However, as discussed previously in relation to Percent Charges Cleared there is considerable uncertainty in determining the lag.
8. Inclusion of the covariates discussed earlier in the report does not improve model fit for Sexual Assault, Robbery with Firearm, Motor Theft and Stealing from MV. For Assault, inclusion of the Male Unemployment series as a covariate shortens the optimal lag from 27 months to 25 months and increases the Linear DNA coefficient

from 1.64 to 1.78, with a slight improvement in statistical fit. For Robbery without Firearm, inclusion of the Cocaine Arrest and Male Unemployment series shortens the optimal lag from 45 to 41 with a slight reduction of the Linear DNA coefficient from 1.85 to 1.82 and a slight improvement in statistical fit. For Break and Enter Dwelling, inclusion of the Prison Rate series lengthens the optimal lag from 30 to 36 months, with an associated lowering of the Linear DNA coefficient from 0.40 to 0.24 and a slight improvement in fit. For Break and Enter non-Dwelling, inclusion of the Prison Rate and Male Unemployment reduces the optimal lag from 10 months to 0 months with a slight lowering of the Linear DNA coefficient from 0.47 to 0.45. When covariates are included, the need for autoregressive error terms is reduced or eliminated. While inclusion of covariates has some impact on model fit, their impact on the size of the linear DNA term is quite modest. It remains to establish the plausibility of these covariates.

Table 4: Summary of model results for Charge rate

<i>Crime Category</i>	<i>DNA Term Lag</i>	<i>DNA Term</i>	<i>Other Model Terms</i>	<i>RMSE</i>	<i>R-Sq Total</i>	<i>AR degree</i>
Assault	27	1.67 [1.13, 2.21]	Outlier: July 2003 Seasonals: Dec, Jan, Feb.	0.9	92%	2
Sexual Assault	19	4.83 [3.93, 5.73]		4.51	87%	0
Robbery with Firearm	54	8.09 [4.71, 11.47]		6.15	18%	0
Robbery without Firearm	46	2 [1.23, 2.77]	Outlier: July 2003	1.79	26%	2
Break and Enter Dwelling	30	0.41 [0.18, 0.65]		0.49	36%	3
Break and Enter Non-Dwelling	10	0.47 [0.29, 0.65]		0.67	36%	2
Motor Theft	1	-0.56 [-0.65, -0.47]	Outlier: July 2003	0.49	51%	0
Stealing from MV	0	0.09 [0.00, 0.18]	Outliers: July 2003 Apr-1995	0.35	68%	1

Figure 10: Model fits to Charge rate for eight crime categories

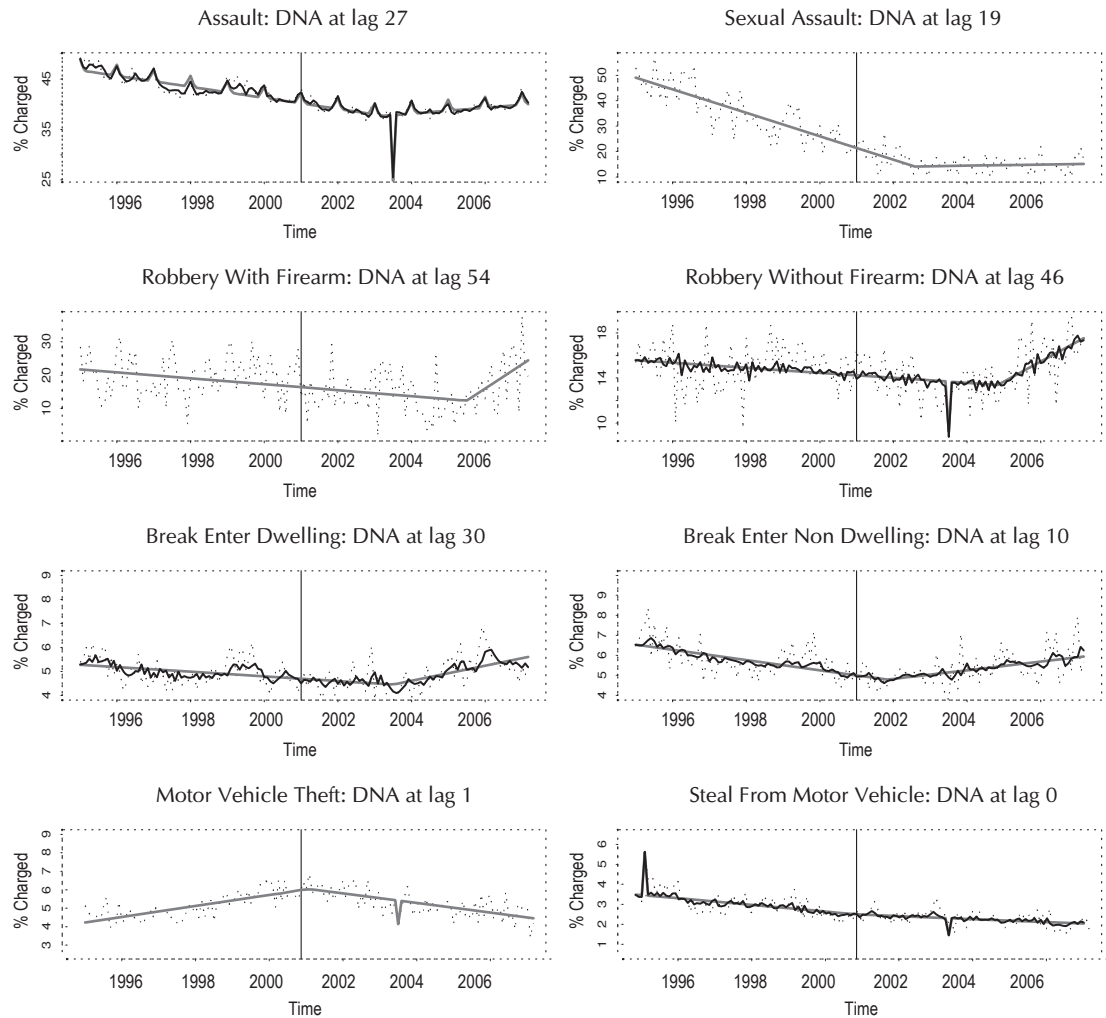


Figure 10 shows the monthly series of Charge rates in eight categories of crime along with the regression model fits. The types of trend patterns observable in Figure 10 are:

1. A downward trend followed by a positive impact of the linear DNA component for all categories of crime except for Motor Vehicle Theft. In these cases the linear DNA component is associated with an improvement in clearance rates relative to previously established downward trends, with the net result being a positive trend after the optimal change point in the first six cases and a negative trend for Motor Vehicle Theft but with a slower rate of decline.
2. For Motor Vehicle Theft the initial upward trend is reversed with the inclusion of the Linear DNA term in the model resulting in a decline in Charge rates post intervention of this crime.

6.2.2 ADDITIONAL SPECIFIC COMMENTS FOR PARTICULAR CRIMES

Assault

Compared to the series for percentage of Assault charges that are cleared, the initial trend for percentage Charges laid is negative and the linear DNA effect is now positive at an optimised lag of 25.

We can note from Figure 10 that the major change in trend appears to commence around the time of the very large outlier in July 2003, a time at which there was a change in police recording practice – the possibility that the observed impact of the linear DNA term in model being actually an artefact of some other change in the process needs to be considered.

Sexual Assault

The average level at which the prior downward trend is stabilised is around 15% and, as noted in the subsection on clear up rates for this crime, this may be a natural buffer below which it is unlikely the charge rate for this crime would fall regardless of other factors in play; in that case DNA cannot be assumed to responsible for all of the change in trend.

Robbery With Firearm

When logistic regression is used to fit the model the results reported above are confirmed.

6.2.3 IMPACT OF LINEAR DNA TERM ON CHARGE RATES

The impact of inclusion of the linear DNA term in the regression model on Charge rates is summarized in Table 5.

Table 5: Impact of linear DNA term on Charge rates

<i>Crime</i>	<i>DNA Term Lag (months)</i>	<i>Charge rate at change point</i>	<i>Annual Trend prior to change point</i>	<i>Annual DNA impact</i>	<i>Annual Trend post change</i>
Assault	27	37.70%	-1.09%	1.67%	0.58%
Sexual Assault	19	14.10%	-4.61%	4.83%	0.22%
Robbery with Firearm	54	12.40%	-0.89%	8.09%	7.20%
Robbery without Firearm	46	13.40%	-0.22%	2.00%	1.78%
Break and Enter Dwelling	30	4.40%	-0.10%	0.41%	0.31%
Break and Enter Non-Dwelling	10	4.80%	-0.26%	0.47%	0.22%
Motor Theft	1	6.00%	0.30%	-0.56%	-0.26%
Stealing from MV	0	2.50%	-0.17%	0.09%	-0.07%

6.3 CHARGE TO CLEAR-UP RATES

6.3.1 OVERALL REGRESSION RESULTS

A summary of the key features of the models fit is presented in Table 6.

In particular:

1. Outliers that were significant were
 - a. A negative outlier in July 2003 (due to a temporary change in police recording of crimes), which impacted the Assault, Motor Theft and Stealing from MV series. A substantial positive outlier in April 1995 was also modelled for the Stealing from MV series.
 - b. Outliers corresponding to a substantial drop in the Robbery with Firearm series in August and October 2004 in the least squares regression analysis. When logistic regression is used these are no longer influential and results with and without them included are very similar.
2. Seasonal factors for the increase in clearance rates in the months of January and February for the Assault series were also included. No other series demonstrated significant seasonal patterns.
3. All P-values are less than 0.00005 except for Break and Enter Non-dwelling with P-value = 0.0041 and Motor Theft with P-value = 0.0003. The 95% confidence intervals for the significant Linear DNA terms reflect these P-values.
4. The trends prior to the onset of the linear DNA term are statistically significant in all cases.
5. In cases where an autoregressive model was required to account for residual autocorrelation the model was well within the stationarity region for the autoregressive parameters.

Table 6: Summary of model results for Charge to Clear-up rates

<i>Crime Category</i>	<i>DNA Term Lag</i>	<i>DNA Term</i>	<i>Other Model Terms</i>	<i>RMSE</i>	<i>R-Sq Total</i>	<i>AR degree</i>
Assault	21	3.27 [1.98, 4.56]	Outlier: July 2003 Seasonals: Dec, Jan.	1.03	97%	2
Sexual Assault	25	4.98 [3.11, 6.86]		6.75	61%	1
Robbery with Firearm (Logistic Regression)	0	0.266 [0.065, 0.4665]		NA	NA	0
Robbery without Firearm	41	3.19 [1.91, 4.47]		4.02	23%	0
Break and Enter Dwelling	39	3.46 [2.56, 4.37]		2.62	80%	1
Break and Enter Non-Dwelling	31	1.37 [0.43, 2.30]		3.06	53%	1
Motor Theft	42	1.54 [0.70, 2.38]	Outlier: July 2003	2.61	79%	0
Stealing from MV	0	NS	Outlier: July 2003	3.4	61%	1

6. The degree of fit as measured by R-Sq Total is very high in some cases especially in view of the simplicity of the regression model used. However in some cases the variability explained by the model is quite low – for example for the two categories of Robbery.
7. The optimal lag for the linear DNA term varies substantially across the crime categories. However the lags for all but the last category of Stealing from MV range from 21 months to 42 months, which is a narrower range of lags observed for Percent Cleared and Percent Charged.
8. None of the covariate series considered were significant apart from the case of Sexual Assault, where inclusion of Male Unemployment (with a negative coefficient) and non Fatal Heroin Overdose series (with a positive sign) resulted in a slight shortening of the optimal lag from 25 months to 23 months and a reduction in the Linear DNA coefficient from 6.85 to 5.68, with a slight improvement in model fit.

6.3.2 IMPACT OF LINEAR DNA TERM ON CHARGE TO CLEAR-UP RATES

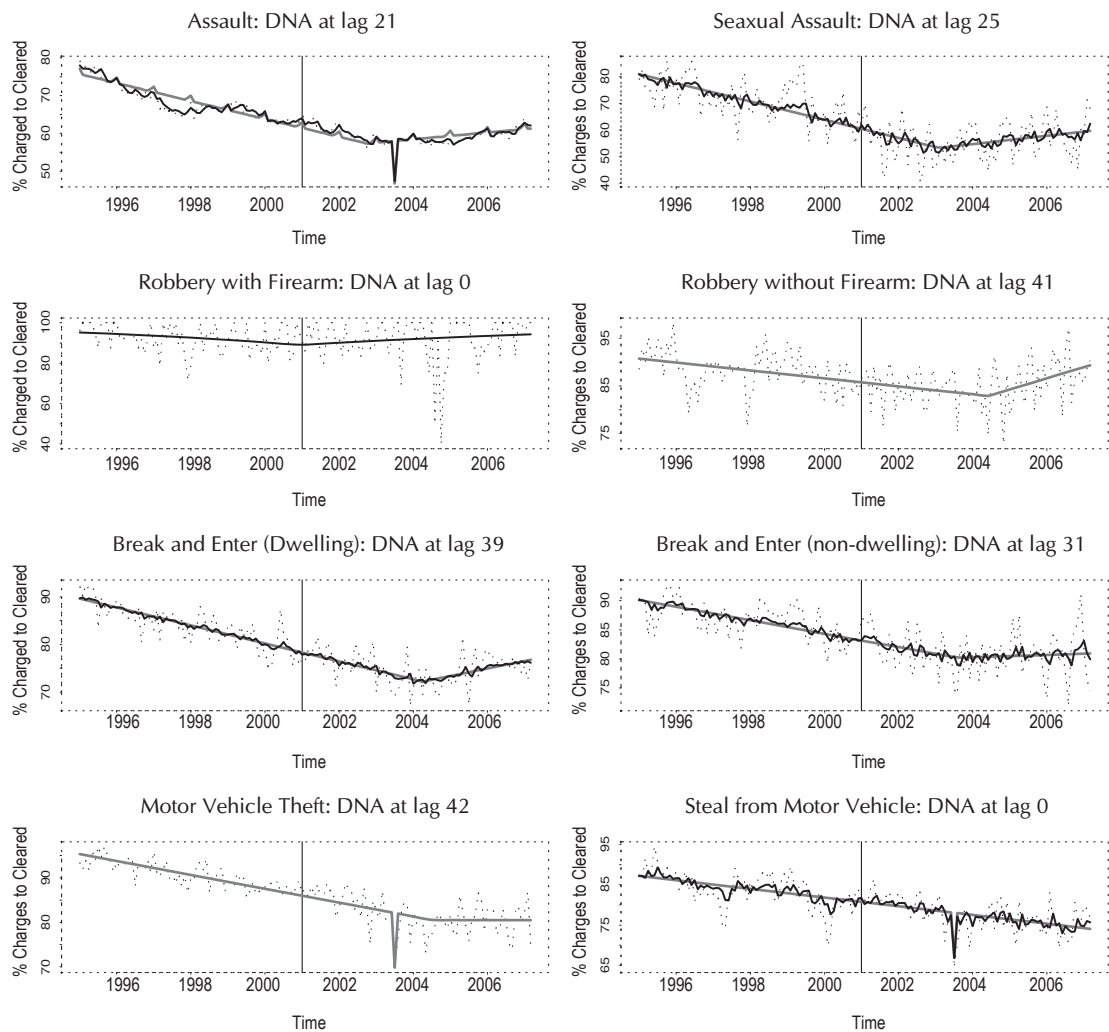
The overall impression from the results in Table 6 and Figure 11 is that there is considerably more similarity across the categories of crime in the effect of the linear DNA term in the model than in the results for clear up rates and charge rates.

In all cases (apart from the Robbery with Firearm crime in which the numbers are small) there is a downward trend in the ratio of charges laid to incidents cleared and the linear DNA effect is either not significant or, when significant, leads to an arrest or reversal of the previous downward trend. Optimised lags at which this occurs vary across the crimes but roughly indicate a two to four year lag is in effect. For Robbery with Firearm, where many of the percentages are 100%, we also used logistic regression in place of the least squares method. When the linear DNA term is included at lag 0 there is a significant downward trend for the first half of the series with a coefficient (on the logit scale) of -0.152 ($P=0.007$) and the linear DNA term is positive with a coefficient of 0.266 ($P=0.009$). When the outliers noted in the least squares regression (August and October 2004) are excluded these logistic regression results are scarcely altered with the trend unchanged and the linear DNA coefficient increasing to 0.293 ($P=0.005$). These results are consistent with the results for the other categories of crime.

Table 7: Impact of linear DNA term on Charge to Clear-up rates

<i>Crime</i>	<i>DNA Term Lag (months)</i>	<i>Charge to Cleared rate at change point</i>	<i>Annual Trend prior to change point</i>	<i>Annual DNA impact</i>	<i>Annual Trend post change</i>
Assault	21	57.30%	-2.37%	3.27%	0.9
Sexual Assault	25	53.30%	-3.43%	4.98%	1.55
Robbery with Firearm (logistic)	0	89.10%	-0.152	0.266	0.114
Robbery without Firearm	41	82.90%	-0.84%	3.19%	2.35
Break and Enter Dwelling	39	72.20%	-1.89%	3.46%	1.58
Break and Enter Non-Dwelling	31	80.20%	-1.16%	1.37%	0.21
Motor Theft	42	80.50%	-1.56%	1.54%	-0.02
Stealing from MV	0	80.70%	-1.08%	0%	-1.08%

Figure 11: Model Fits to Percentage Charged to Cleared for eight crime categories



The reasonable consistency of the results across all of the crime categories seen for this outcome measure (and not seen for the previous two outcome measures of Clear-up rate and Charge rate) may suggest that there is an unaccounted for factor in prosecution practice impacting all crimes in a similar way that has resulted in the trend changes observed. Any such factor could be confounded with the linear DNA factor, in which case it is would be difficult to conclude that implementation of DNA testing in 2001 caused the observed change in downward trend in prosecution rates (as measured by charges laid to incidents cleared).

7. ANALYSIS OF CONVICTIONS IN LOCAL AND HIGHER COURTS

In this section we address the question: “Has DNA testing increased the proportion of charges laid that result in convictions and if so, for which categories of crime?”

Monthly counts of charges laid and convictions made in Local Courts and Higher Courts are used to calculate percentage convictions for each month. There are seven selected ASOC Categories of crime:

- assault
- sexual assault
- robbery
- unlawful entry with intent/burglary
- break and enter
- motor vehicle and related offences
- theft (except motor vehicle) and other.

Thus, in total, we will examine fourteen time series of percentage of convictions in this analysis.

Appendix B contains graphs of the numbers of charge brought before the Local and the Higher courts in each category of crime, the numbers of convictions and the percentage convicted. Appendix B also contains a discussion of the qualitative features of the series such as trends and other notable features. Initial analysis showed that in for Assault and Sexual Assault convictions in the Local Courts there appeared to be an anomaly for September 2000 associated with the Olympics and a model term was included to account for this.

7.1 RESULTS FOR LOCAL COURT CONVICTION RATES

7.1.1 SUMMARY OF REGRESSION MODELLING RESULTS FOR LC CONVICTION RATES

A summary of the regression modelling results LC Conviction rates for the six categories of crime is given in Table 8.

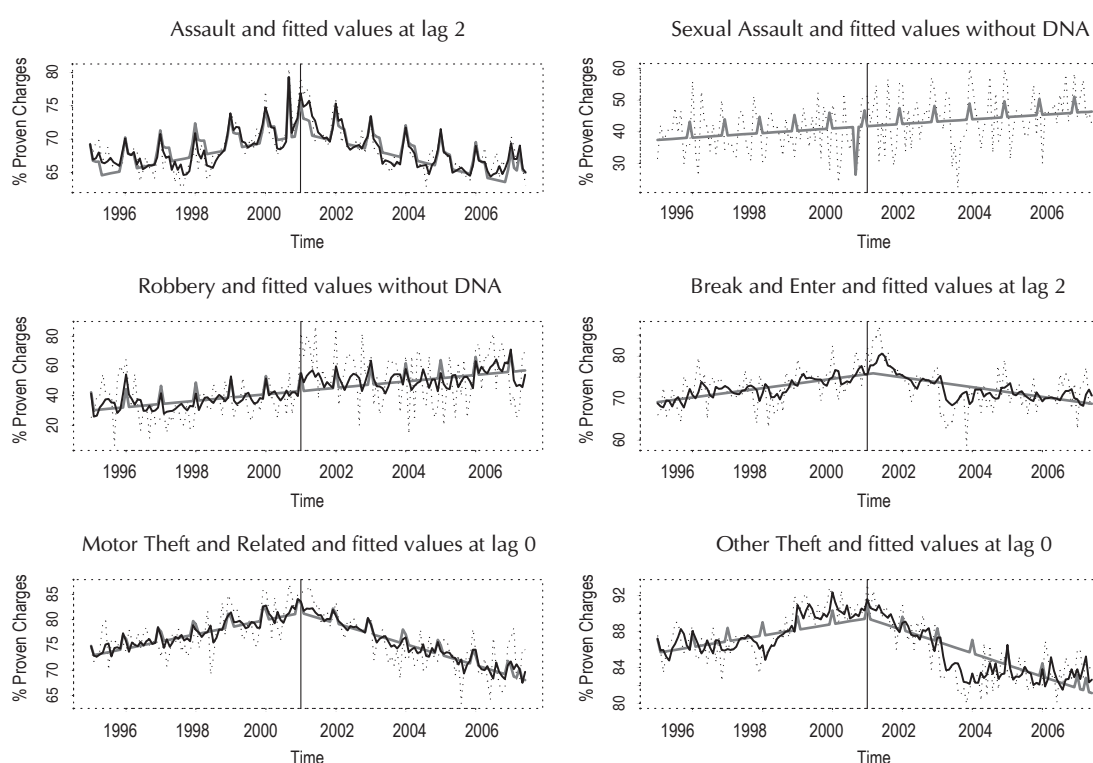
Table 8: Summary of model results for LC Conviction rates

<i>Crime Category</i>	<i>DNA Term Lag</i>	<i>DNA Term</i>	<i>Other Model Terms</i>	<i>RMSE</i>	<i>R-Sqd Total</i>	<i>AR degree</i>
Assault	2	-2.32	Olympic Month Seasonals for: Dec, Jan, Feb, Mar, Apr	1.5	80%	3
Sexual Assault	-	NS	Olympic Month Seasonal: Dec.	7.72	13%	2
Robbery	-	NS	Seasonal: Jan	15.42	28%	2
Break and Enter	2	-2.27		3.92	32%	2
Motor Theft and Related	0	-3.47	Seasonals: Jan, Dec.	3.14	59%	1
Other Theft	0	-1.93	Seasonal: Jan.	1.7	73%	2

Figure 12 shows the monthly conviction rates for the six categories of crimes along with the fixed effects and the autoregressive error component.

Rather than give a detailed summary of the regression model results for each category of crime we will discuss the group of four crimes consisting of Assault, Break and Enter, Motor Theft and Other Theft – these show similar trend patterns over time. Results for Sexual Assault and Robbery will be discussed individually.

Figure 12: Monthly Convictions in Lower Courts with Fitted Values



7.1.2 ASSAULT, BREAK AND ENTER, MOTOR THEFT AND OTHER THEFT

The time series for these four categories, although unrelated, show very similar trend patterns and can all be broadly characterized as an initial upward trend to around 2001, then a decline to around 2004 and then a flattening out thereafter.

The model results for the linear DNA term use this term as a way of capturing the downward trend after 2001. However because of the flattening out around 2004 this does not provide a good representation of the overall trend pattern and, since none of the available covariates capture this either, the model residuals are positively correlated and require autoregressive models to adequately account for the deviations from trend (consisting of the upward trend to 2001 and then a downward trend thereafter. Not surprisingly (in view of the time series graphs) the optimization of the linear DNA term lag does not result in much change from the zero lag.

In summary, for these four crimes the Linear DNA term has a negative coefficient suggesting that, if DNA testing is the cause of this change in trend, its influence started soon after its introduction and it had a negative effect. This seems inherently implausible. It is more likely that some other factor or factors unknown to us is impacting these four series. It is, regardless, not possible to conclude that DNA testing has had a positive association on conviction rates in the Local Courts for these four crimes.

7.1.3 SEXUAL ASSAULT

The Local Court conviction rate for this crime appears to be trending upward over the whole period and the linear DNA term is not significant in any analysis performed. Covariates do not improve the model, nor is serial dependence in regression residuals noted. The fit of the linear trend model is very poor with a low R-squared. However no obvious deviations in level of this series from this overall upward linear trend are obvious to the eye (or through analysis of residual autocovariances).

In summary, any impact of DNA testing on Local Court convictions for the crime of Sexual Assault has not been detected by our analysis. Given the level of month-to-month variability in this series any such impact will be difficult to detect.

7.1.4 ROBBERY

The numbers of cases sent to court for this crime are rather lower than for the other categories and, in view of this, we repeated the analysis presented in the above table using logistic regression. The results for Robbery noted above are confirmed when logistic regression is used – the coefficient of the linear DNA variable (on the logit scale) is -0.114 ($P=0.023$). Consequently we will rely on the results for time series regression as presented above.

The trend in this series has some similarities to the group of four crimes considered earlier but is rather more complex. The rise in 2001 is modelled by the Cocaine variable (with a positive sign) and the heroin variable NFHOD (with a negative sign). It is not clear to us whether the significance of these variables has any meaning whatsoever other than chance association. When they are included in the model, the Linear DNA term is significant but negative at the optimised lag 17. However when the two drug use related covariates are excluded from the model, autoregressive terms are required to model

the serial dependence in the residuals and the linear DNA term is no longer significant, indicating it plays no part in modifying the overall trend.

The local level for this Robbery series has complex behaviour, which is not well captured by the regression model, and this is reflected in the low R-squared values.

7.2 PERCENTAGE OF CONVICTIONS IN HIGHER COURTS

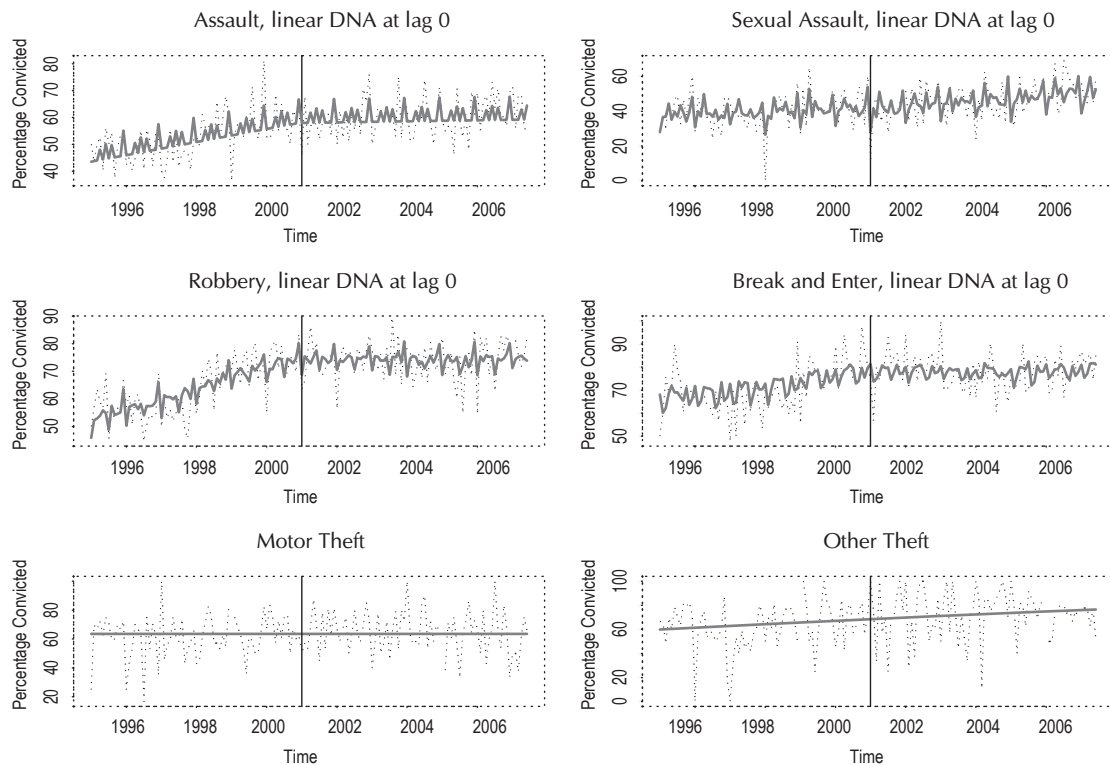
7.2.1 OVERALL REGRESSION RESULTS

Table 9 below presents a summary of the main features of the model, as they relate to the assessment of the Linear DNA term. Note that for these models it is not possible to obtain the R-squared measure of fit. Figure 13, which shows the observed HC Conviction rate along with the model fits, can be used to assess the quality of the fit from the model. In some cases there is considerable variation around the fitted regression model.

Table 9: Summary of model results for HC Conviction rates

<i>Crime Category</i>	<i>DNA Term Lag</i>	<i>DNA Term</i>	<i>Other Model Terms</i>	<i>Lag degree (q)</i>
Assault	0	-0.09	Seasonals: Apr, Jun, Aug, Dec	0
Sexual Assault	0	0.037	Seasonals: Dec, Jan Apr, Jun, Aug	2
Robbery	0	-0.171	Seasonals: Dec, Jan, Jul.	2
Break and Enter	0	-0.098	Seasonals: Feb, Mar, Aug, Sep, Nov, Dec	2
Motor Theft and Related	0	NS	-	0
Other Theft	0	NS	-	0

Figure 13: Monthly Convictions in Higher Courts with Fitted Values



The results for the Higher Court Convictions provide no evidence to support the conclusion that introduction of DNA testing has increased the conviction rate in all cases apart from the crime of Sexual Assault. In all other cases the linear DNA variable is either not significant or, if significant, has the effect of reducing the conviction rate. In these cases the representation of the series by a constant (Motor Theft), a constant linear increase (Other Theft), or an upward trend with a decline in trend around 2001 represented by the linear DNA variable appears to provide a reasonably summary of the series – in some cases some of the monthly dummy variable are significant but do not follow any sensible pattern.

In the case of Sexual Assault, the series trends upwards initially and has an accelerating trend after 2001, and this is captured by the linear DNA variable. This is the only instance where there is support for the possibility that DNA testing has increased conviction rates in the Higher Courts. However the effect is slight and enters the model with a possibly implausibly zero lag.

8. SUMMARY OF RESULTS AND ASSESSMENT OF IMPACT OF ADVENT OF DNA TESTING

Table 10 gives a summary of the significant linear DNA terms. Cells in the table coloured black are cases where there is a statistically significant effect but it is negative, in which case the linear DNA term corresponds to a worsening of the particular rate indicated. For example, the linear DNA term has a statistically significant but negative impact for Clear-up rate, LC Conviction rate and HC Conviction rate for Assault. The cells marked grey are cases where the linear DNA term has a statistically significant and positive impact on rates. In such cells the lag at which the linear DNA terms is optimized for fit in the model is shown. Blank cells are cases where the linear DNA term is not statistically significant.

Table 10: Summary of significant linear DNA effects on all outcome measures

	<i>Assault</i>	<i>Sexual Assault</i>	<i>Robbery With Firearm</i>	<i>Rob. Without Firearm</i>	<i>Break & Enter Dwelling</i>	<i>Break and Enter non Dwelling</i>	<i>Motor Vehicle Theft</i>	<i>Steal from Motor Vehicle</i>
Clear-up rate		18	56	47	29	7		
Charge rate	27	19	54	46	30	10		0
Charge to Clear-up rate	21	25	0	41	39	31	42	
LC conviction rate								
HC conviction rate		0						

8.1 SUMMARY OF FINDINGS FOR CLEAR-UP, CHARGE AND CHARGE TO CLEAR-UP RATES

For Assault the results are mixed. In particular, the results for clear-up rate may reflect a tendency for this category of crime to include a percentage of less serious assault crimes in which DNA evidence is unlikely to play a crucial role in clearing the crime. If this percentage of less serious assault crimes fluctuates through time then any impact of the advent of DNA testing will be masked. For the other two Assault outcome series there is a positive Association with the growth in the DNA database at a lag of around 2 years (27 months for Charge rate and 21 months for Charge to Clear-up rate).

For the two motor vehicle related crimes, the results are even more mixed and no consistent picture of the impact of the growth of the DNA database on these categories of crimes emerges. Note that in the cases where there is a positive association the impact is very small – see Table 11.

For five crimes (Sexual Assault, Robbery with Firearm, Robbery without Firearm, Break and Enter Dwelling and Break and Enter non-Dwelling) there is consistent evidence that the advent of DNA testing is positively associated with an improvement in Clear-up rate, Charge rates and Charge to Clear-up rates relative to prior trends in the monthly series. The lags at which the linear DNA variable is most strongly associated are reasonably consistent, particularly in view of the large degree of uncertainty with which these lags are determined across the three outcome measures and within each of these five crime categories (see Table 10). This is less so for Break and Enter non-Dwelling. For Robbery With Firearm, the lag for Charge to Clear-up rate is zero, which is likely to be implausible.

8.2 SUMMARY OF FINDING FOR CONVICTION RATES

Apart from Sexual Assault in the Higher Courts, there is no evidence from our analysis that the advent of DNA testing has had any discernible and positive impact on conviction rates in either court.

The introduction of DNA testing in January 2001 is statistically significantly associated with a reduction in conviction rates and this association is immediate or almost immediate in all cases. Given the likelihood of substantial time lags in solving and prosecuting crimes in the courts this immediate association is unlikely to be a causal one. That is, we would rule out the possibility that the advent of DNA testing had an impact on reducing conviction rates.

For Sexual Assault cases tried in the Higher Courts, the positive association is slight and not mirrored in the corresponding lower court series. Moreover, the effect size is very small as is evident in Figure 13. That, and the short lag at which this effect is observed, would suggest that this isolated result is not evidence of a causal link between the advent of DNA testing and the conviction rate for Sexual Assault.

8.3 IMPACT OF LINEAR DNA TERM ON CLEAR UP, CHARGE AND CHARGE TO CLEAR-UP RATES

This section provides an assessment of the impact on the modelled level of the three police related outcome series for each crime. Crime types are colour coded as for Table 10. For each row of the table, several numerical values are presented: first the month at which the impact of DNA testing is optimally included, second; the rate at that time is given, third; the forecast rate 12 months hence (assuming that the trend established in the model continues without any impact of the linear DNA term); fourth; the forecast rate 12 months hence (assuming that the linear DNA term is included in the forecasting) and, finally; the difference between these two forecasts. Note this last column is simply the coefficient of the linear DNA term observed in the previous tables (Table 1, Table 4, Table 6).

In order to infer a causal relationship between the advent of linear DNA testing and the improvement in the various outcome measures summarised in Table 11, additional knowledge and information beyond that available in this study is required. In particular, other explanations for the observed associations and improvement in outcomes would need to be ruled out.

The size of the estimated impact may be implausible in some cases. For instance, the clear-up rate for Robbery with Firearm at the point of optimal impact (September 2005) is 14.1%. The impact of the linear DNA terms is estimated to be 7.0%, which as a percentage of the level is almost 50%. On the other hand some of the impacts are modest or small. We know of no way to independently check the plausibility of the effect sizes implied by the results in Table 11.

Table 11: Assessment of impact on rates 12 months post the linear DNA term

<i>Outcome Measure</i>	<i>Crime</i>	<i>Month in which linear DNA term commences</i>	<i>Charge to Cleared rate at change point</i>	<i>Forecast Level 12 months post linear DNA term without DNA testing</i>	<i>Forecast Level 12 months post linear DNA term with DNA testing</i>	<i>Impact One Year After inclusion of Linear DNA term in model</i>
Clear-up Rate	Assault	Oct-04	66.3%	66.7%	65.8%	-0.9%
	Sexual Assault	Jul-02	27.5%	22.8%	26.9%	4.2%
	Robbery with Firearm	Sep-05	14.1%	13.2%	20.2%	7.0%
	Robbery without Firearm	Dec-04	16.7%	16.7%	17.9%	1.2%
	Break and Enter Dwelling	Jun-03	6.0%	6.0%	6.4%	0.4%
	Break and Enter Non-Dwelling	Aug-01	5.8%	5.6%	6.1%	0.5%
	Motor Theft	Feb-01	7.0%	7.4%	6.8%	-0.6%
	Stealing from MV		3.2%	3.1%	3.1%	0.0%
Charge Rate	Assault	Apr-03	37.7%	36.6%	38.3%	1.7%
	Sexual Assault	Aug-02	14.1%	9.5%	14.3%	4.8%
	Robbery with Firearm	Jul-05	12.4%	11.5%	19.6%	8.1%
	Robbery without Firearm	Nov-04	13.4%	13.2%	15.2%	2.0%
	Break and Enter Dwelling	Jul-03	4.4%	4.3%	4.7%	0.4%
	Break and Enter Non-Dwelling	Nov-01	4.8%	4.5%	5.0%	0.5%
	Motor Theft	Feb-01	6.0%	6.3%	5.7%	-0.6%
	Stealing from MV	Jan-01	2.5%	2.3%	2.4%	0.1%
Charge to Clear-up Rate	Assault	Oct-02	57.3%	54.9%	58.2%	3.3%
	Sexual Assault	Feb-03	53.3%	49.9%	54.9%	5.0%
	Robbery with Firearm (logistic)	Jan-01	89.1%	87.3%	90.1%	2.8%
	Robbery without Firearm	Jun-04	82.9%	82.1%	85.3%	3.2%
	Break and Enter Dwelling	Feb-04	72.2%	70.3%	73.8%	3.5%
	Break and Enter Non-Dwelling	Aug-03	80.2%	79.0%	80.4%	1.4%
	Motor Theft	Jul-04	80.5%	78.9%	80.5%	1.5%
	Stealing from MV		80.7%	79.6%	79.6%	0.0%

9. DISCUSSION

The results of this study quantify the significance, size and direction of association between the advent of DNA testing and the subsequent growth in the DNA database and the various outcome measures: Clear-up rate, Charge rate and Conviction rates in both court jurisdictions. For conviction rates, there is no evidence (apart from a very mild association at an implausibly short lag for Sexual Assault in the higher courts) for a conclusion that the advent of DNA testing has had a positive impact. For the police outcome series of Clear-up, Charge and Charge to Clear-up rates, there is consistent evidence of a positive association for 5 of the eight crime categories considered and mixed evidence for the Assault and the two motor vehicle related categories.

In relation to the observations for the police outcome series, the lags at which the association with the advent of DNA testing and subsequent database growth are quite long and vary across crime categories. Typically the lags tend to be in the order Break and Enter Non Dwelling (shortest lags), Sexual Assault, Break and Enter Dwelling, Robbery without Firearm and Robbery with Firearm (longest lags). It is possible that these differences in lags across crime categories are due, in part, to differences in average prison sentences for these crimes.

In discussions with police it emerged that long lagged effects are quite plausible and short lags are not. There are several reasons for this, including:

- The fact that the database wasn't used for 10 months after testing began
- The fact that there are long lags between the presentation of DNA samples and their analysis by the drug analytical laboratory (DAL)
- The fact that some offenders (e.g. robbery offenders) spend a long time in prison before being released
- The fact that criminal investigation often continues for some time even after a DNA match has been made (to gather further evidence)

In order to use the results concerning association to reach a conclusion of causality in which DNA testing increases the police effectiveness in solving and prosecuting crime it is necessary to rule out other possible explanations for the observed association.

As noted before, there is no prior information concerning suitable covariates that might explain fluctuations in the various outcome measures considered in this report. Covariates related to the economy, drug use and prison population which have proved to be important in other studies of levels of certain crimes were considered in the modelling analysis of this report but removal of these factors did not alter the results in many instances by more than a modest amount.

Nonetheless, it is possible that there are alternative factors at work in the police service that explain the fluctuations in the series and could confound the observed associations with the linear DNA term in the modelling. Our examination of police workloads, using the numbers of reported incidents in each crime category as a proxy, did not improve the modelling. This measure is not a direct measure of police resource allocation, workloads, prioritisation and the like and it would be useful to explore the possibility (even if for a single crime category) of obtaining more detailed resource allocation data.

In discussions with police some other explanations for our positive effects were raised. They include:

- The fact that some time after DNA testing was introduced, the police established a metropolitan robbery unit. This unit may have used DNA evidence but its establishment also represented a significant increase (focussing) of resources on the crime of robbery.
- The fact that over time police have gained more resources (additional police) and have become more professional in their approach to criminal investigation (e.g. establishment of crime management units, greater concentration use of modus operandi information to identify offenders)

Further information, if available, that would quantify these effects in a way suitable for inclusion in the time series analysis would be useful.

In these discussions the possibility of negative or null effects due to the advent of DNA testing were also discussed. At least two explanations for negative effects were suggested:

- Police may have become over-reliant on DNA and other forensic evidence in some cases and not pursued other investigative avenues when DNA evidence was not available.
- There might have been a growth in the sorts of cases where victims for one reason or another won't give evidence or where police for one reason or another (e.g. sexual assault cases where consent is the issue, not whether or not sexual intercourse took place)

The one explanation given for a null effect was that the impact of DNA testing might have been restricted to cases that took more than 180 days to finalise. This is the period it will be recalled, over which we examined changes in our outcome measures.

Other issues that might be considered:

- What evidence is there which is inconsistent with the advent of DNA testing having led to improvements in clear-up, charge and conviction rates?
- What other interpretations is this evidence susceptible to?

10. FURTHER RESEARCH

This report has used observational data on various outcome measures and sought to determine if any change in these series can be associated with the advent of DNA testing and the subsequent growth in the DNA database. The key assumptions that underpin the analysis and results presented are: that the trend in the outcome measure is linear and that the impact of the growth of the DNA database is linear at a lag determined to optimally fit the model.

These two assumptions are rather simple and, as is evident from a comparison of observed and fitted values in the Figures presented above, the model representation of the data is sometimes excellent and at other times rather poor. This is also reflected in the R-squared measure of fit. In some cases, inclusion of covariates and/or inclusion of an autoregressive model for positive serial dependence go some way toward accounting for the deviations observed from the linear trend and linear DNA impact. The representation of the trend prior to the any impact of DNA testing by more complex temporal functions such as polynomials, splines and regression splines could be pursued. However this is likely to result in models that confound the impact of DNA.

Concerning the form of the impact of the growth in the DNA database, we have used a linear growth to summarize it. However, as a result of ex-prisoners who permanently cease their criminal activity the initial linear growth in utility of the samples may, in time, reach steady state, in which the numbers of new samples is offset by the 'retirement' of historical samples. Also, the form of the DNA impact is assumed to be the same across all crime categories. As further knowledge of the impact of DNA sampling is accumulated around the world, there will be opportunities to further improve the shape of the impact in response to DNA testing on the outcome measures.

In summary, in order to move from the simple assumptions used in this analysis it will be necessary to:

1. Obtain an improved understanding of the other factors that could influence the temporal fluctuations in the levels of the outcome series
2. Obtain information on how long samples accumulated in the DNA database remain useful in identifying and prosecuting offenders. Such information may vary for different categories of offender.

Concerning the outcome measures used in this report, there are two points of caution that should be mentioned. The first concerns the obvious fact that the three police outcome measures of Clear-up rate; Charge rate and Charge to Clear-up rate are not independent of each other. The first two use the same denominator (number of reported incidents) and the last takes the ratio of the first two. This needs to be kept in mind when considering the overall strength of evidence suggested by Table 11.

The second point of concern with the outcome measure used for the police series is that they are all based on 180 days after the recording of a crime. For some, even all, crime categories considered here, this may not be sufficient time to fully capture all cases in which DNA has utility in solving and charging crimes. Any differential effects in time (due to fluctuations in time through the testing and matching process of crime scene forensic evidence) in the coverage of crimes committed in which DNA evidence plays a

part could manifest itself in unaccounted for temporal fluctuations in trend and level of the outcome series. One straightforward option to investigate this further would be to model the 360 day Clear-up and Charge rates for a selection of crimes.

We close this report by considering what sort of research would help advance our understanding of the impact of DNA testing on criminal investigation and prosecution. Future research should direct itself towards:

- 1) Better understanding and quantification of the factors that influence the outcome series considered here. These will primarily be concerned with a better understanding of the way in which DNA evidence is used by police to solve and prosecute crime, in the context of resource allocation and structural changes in policing practice and priorities.
- 2) Further analysis of data beyond June 2007, particularly for convictions, where there are likely to be long lags (although without a better understanding of the reasons for the trend patterns observed in the data so far this will be of limited utility on its own).
- 3) Determination of the coverage afforded by 180 clearance rates of crimes in which DNA evidence is likely to play a key role and measurement of the time from location of a DNA sample at a crime scene to prosecution of an offender in a case where DNA evidence is used.
- 4) Further analysis of the conviction rate series to determine historical changes in trends and levels, particular those around 2001. Plausible explanations need to be found for the increasing trend prior to 2001, the decrease thereafter and, in some crime categories, the levelling out from 2004 onwards for local court conviction rates. It would also be helpful to obtain an explanation for why the trend patterns differ between higher and lower court conviction rates for the same crimes.
- 5) A better understanding of the likely time lags for crimes of each type to reach trial in determining plausible lags for the impact of the advent of DNA testing to be noticeable.

The above suggestions for research are aimed at improving the methodology used in this report; that is, they are aimed at improving the interrupted time series approach to answering the question posed. There are other possibilities, some of which were discussed in the introduction to this report. The ideal would be a randomised controlled trial in which DNA evidence is gathered from a large sample of crime scenes but provided to investigators in only a random sub-sample of cases. The cases could then be examined to see whether criminal investigation outcomes are superior in cases where DNA evidence has been made available than in cases where it has not. Another alternative would be to conduct a prospective longitudinal study of a cohort of cases to see whether those where DNA evidence are, controlling for other relevant factors, more likely to result in a clear up, arrest and/or prosecution. These methods would provide a more definitive test of the value of DNA evidence if they could be implemented but their feasibility would have to be assessed.

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12. NOTES

- 1 http://www.crimtrac.gov.au/systems___projects_key_dates_in_the_history_of_forensic_dna_profiling.html, extracted 20th June, 2008.
- 2 http://www.crimtrac.gov.au/systems___projects_key_dates_in_the_history_of_forensic_dna_profiling.html, extracted 20th June, 2008.
- 3 A serious indictable offender is defined as a person convicted of an offence carrying a maximum penalty of five or more year's imprisonment Haesler 2003).
- 4 Forensic evidence includes DNA evidence as well as other crime scene evidence, such as footprints and fingerprints.
- 5 Cited in Bradbury and Feist 2005, p. 63)
- 6 Cited in Bradbury and Feist (2005, p. 64)
- 7 This last variable can be increased by focussing more attention on prolific offenders.

APPENDIX A

Graphs of time series
from Police data

Figure 1

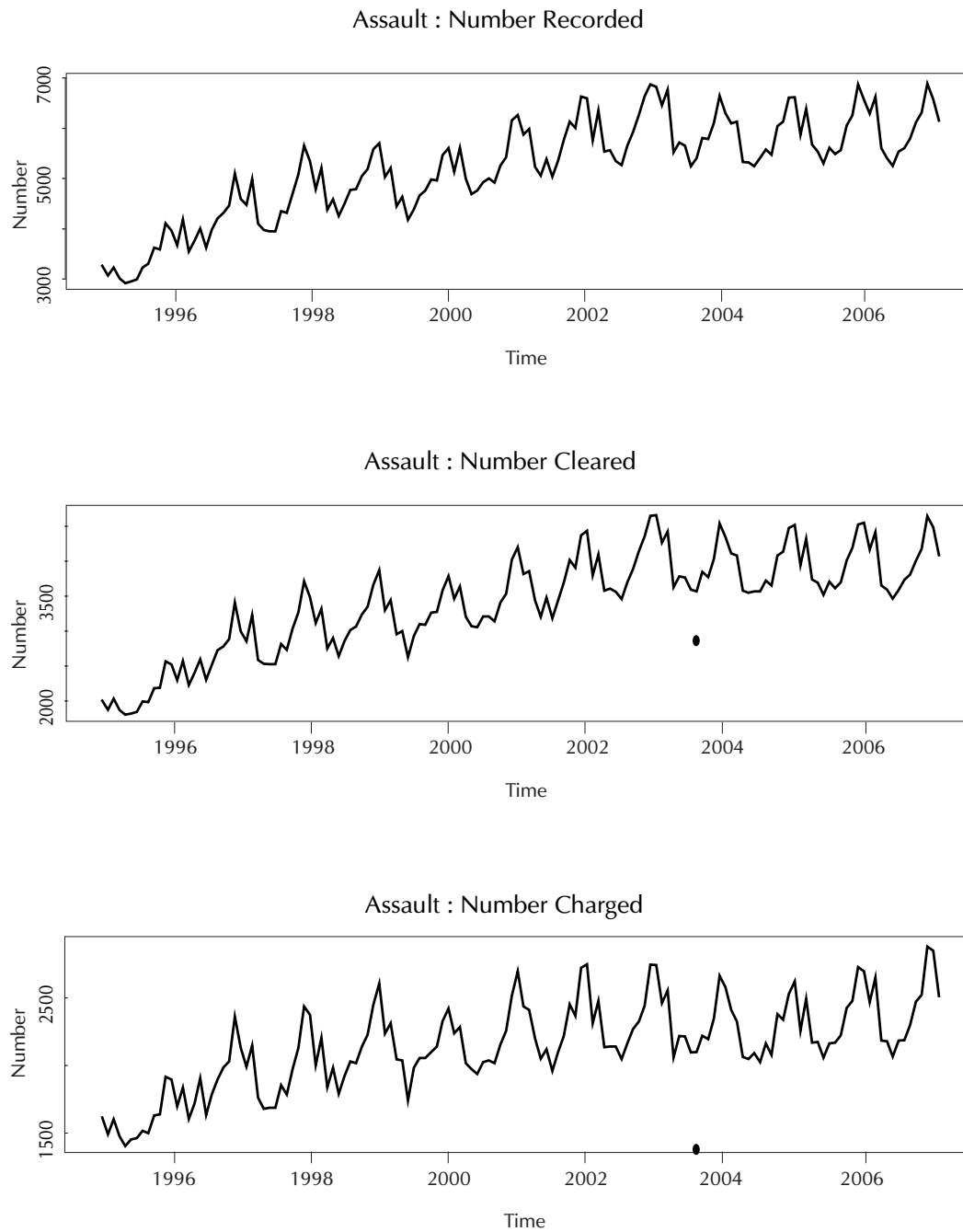


Figure 2

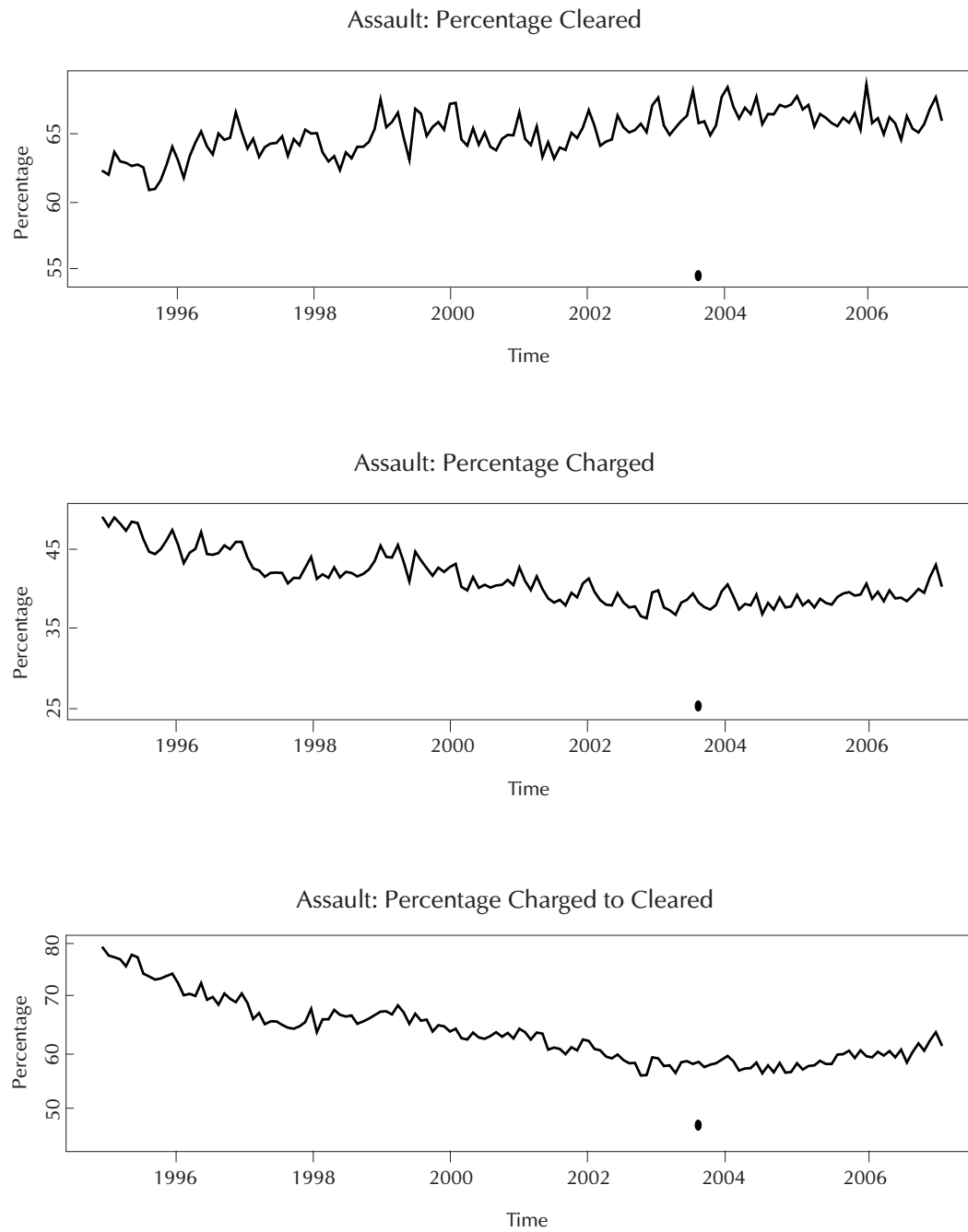


Figure 3

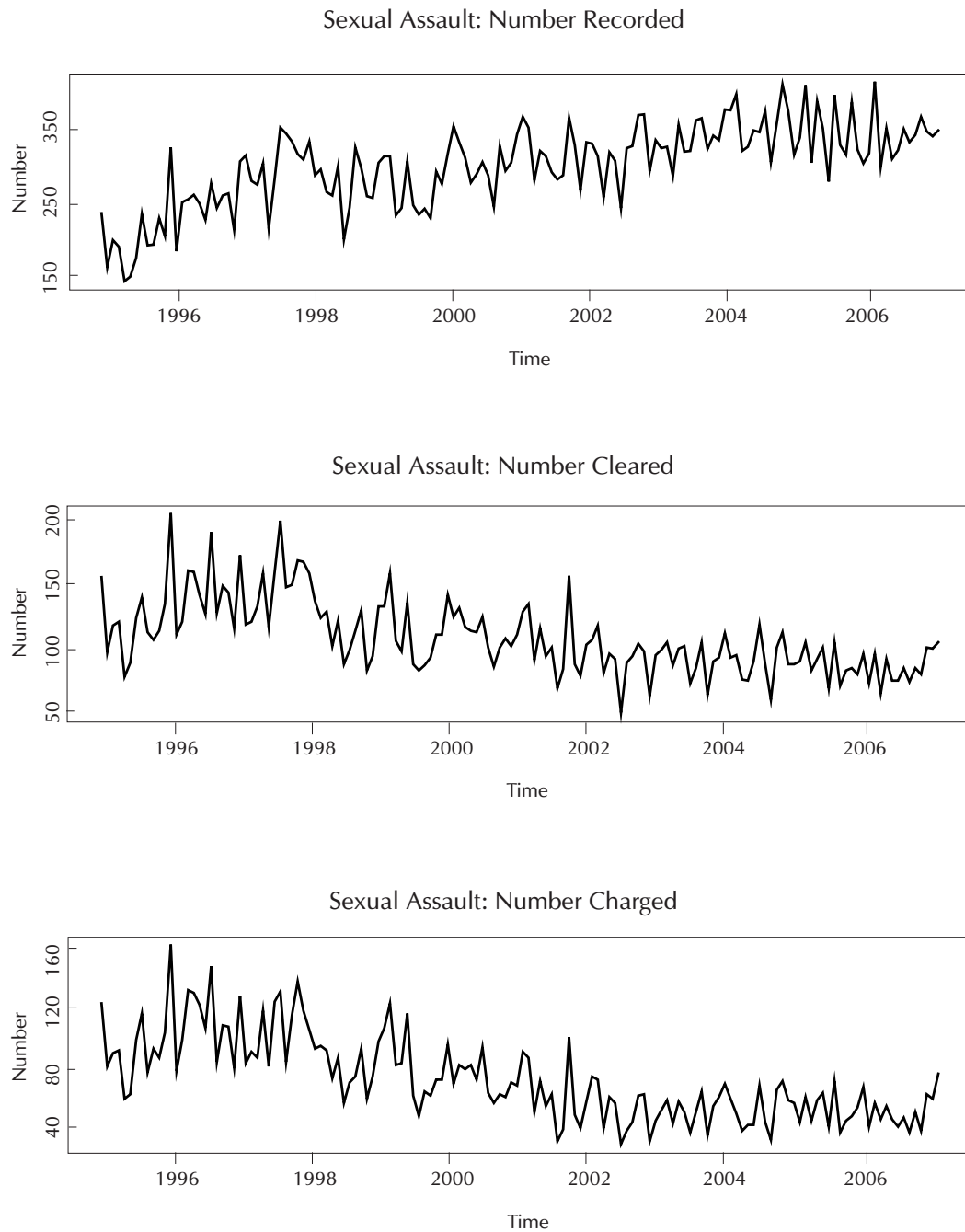


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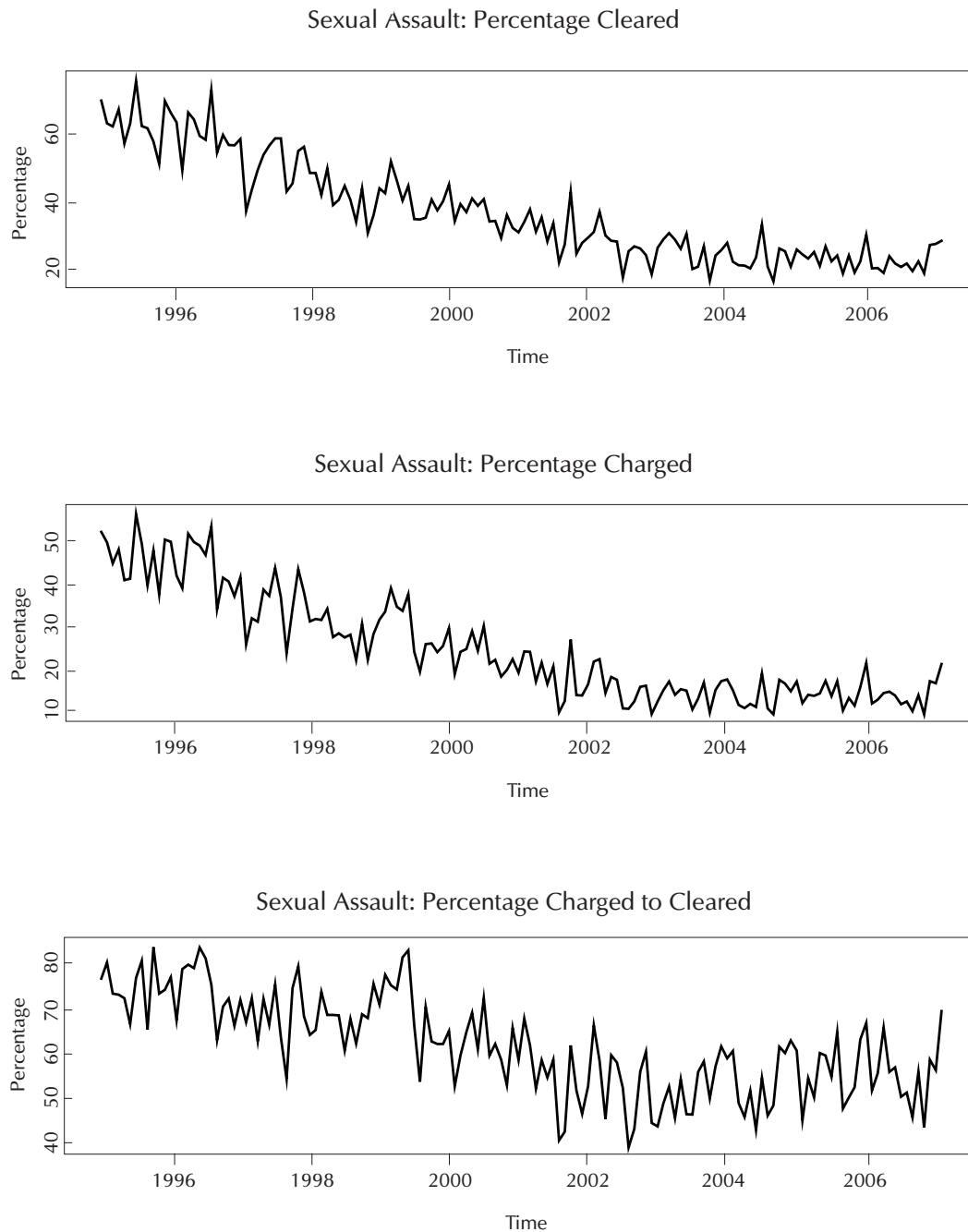


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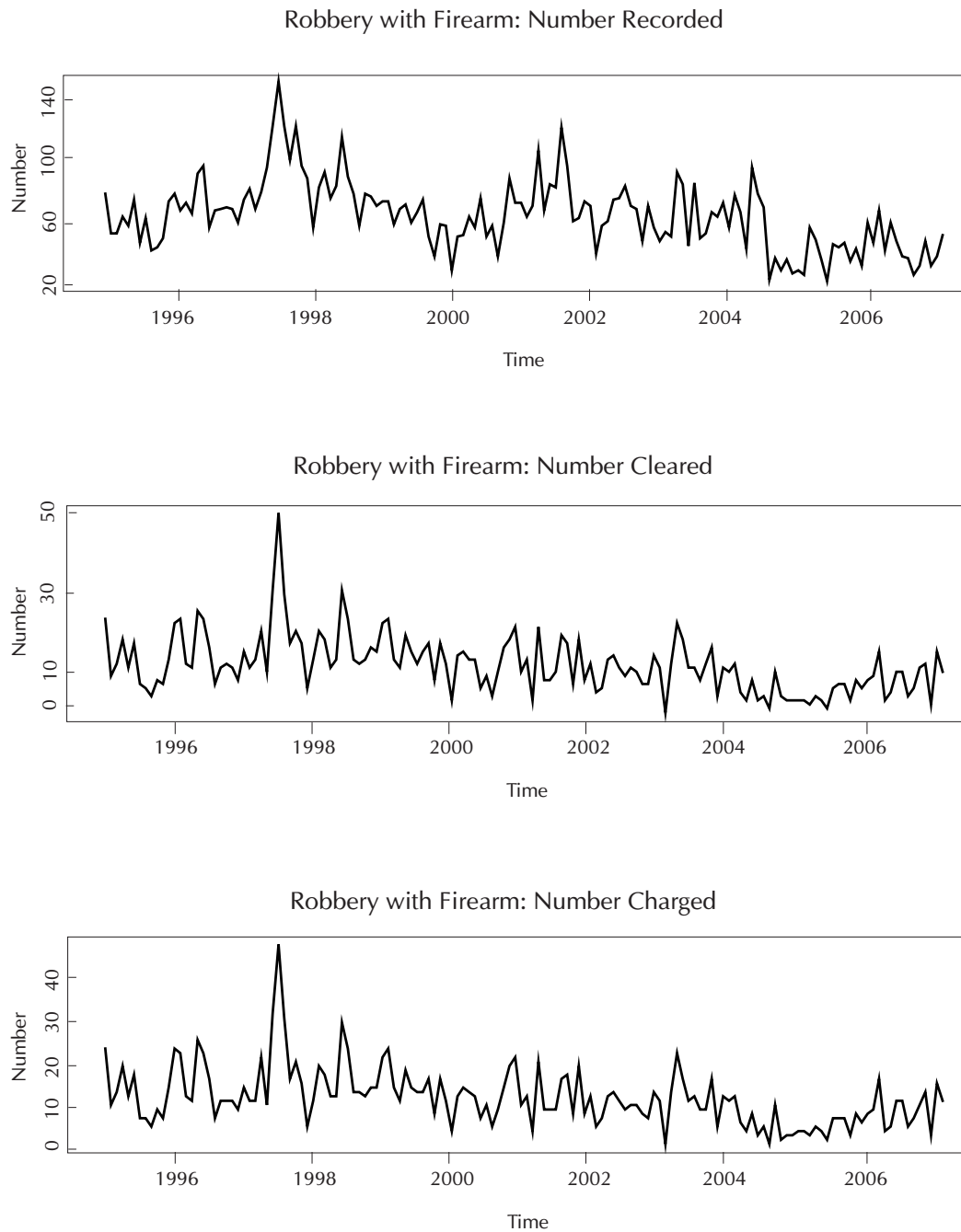


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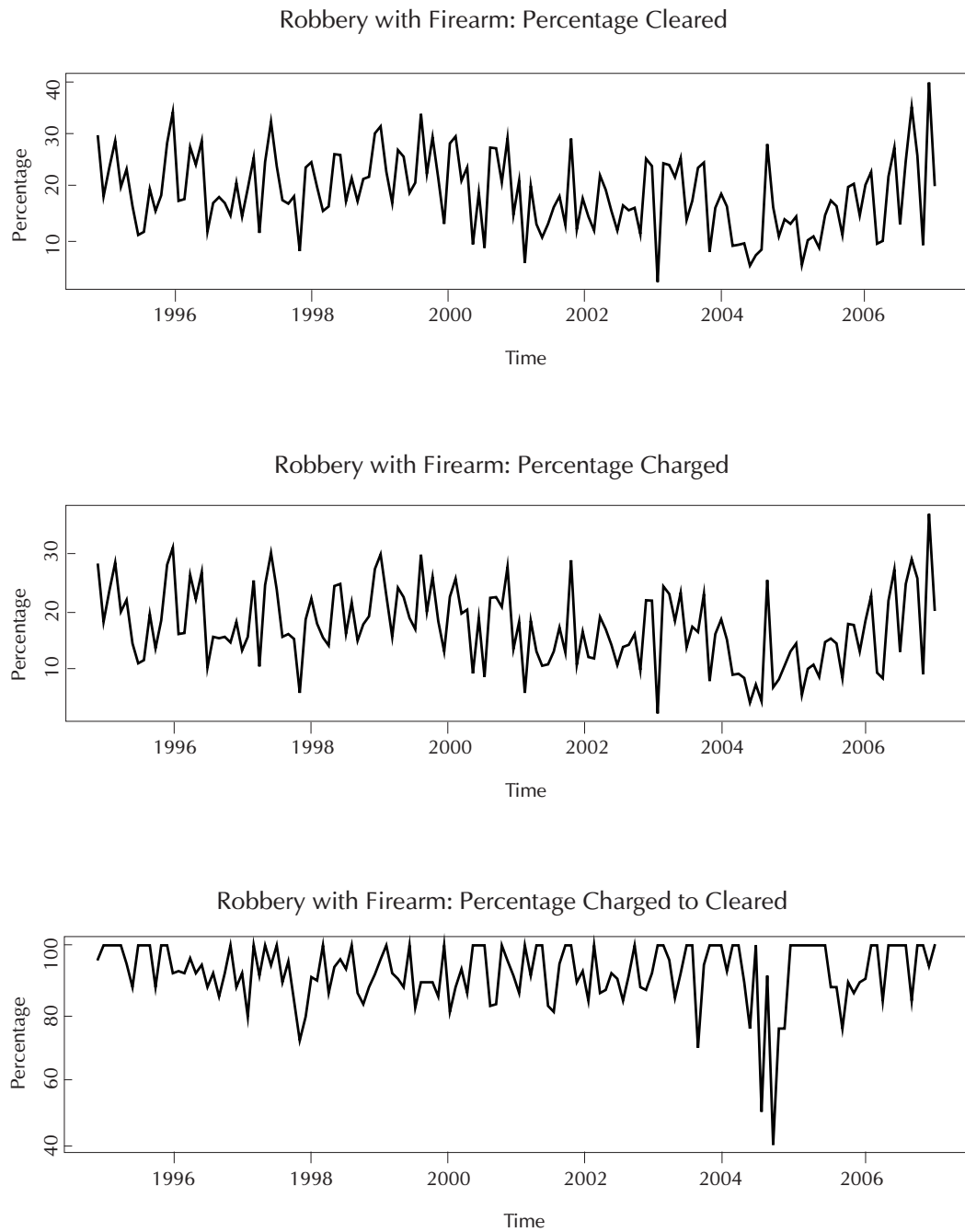


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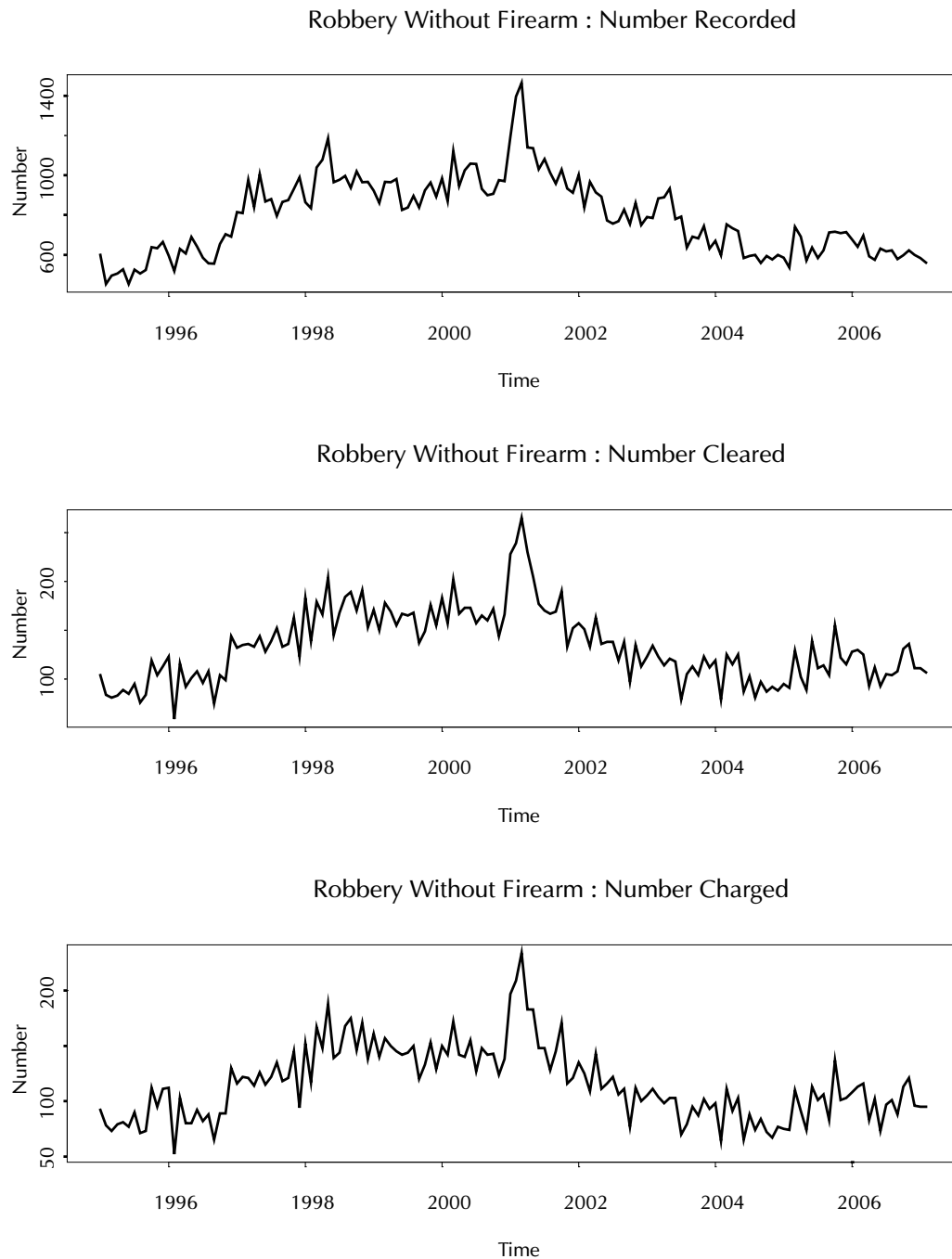


Figure 8

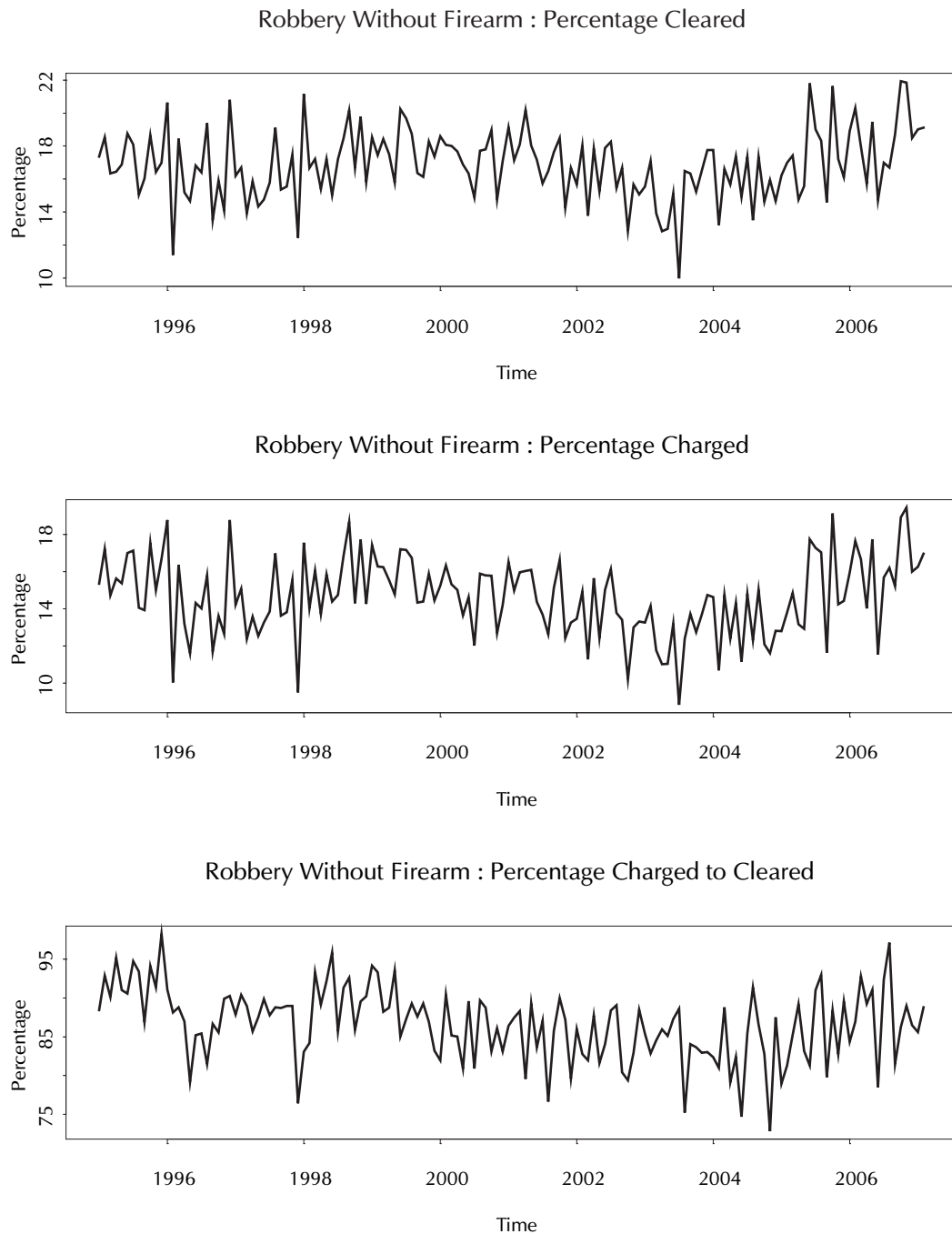


Figure 9

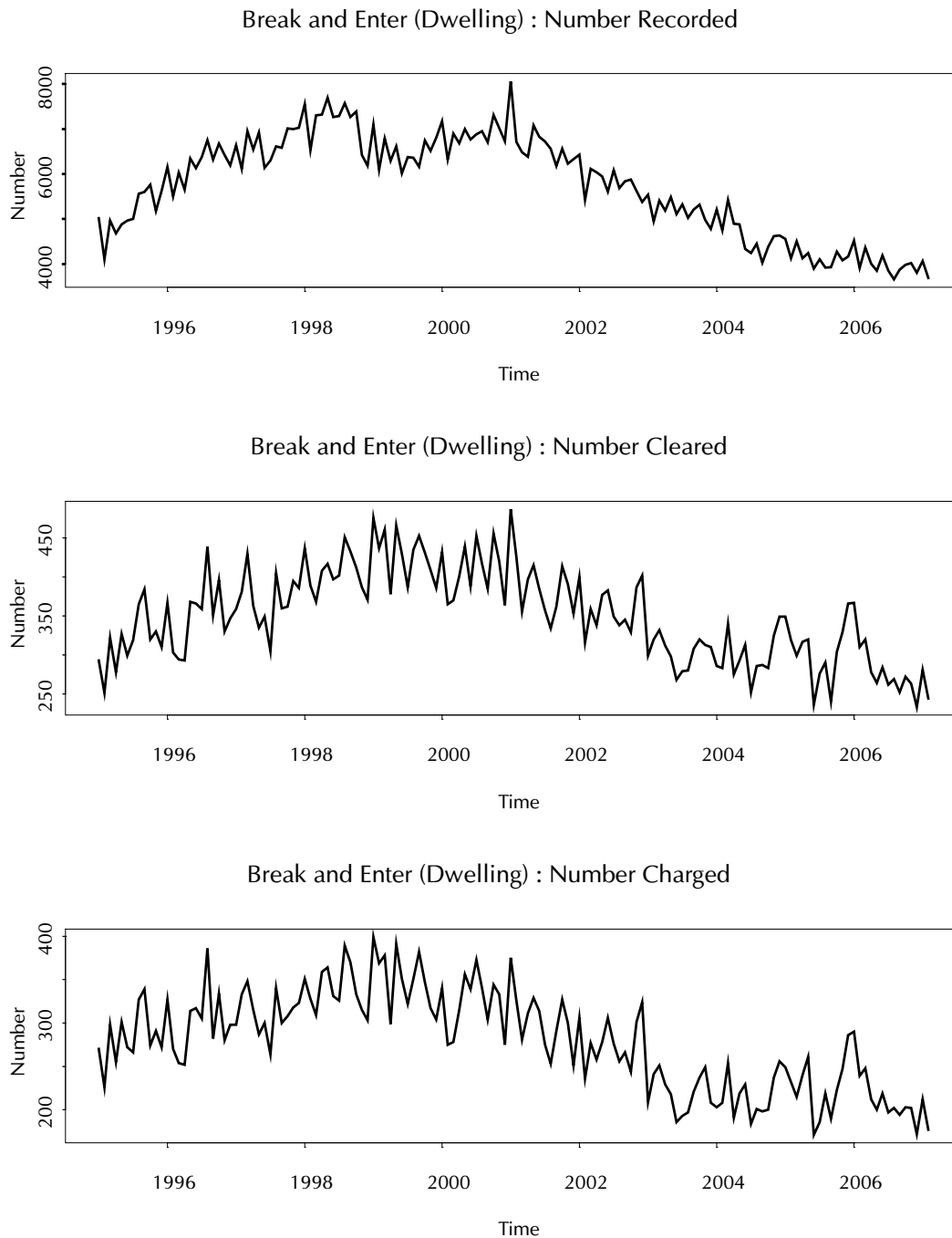
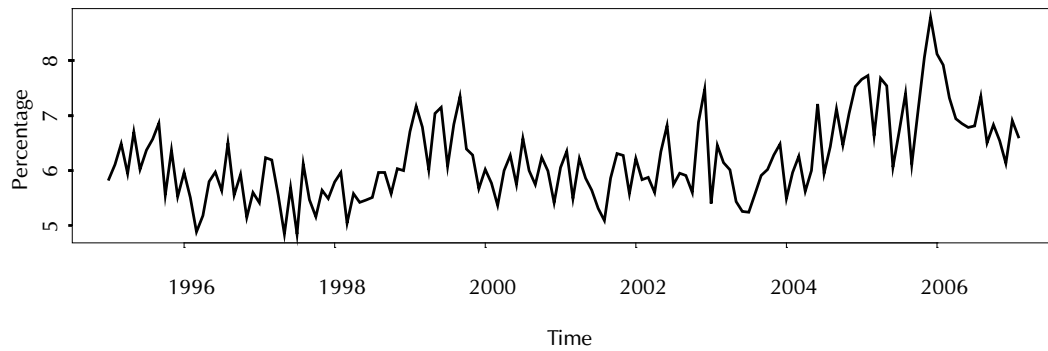
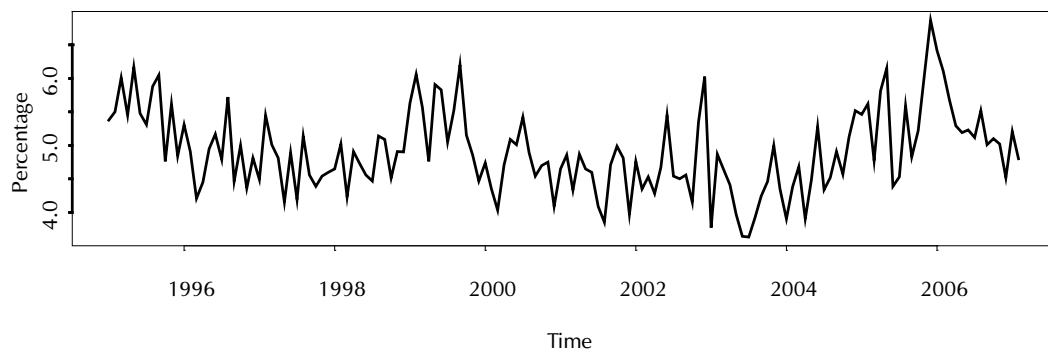


Figure 10

Break and Enter (Dwelling) : Percentage Cleared



Break and Enter (Dwelling) : Percentage Charged



Break and Enter (Dwelling) : Percentage Charged to Cleared

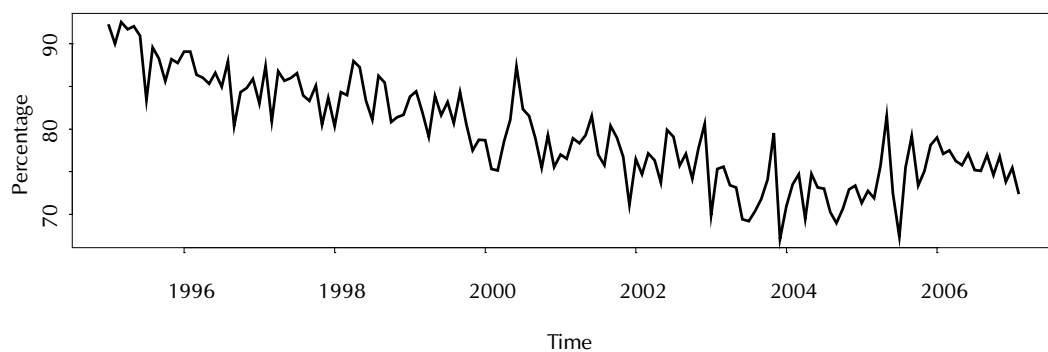


Figure 11

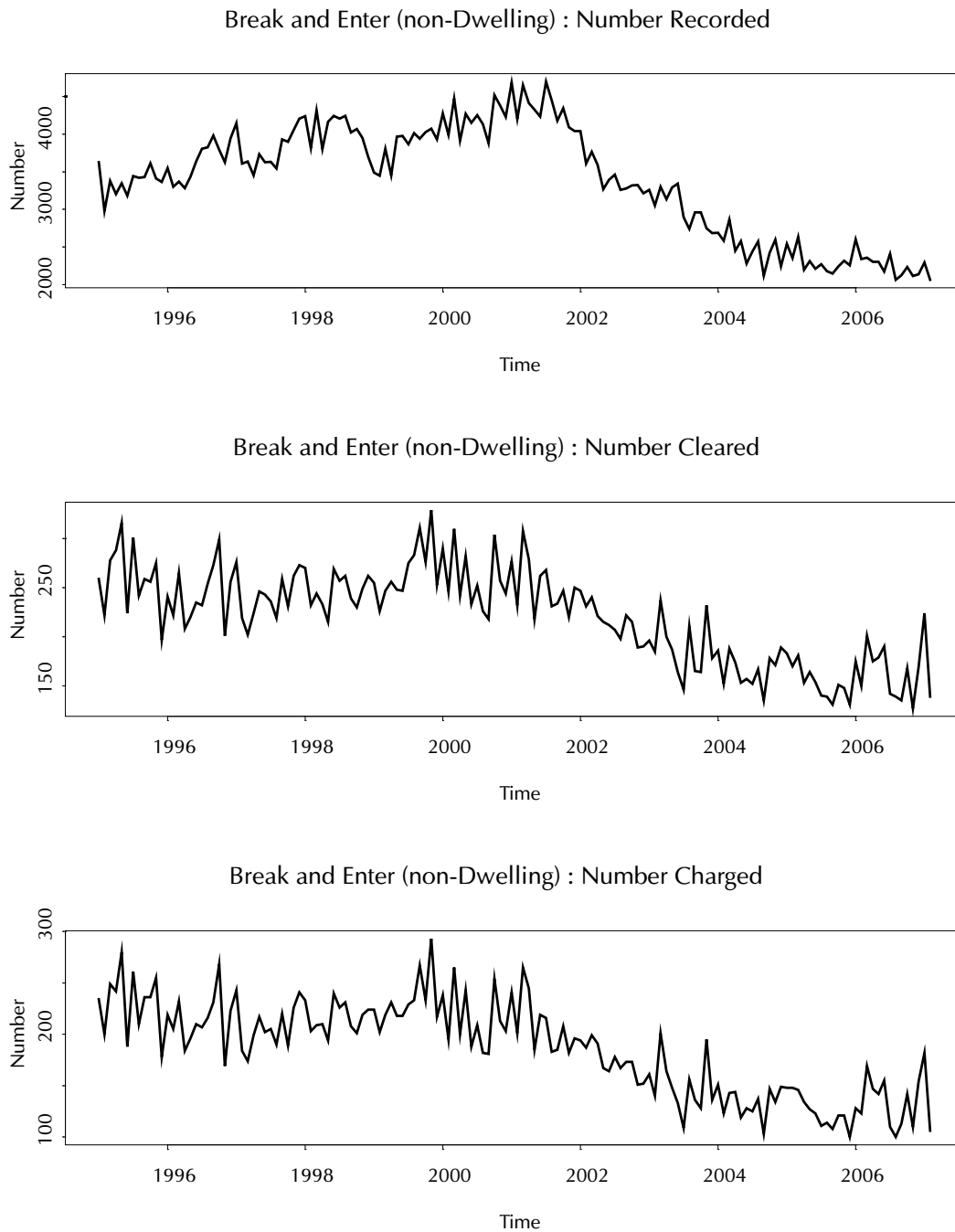
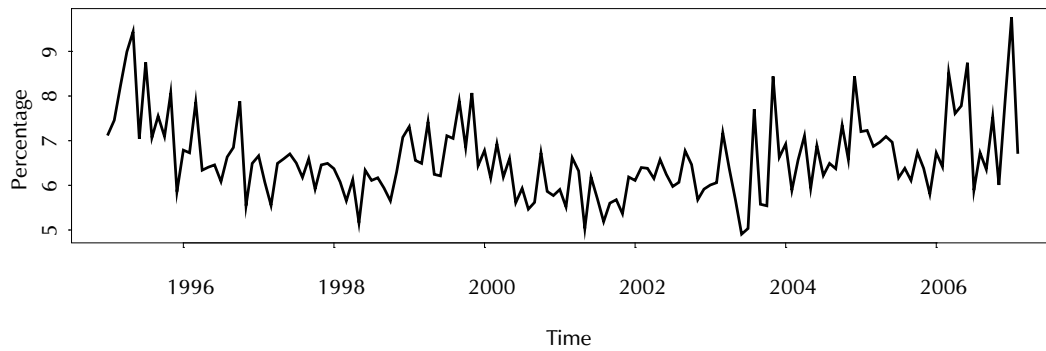
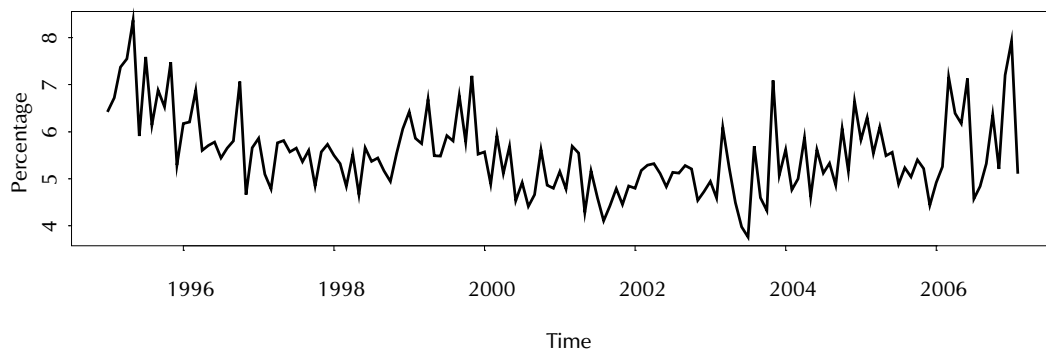


Figure 12

Break and Enter (non-Dwelling) : Percentage Cleared



Break and Enter (non-Dwelling) : Percentage Charged



Break and Enter (non-Dwelling) : Percentage Charged to Cleared

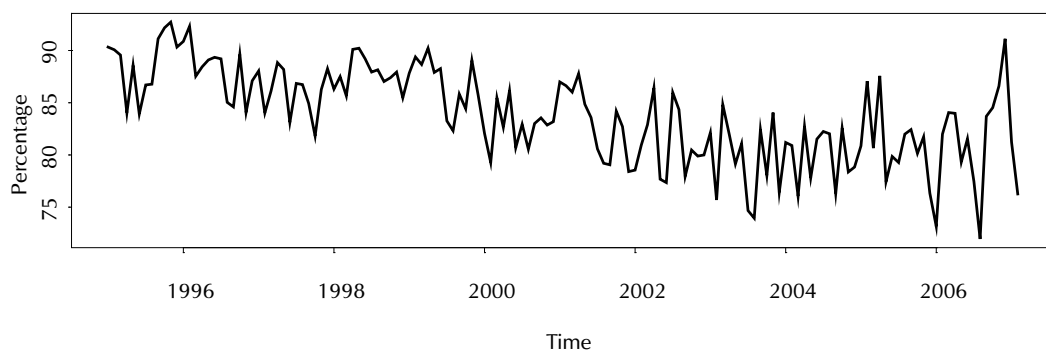


Figure 13

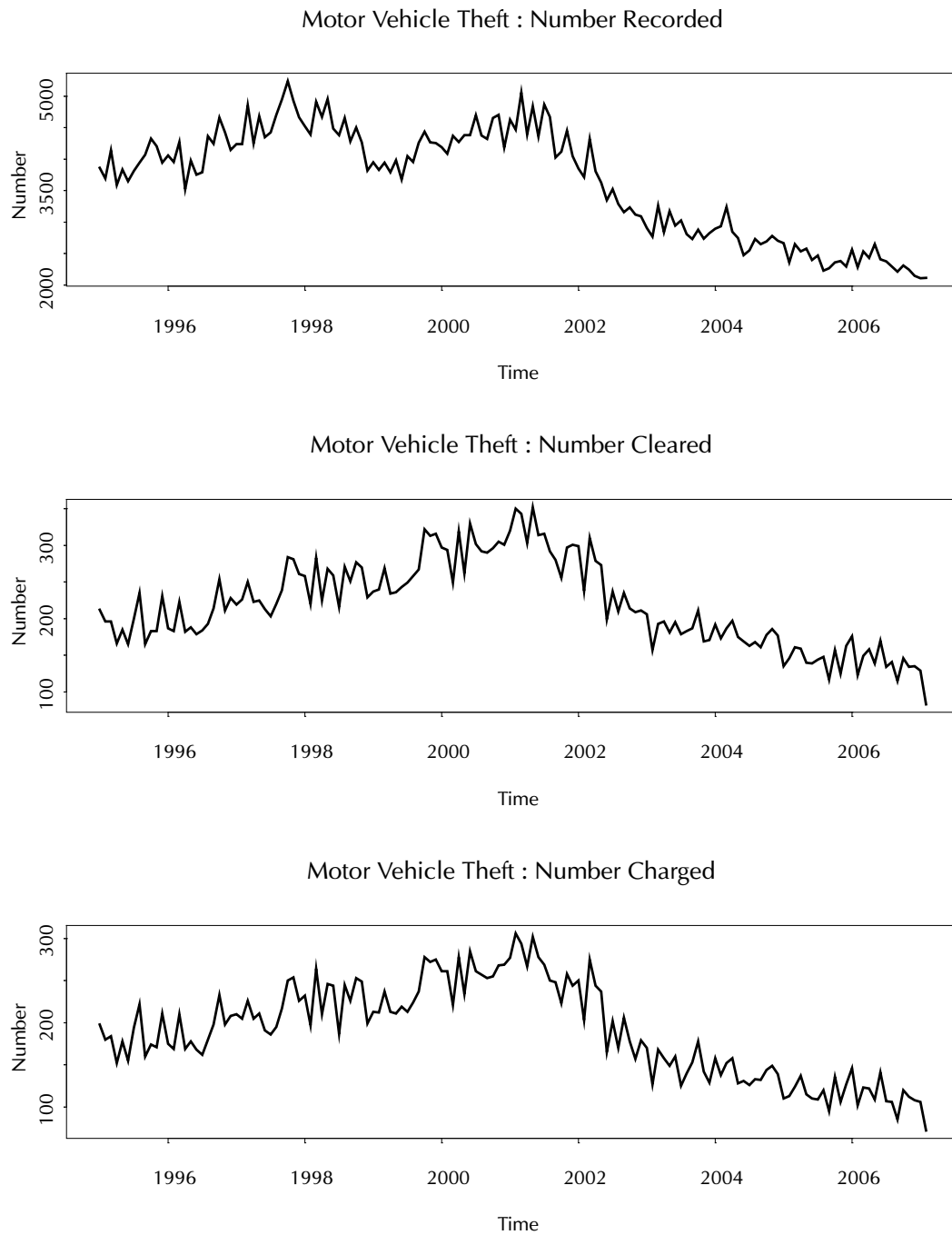


Figure 14

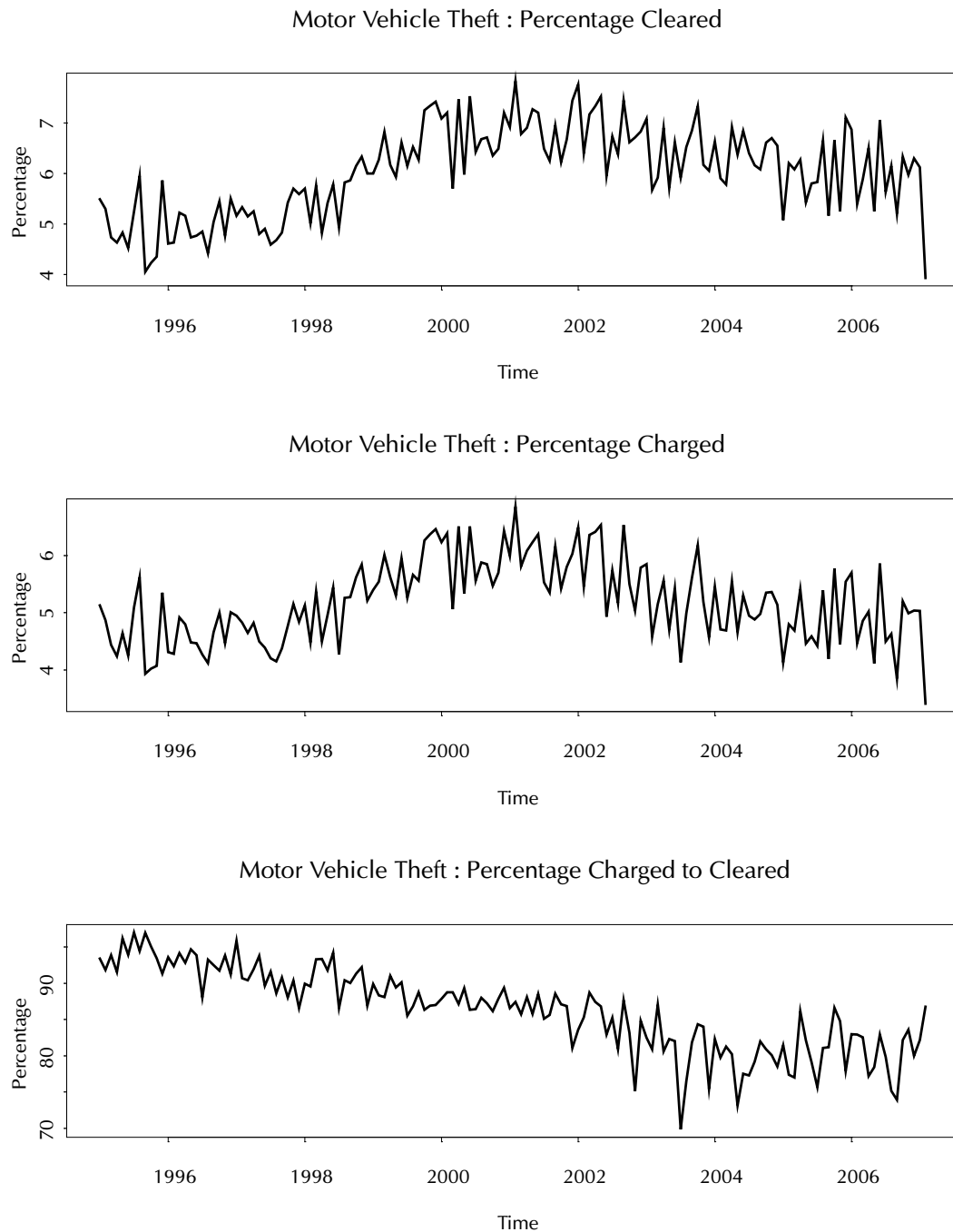


Figure 15

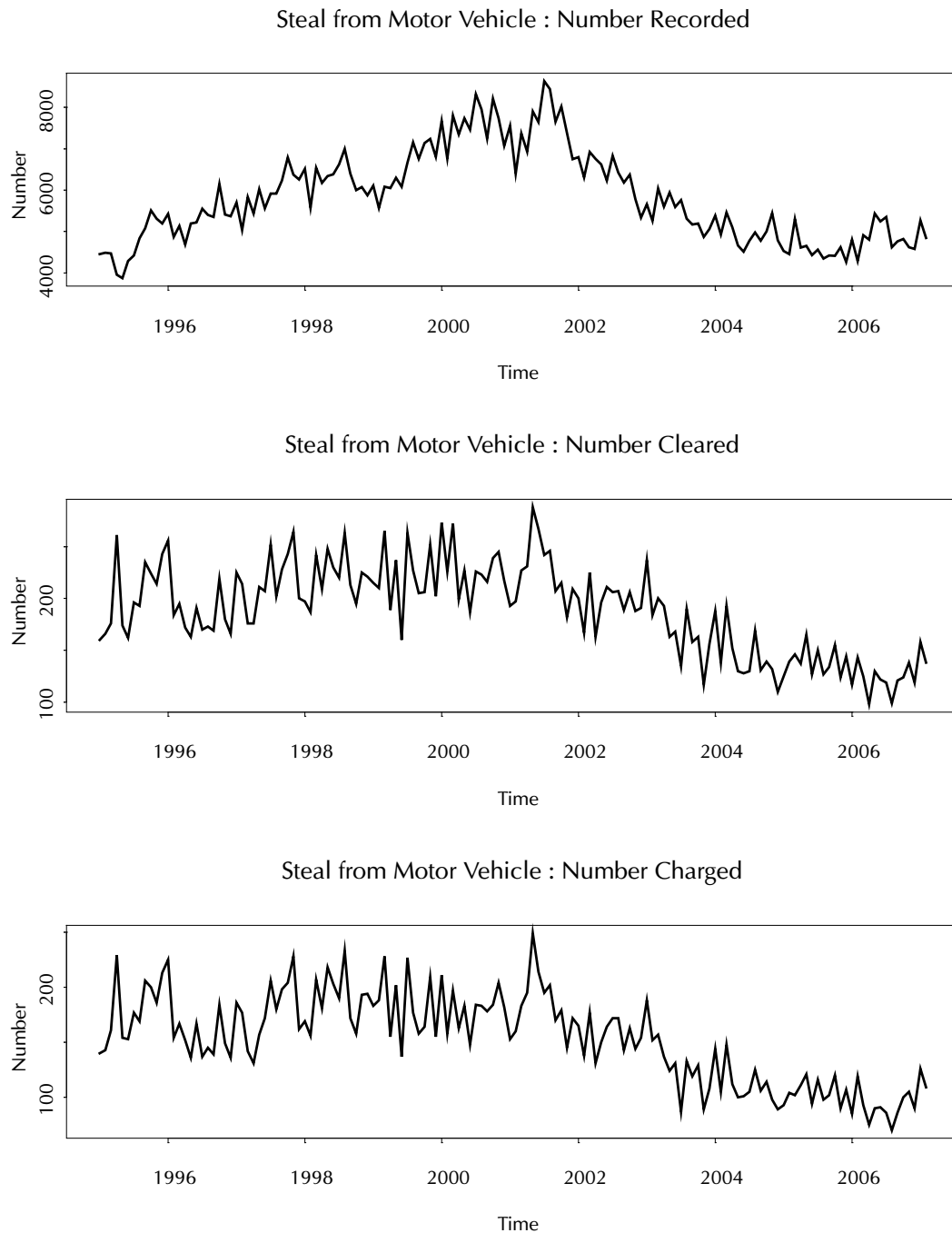
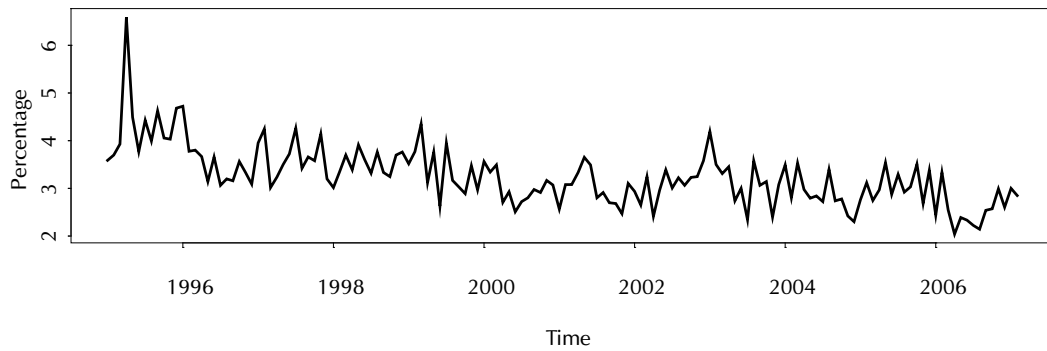
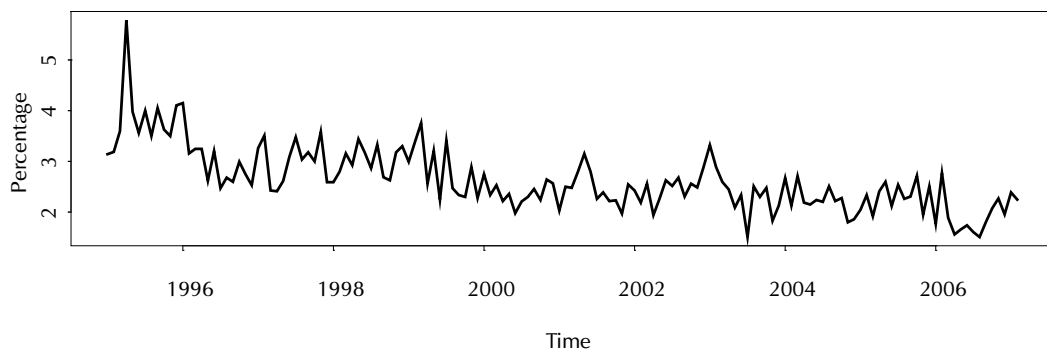


Figure 16

Steal from Motor Vehicle : Percentage Cleared



Steal from Motor Vehicle : Percentage Charged



Steal from Motor Vehicle : Percentage Charged to Cleared

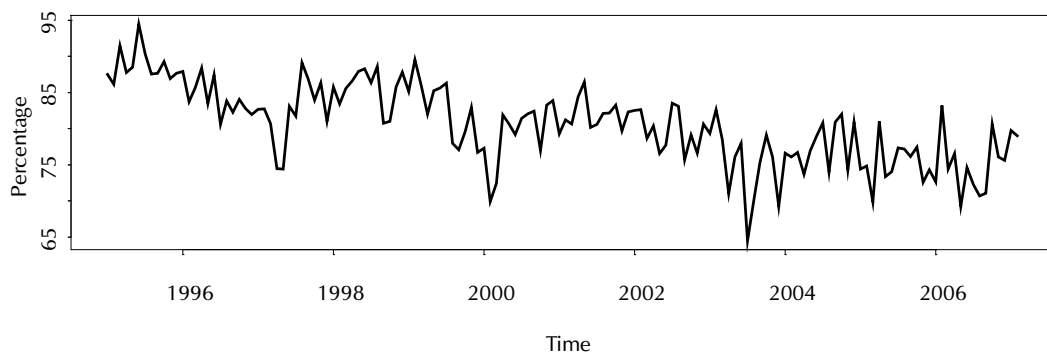


Figure 17

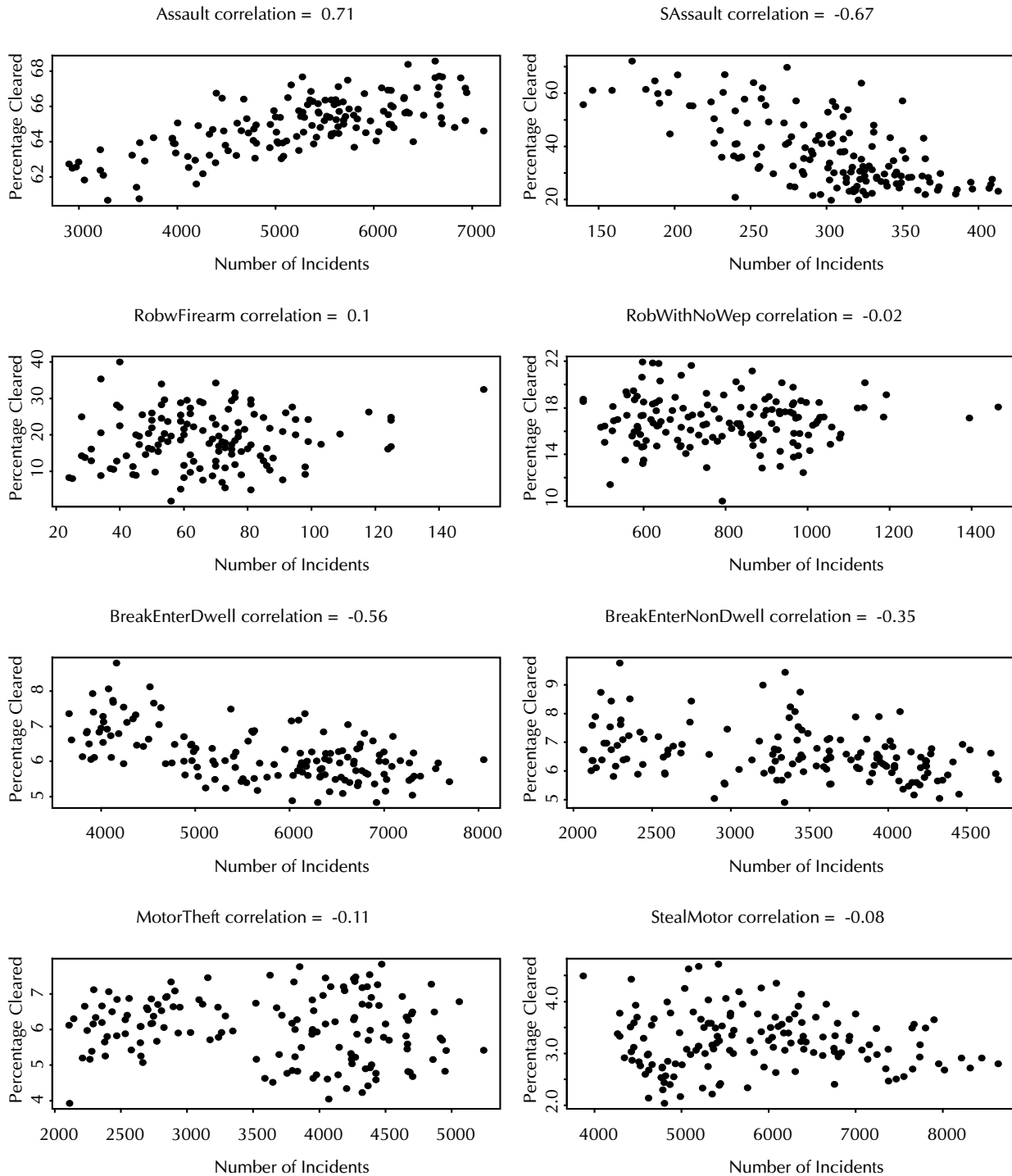


Figure 18

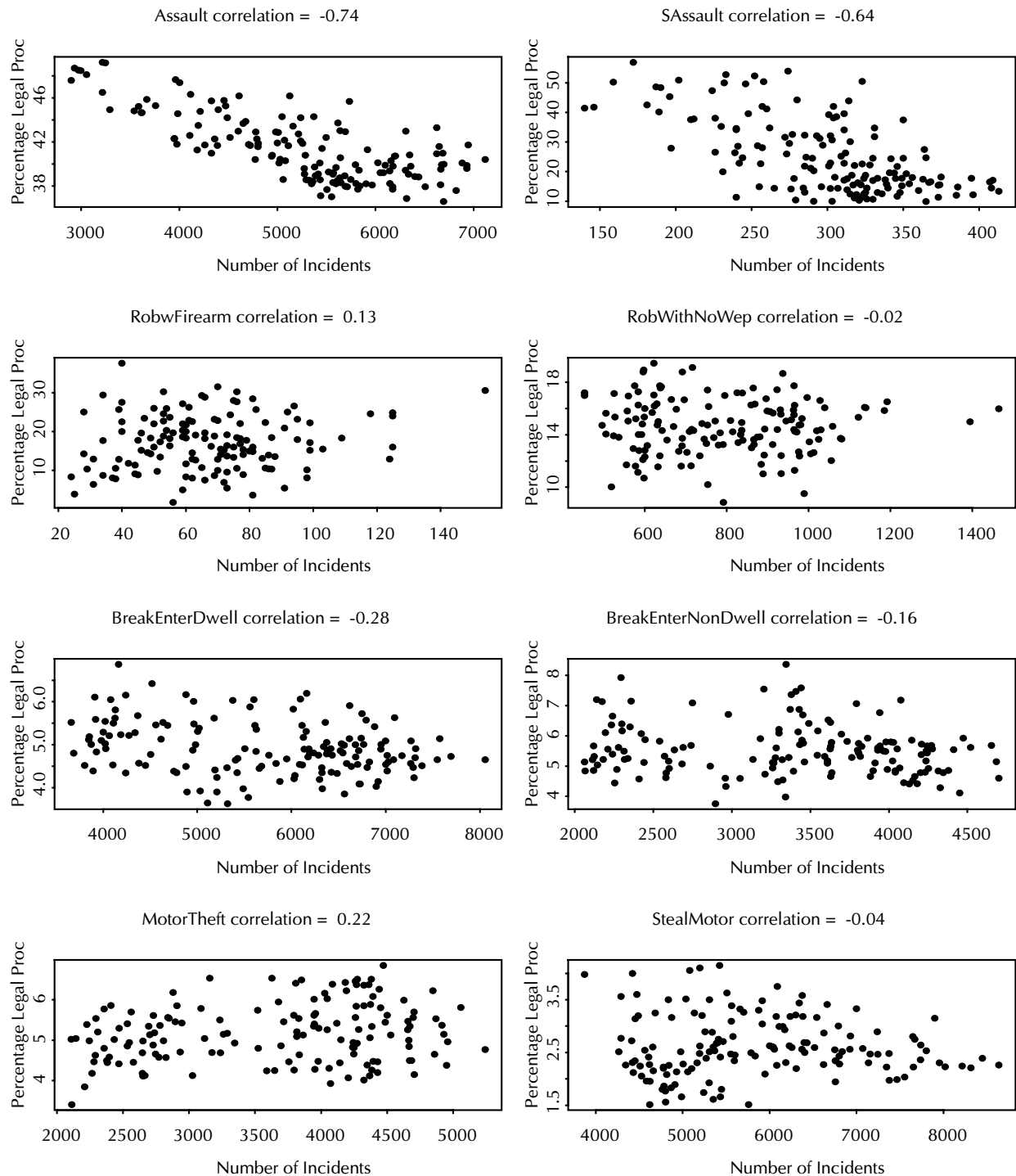
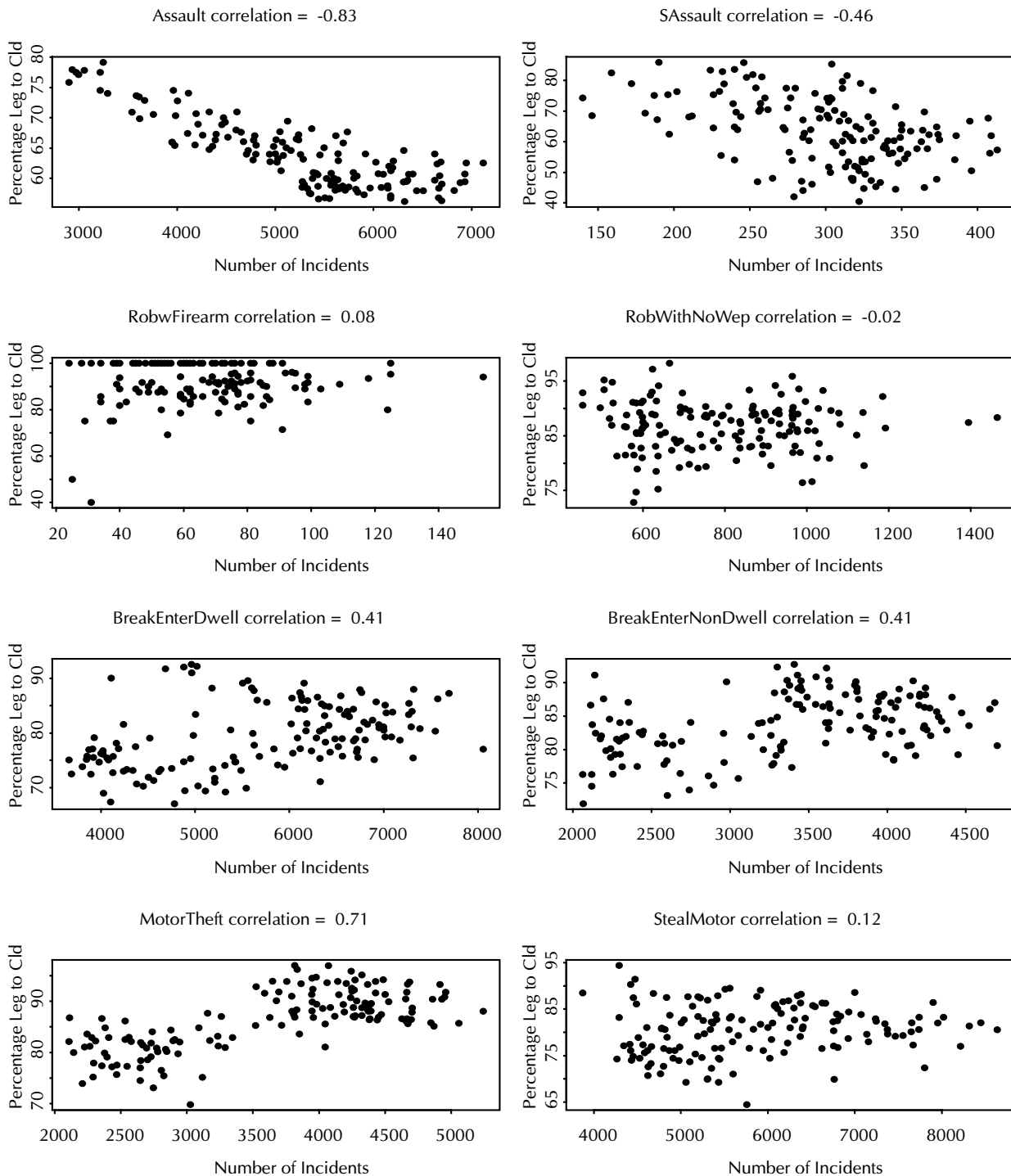


Figure 19



OBSERVATIONS ON EACH CATEGORY OF CRIME

1.1 ASSAULT

Referring to Figure 1 of Appendix A it can be seen that the total number of Assault cases recorded has an upward trend from 1995 to 2003 which then flattens out for the rest of the investigation period. There is a reasonably strong seasonal pattern superimposed on this trend with a peak in summer.

The total number cleared and the total number of proceedings have similar trends and seasonal patterns as the total number recorded – see Figure 2 of Appendix A. Both show a distinctly unusual low value in July 2003 (shown as the solid isolated point). “The crime data anomaly in July 2003 occurred because there was a significant change in the way police proceeded against offenders. We think the change might have produced a temporary delay in the recording of legal process data in the police system (COPS)” [pers comm via email from Dr Weatherburn]. In the course of our various regression analyses we adjust for this isolated outlier using a dummy variable for the month of July 2003. We also examined if there was a ‘catchup’ effect over the subsequent few months and could not detect a significant compensatory increase in numbers cleared or charged.

Time series plots of the three outcome variables listed above are shown in Figure 2 of Appendix A. The clear up rate has an upward trend in the period 1995-2003 and then stabilises from 2003 to 2007. On the other hand, the percentage of legal proceedings has a downward trend in the period 1995-2003, which then stabilises and have a slight upward trend near the end of the investigation period.

The percentage of legal proceedings to cleared has similar pattern to percentage of legal proceedings.

Note that there is a slight seasonal effect in the Percent Cleared series which is mainly concentrated in increased values for December, January and February. However the seasonal pattern is nowhere near as marked as that in the series of counts shown in Figure 1 and is even less evident in the other two series of Figure 2.

For Assault there is a tendency for the Percentage Cleared to increase with the numbers of Assaults (See Figure 20) suggesting that increased caseload associated with Assault cases is not leading to decreased clearance rates. However the opposite is the case for Percentage of legal Proceedings (see Figure 21) and Percentage of legal proceedings to cleared (see Figure 22) in which the increasing case load appears to be associated with a decreasing charge – see main report for a discussion of impact of workload on clear up and charge rates.

1.1.1 SEXUAL ASSAULT

Overall, the total number recorded has an increasing pattern with a strong increase in the period 1995-mid 1997 and then a slightly upward trend afterward. There is no obvious seasonal pattern.

The total number cleared also has a substantial increase in the period 1995 to mid1997. However, it drops sharply in the period mid 1997-mid 1998, and then has a slight downward trend over the period 1998 to 2002 after which there is no upward or downward trend.

The total number of legal proceedings has similar pattern as the total number cleared.

The percentage cleared has an obvious downward trend in the period 1995-mid 2001, which then gradually stabilises out until the end of the investigation period.

The percentage of legal proceedings has similar pattern as the percentage cleared.

The percentage of legal proceedings to cleared has a different pattern. It stays fairly level in the period 1995-mid 1998. After that, there is an obviously downward trend until later 2001. From 2001-2007, there is a slightly upward trend.

1.1.2 ROBBERY WITH FIREARM

The total number recorded shows peaks in mid 1997, mid 2001 and mid 2003, an upward trend in the period 1995-mid 1997, a downward trend in mid 1997-early 2001 and then upward in 2000 to mid 2001. It then has a downward trend with a few peaks (abrupt drop in mid 2004) until the end of the investigation period.

The total number cleared roughly follows the total number recorded with for the first half of the series.

The number of legal proceedings has a similar pattern.

The percentage cleared and percentage of legal proceedings have similar pattern. There is a fairly stable period in 1995-2000 followed by a slightly downward trend in the period 2000-mid 2004. After that, there is an obvious upward trend.

The percentage of legal proceedings to cleared stays fairly stable with some sharp drops in late 2004, which appear to be outliers. However, in the logistic regression modelling used for this series these seeming outlier do not have undue influence on the fitted models and are therefore considered to be within the expected range of variation for binomial counts.

1.1.3 ROBBERY WITHOUT FIREARM

The total number recorded of robberies without firearm has an upward trend in the period 1995-2001 with peaks in mid 1998 and early 2001. After that, there is a downward trend in the period early 2001 and early 2004, which then stabilises out until the end of the investigation period. There is no obvious seasonal pattern.

The total number cleared and number of legal proceedings have similar patterns as those for total number recorded.

The percentage cleared shows a downward bow over the period 1995-mid 1999, followed by a downward trend in mid 1999- late 2004. It then has an upward trend until the end of the investigation period.

The percentage of legal proceedings and percentage of legal proceedings to cleared appear to have similar pattern as percentage cleared.

1.1.4 BREAK ENTER DWELLING

The number recorded has an upward trend in 1995-mid 1998. It has a downward trend in mid 1998-mid 1999, and then gradually increases to a peak in Jan 2001. From 2001-mid 2004, there is an obvious downward trend which then gradually levels out until the end of the investigation period. There is no obvious seasonal pattern.

The number cleared has an upward trend in 1995-2001 followed by a downward trend in 2001-mid 2003; which then gradually levelled out until the end of the investigation period.

The number of proceedings has an upward trend in 1995-mid followed by a downward trend in 2001-mid 2003; which then gradually levelled out until the end of the investigation period.

The percentage cleared and legal proceedings follow each other closely showing an initial downward trend until 1998, with peaks in mid 1999 and late 2002. In mid 2003-late 2005 there is an upward trend followed by a downward trend in late 2005-2007. Overall the trend patterns in these series are complex.

The percentage of legal proceedings to cleared has a downward trend in 1995 to 2004, followed by an upward trend in late 2004-2005 then a downward trend until the end of the investigation period.

1.1.5 BREAK ENTER NOT DWELLING

The number recorded has an upward trend in 1995-mid 2001. From 2001-mid 2004, there is an obvious downward trend; which then gradually levelled out until the end of the investigation period. January has a higher value than other month.

The number cleared is fairly stable in 1995-mid 1999 with a hump in mid 1999 to early 2001, followed by a downward trend in 2001-mid 2003; which then gradually levelled out until the end of the investigation period. January has a higher value than other month.

The number of proceedings has similar pattern as the number cleared.

The percentage cleared and legal proceedings follow each other reasonably closely showing an overall downward trend to mid 2001 and an upward trend thereafter. There is an additional rise and fall over the period 1999-2000.

The percentage of legal proceedings to crimes cleared has a downward trend in 1995 to 2004, followed by an upward trend until the end of the investigation period.

1.1.6 MOTOR THEFT

The number recorded has an upward trend in 1995-early 1998 and then a downward trend in early 1998 to mid 1999. After that, in mid 1999-mid 2001 the trend is upward again, followed by a downward trend in mid 2001-mid 2003; which then gradually stabilises in mid 2003-2007. This number increases in March.

The number cleared has an upward trend in 1995-mid 2001. After that, it has a downward trend in mid 2001-mid 2003; which then gradually stabilises in mid 2003-2007. This number is higher in March.

The number of legal proceedings has similar pattern as number cleared.

The percentage cleared has an upward trend in 1995-mid 2001, followed by a downward trend in mid 2001-2007.

The percentage of legal proceedings has similar pattern.

The percentage of legal proceedings to cleared, however, has a different pattern. It has a downward trend in 1995-late 2003. After that, it seems to be fairly stable.

1.1.7 STEAL MOTOR THEFT

The number recorded has an upward trend in 1995-mid 2001, followed by a downward trend in mid 2001- mid 2004. It then levelled out in the period mid 2004-2007. October has a higher value than other months.

The number cleared has a slight upward trend in 1995-mid 2001. After that, it has a downward trend in mid 2001-late 2004; which then gradually stabilises until the end of the investigation period. October has a higher value than other months.

The number of legal proceedings has similar pattern as number cleared.

The percentage cleared has a slight downward trend in the period 1995- early 2001. After that it stays fairly level. There is a point in April 1995 which appears to be an outlier.

The percentage of legal proceedings has similar pattern.

The percentage of legal proceedings to cleared, however, has a different pattern. It has a downward trend in 1995-late 2003. After that, it seems to be fairly stable.

APPENDIX B

Graphs of time series
from Court data

Figure 1

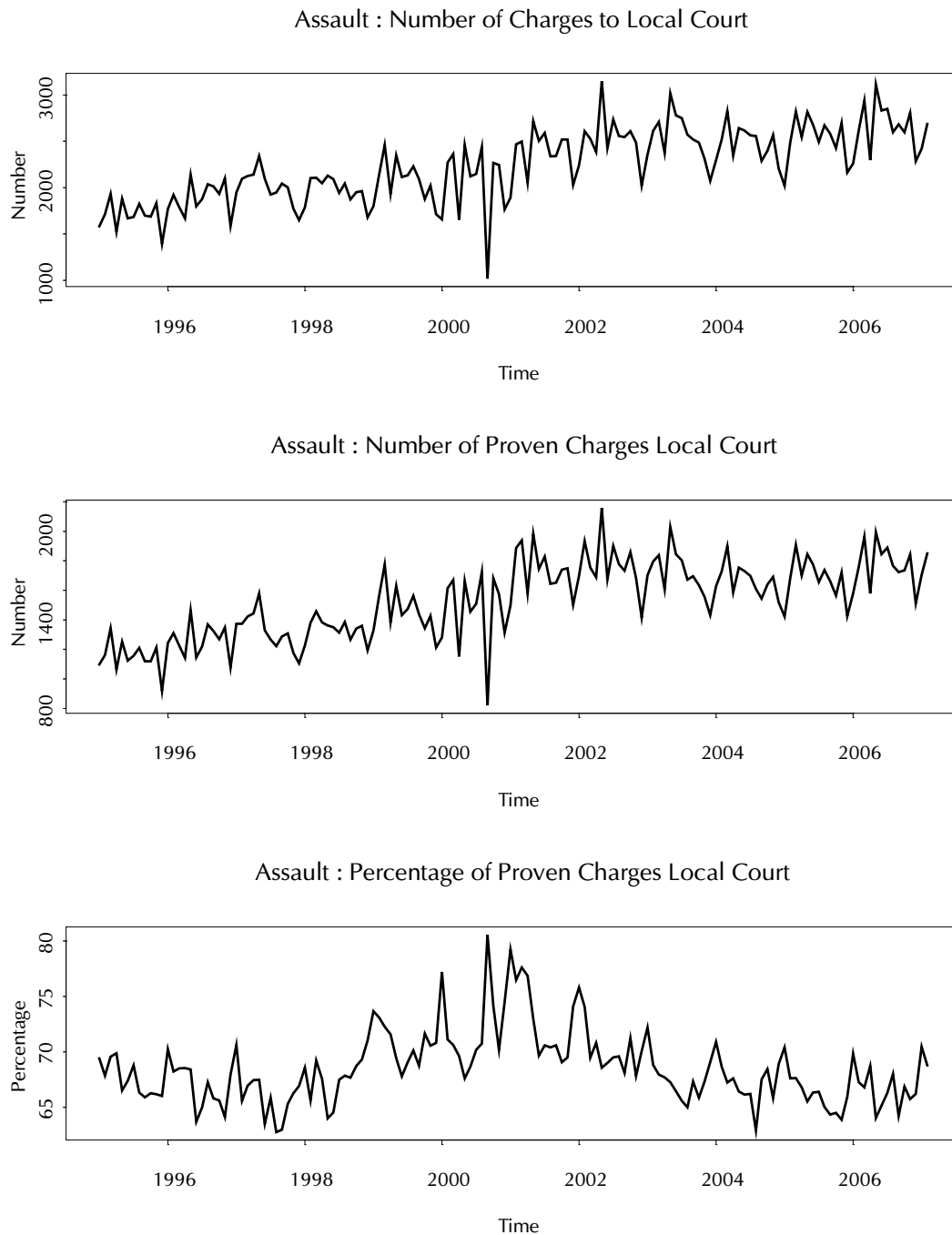


Figure 2

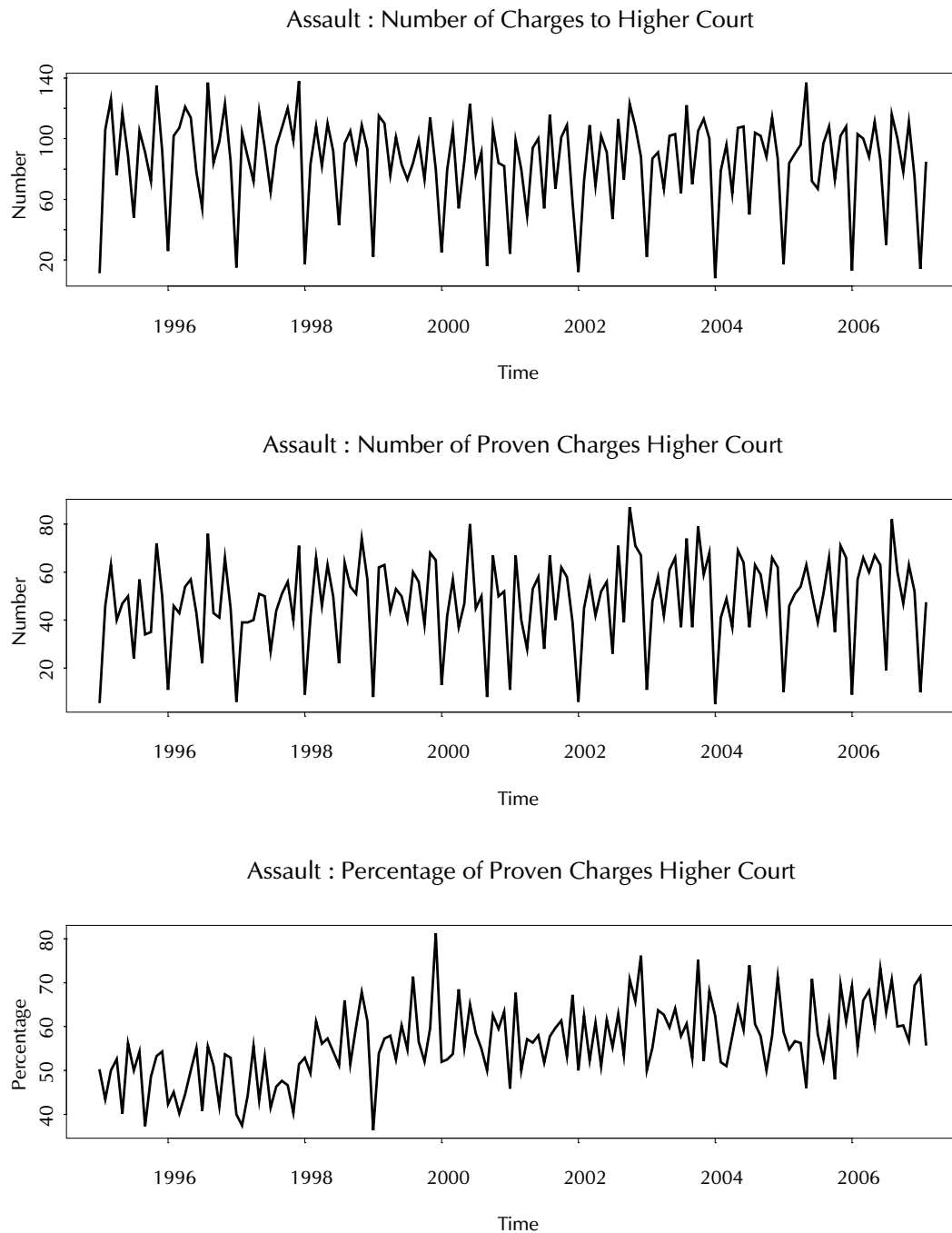
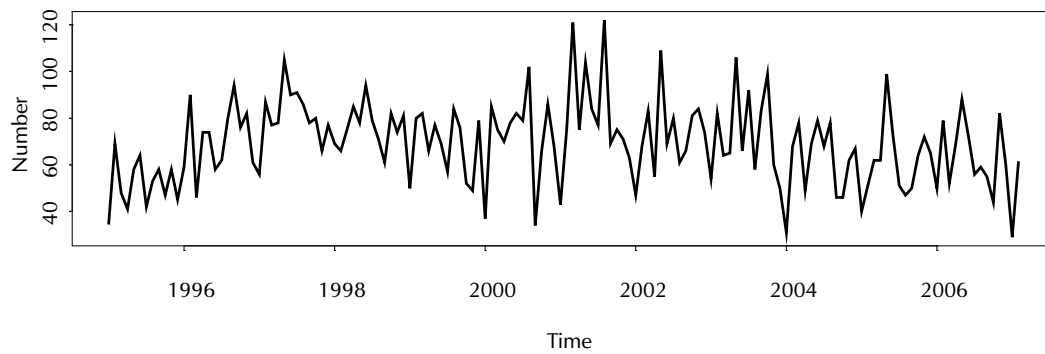
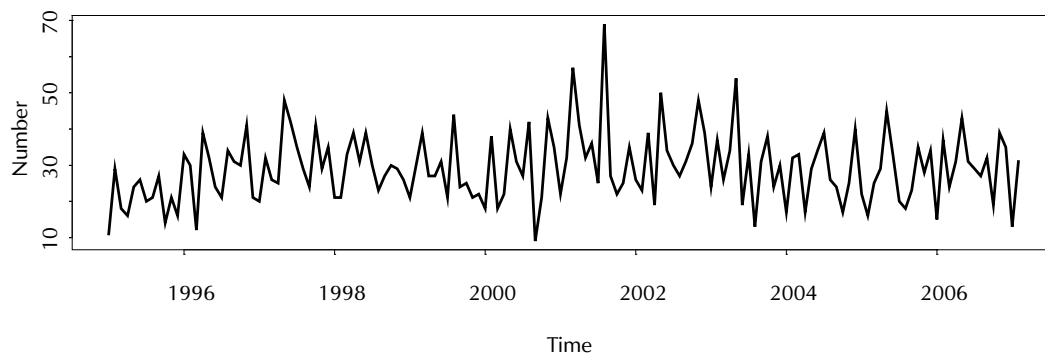


Figure 3

Sexual Assault : Number of Charges to Local Court



Sexual Assault : Number of Proven Charges Local Court



Sexual Assault : Percentage of Proven Charges Local Court

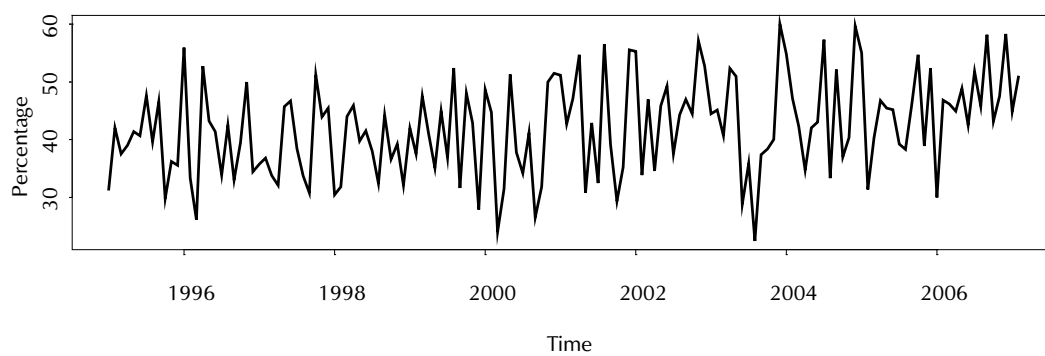


Figure 4

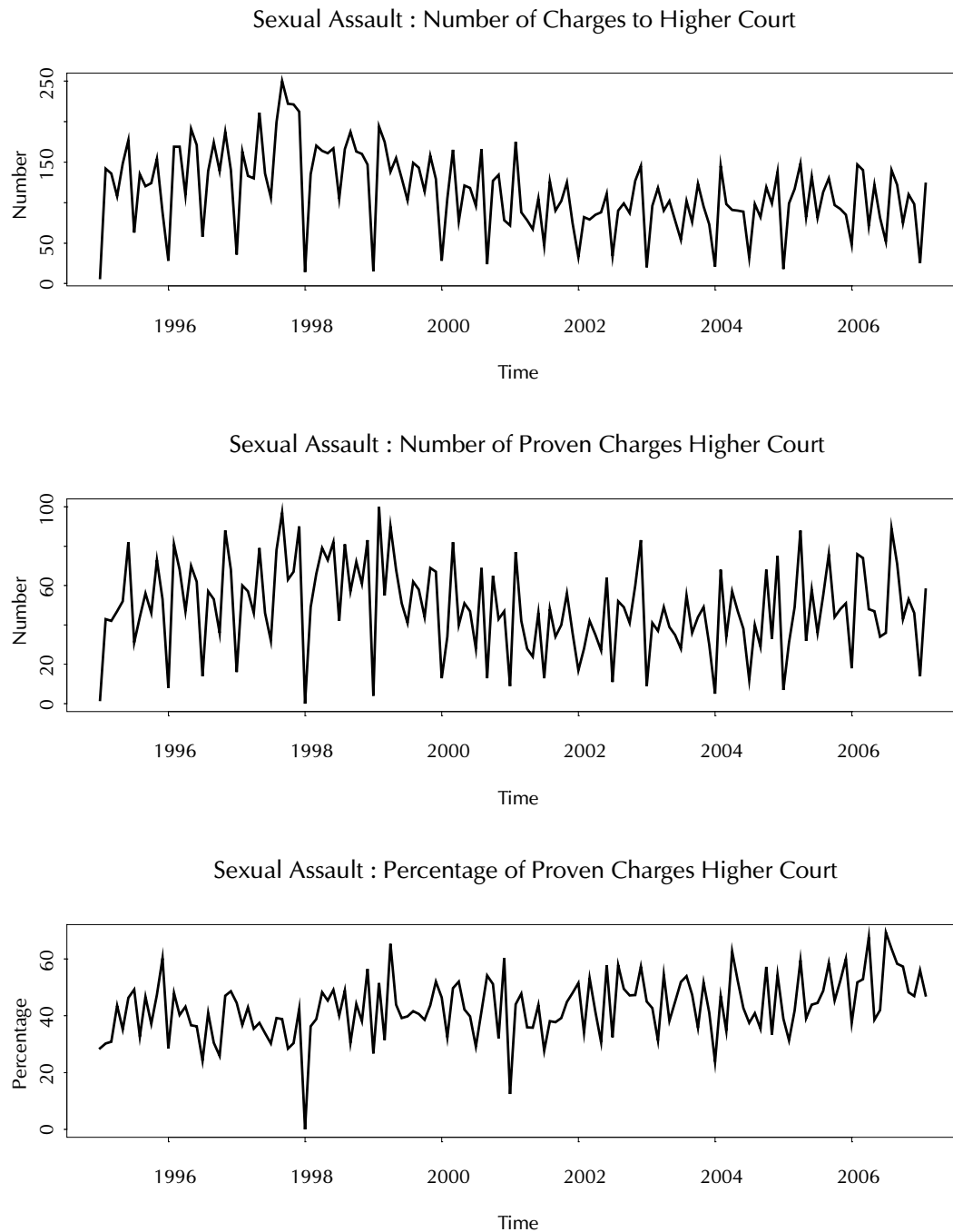


Figure 5

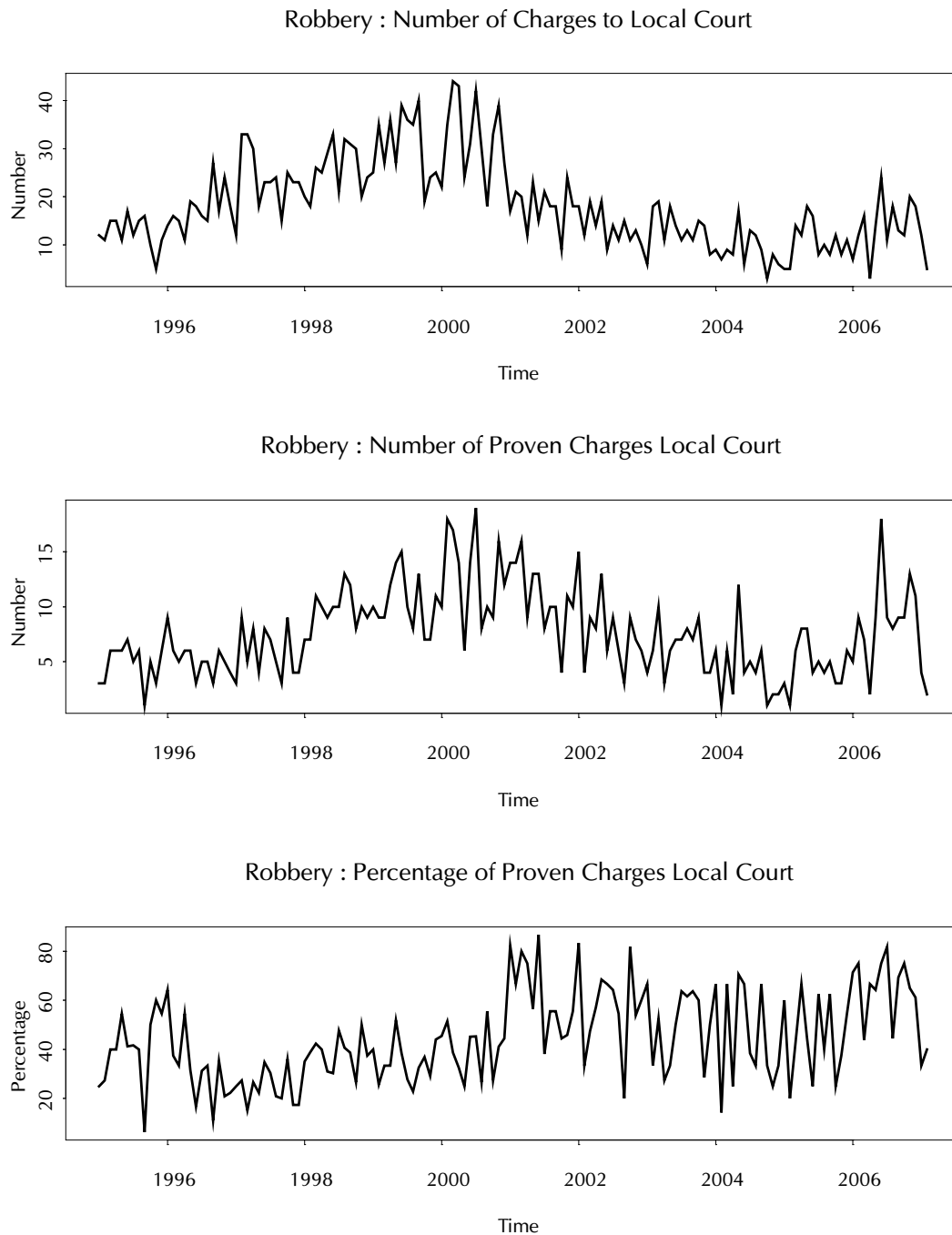
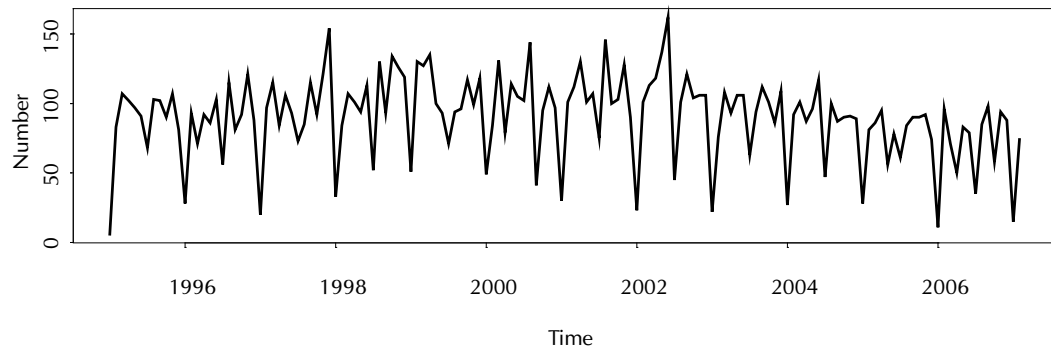
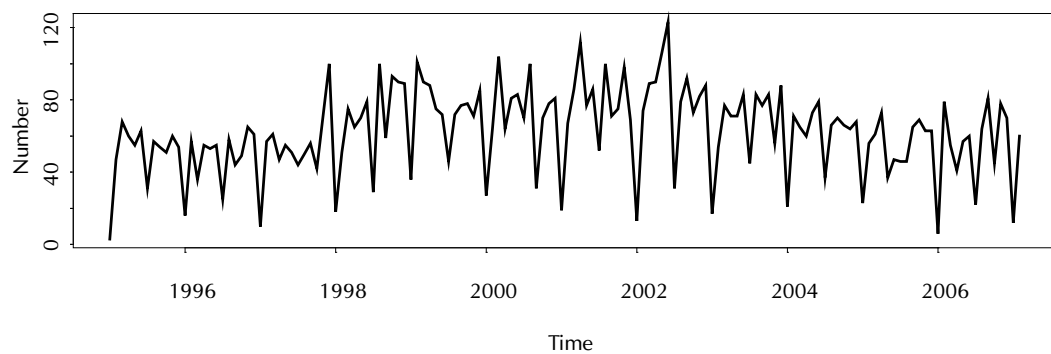


Figure 6

Robbery : Number of Charges to Higher Court



Robbery : Number of Proven Charges Higher Court



Robbery : Percentage of Proven Charges Higher Court

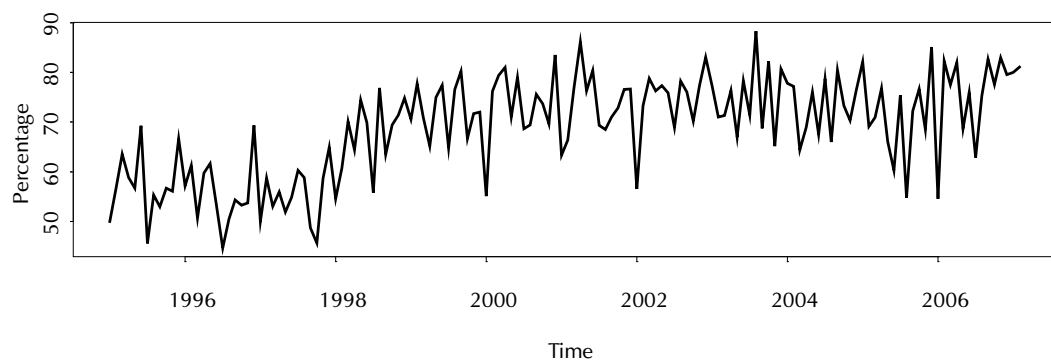
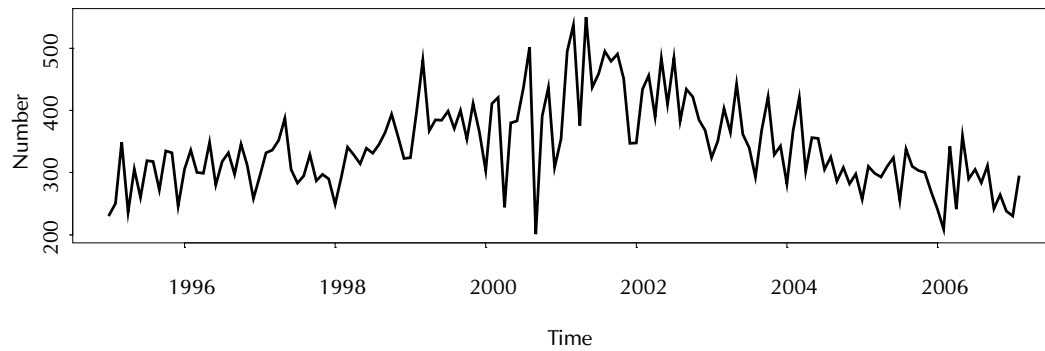
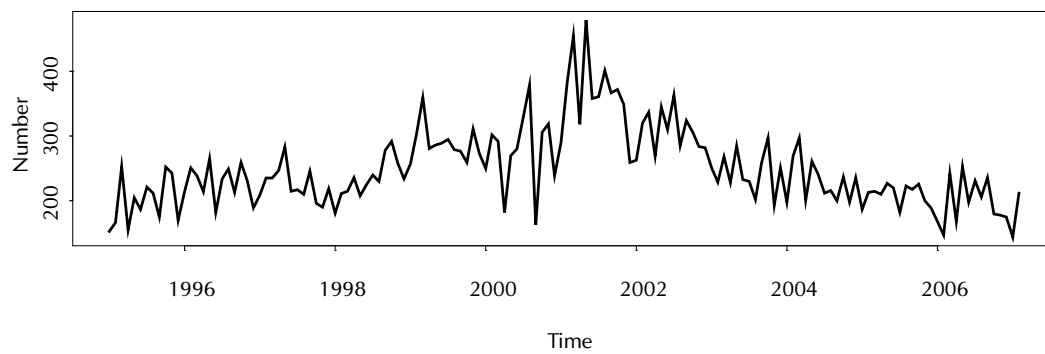


Figure 7

Break and Enter : Number of Charges to Local Court



Break and Enter : Number of Proven Charges Local Court



Break and Enter : Percentage of Proven Charges Local Court

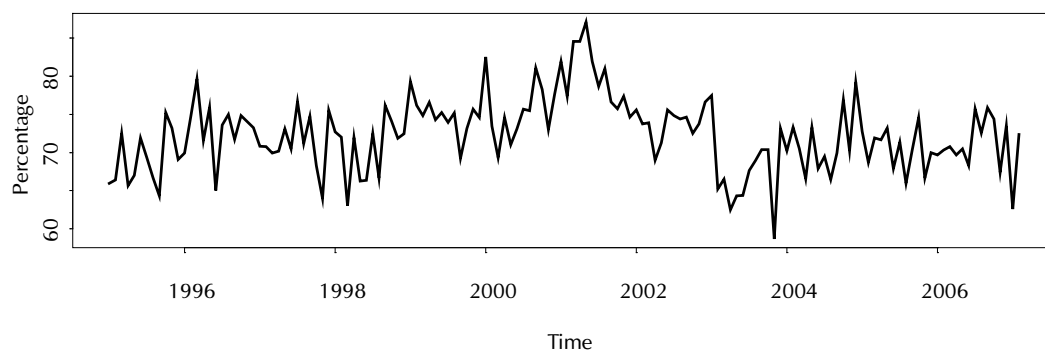
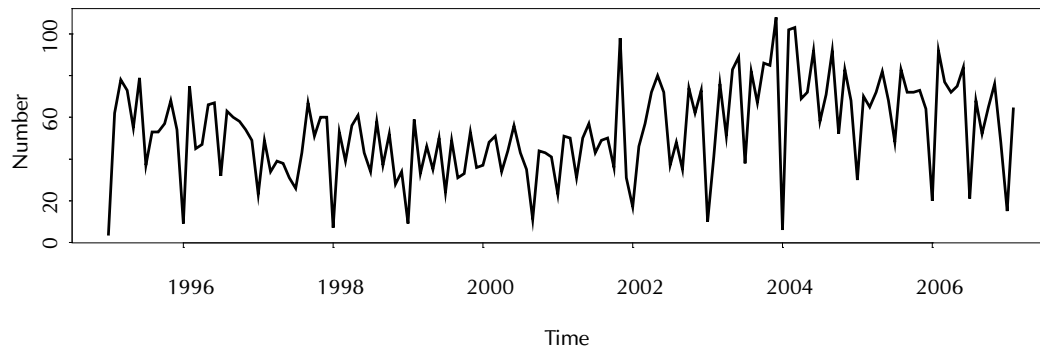
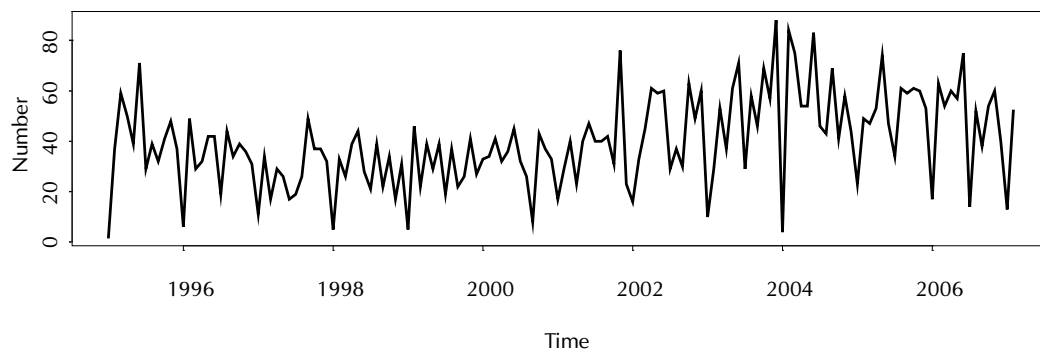


Figure 8

Break and Enter : Number of Charges to Higher Court



Break and Enter : Number of Proven Charges Higher Court



Break and Enter : Percentage of Proven Charges Higher Court

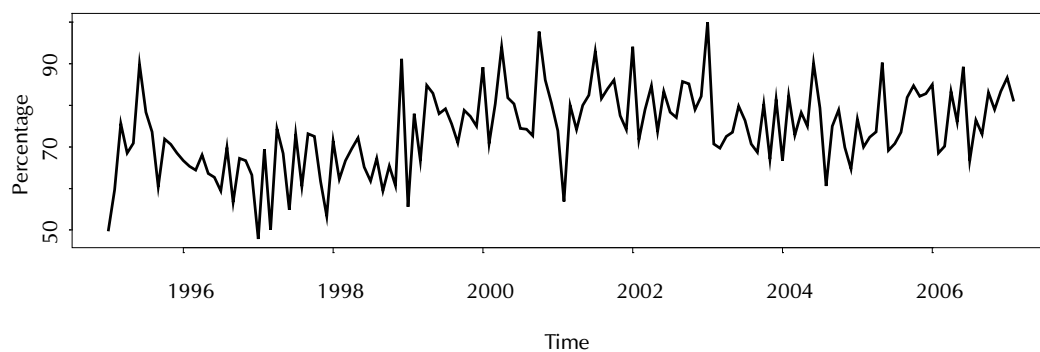
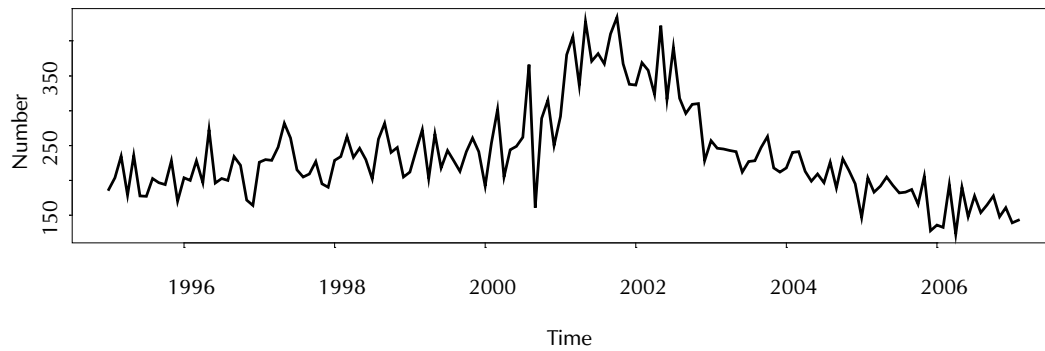
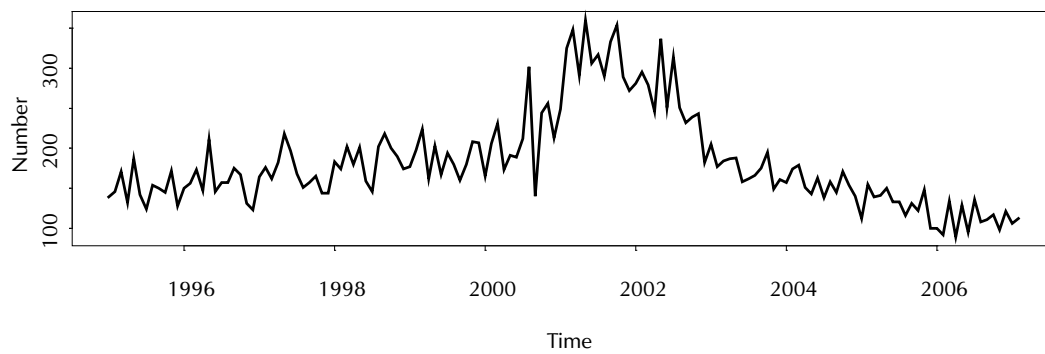


Figure 9

Motor Theft and Related : Number of Charges to Local Court



Motor Theft and Related : Number of Proven Charges Local Court



Motor Theft and Related : Percentage of Proven Charges Local Court

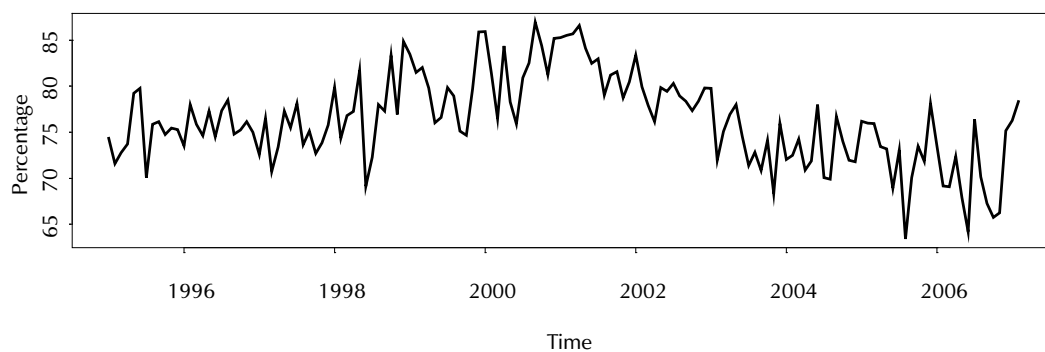
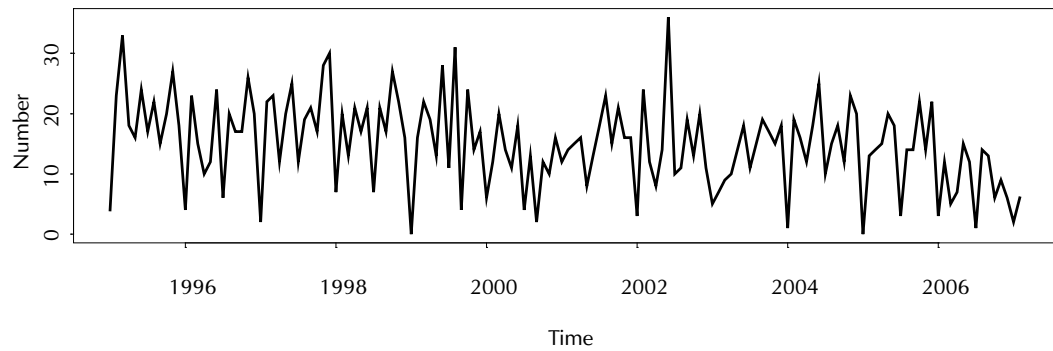
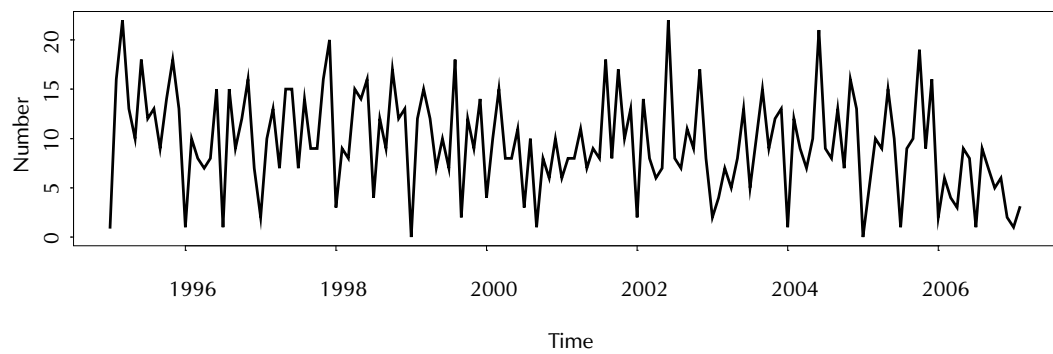


Figure 10

Motor Theft and Related : Number of Charges to Higher Court



Motor Theft and Related : Number of Proven Charges Higher Court



Motor Theft and Related : Percentage of Proven Charges Higher Court

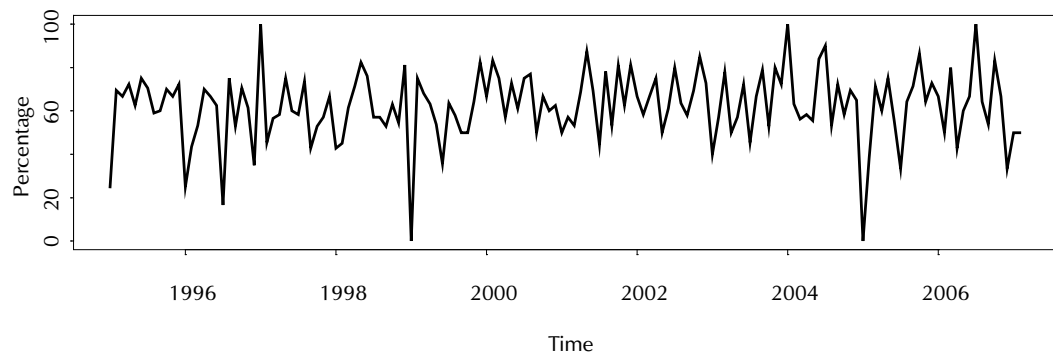


Figure 11

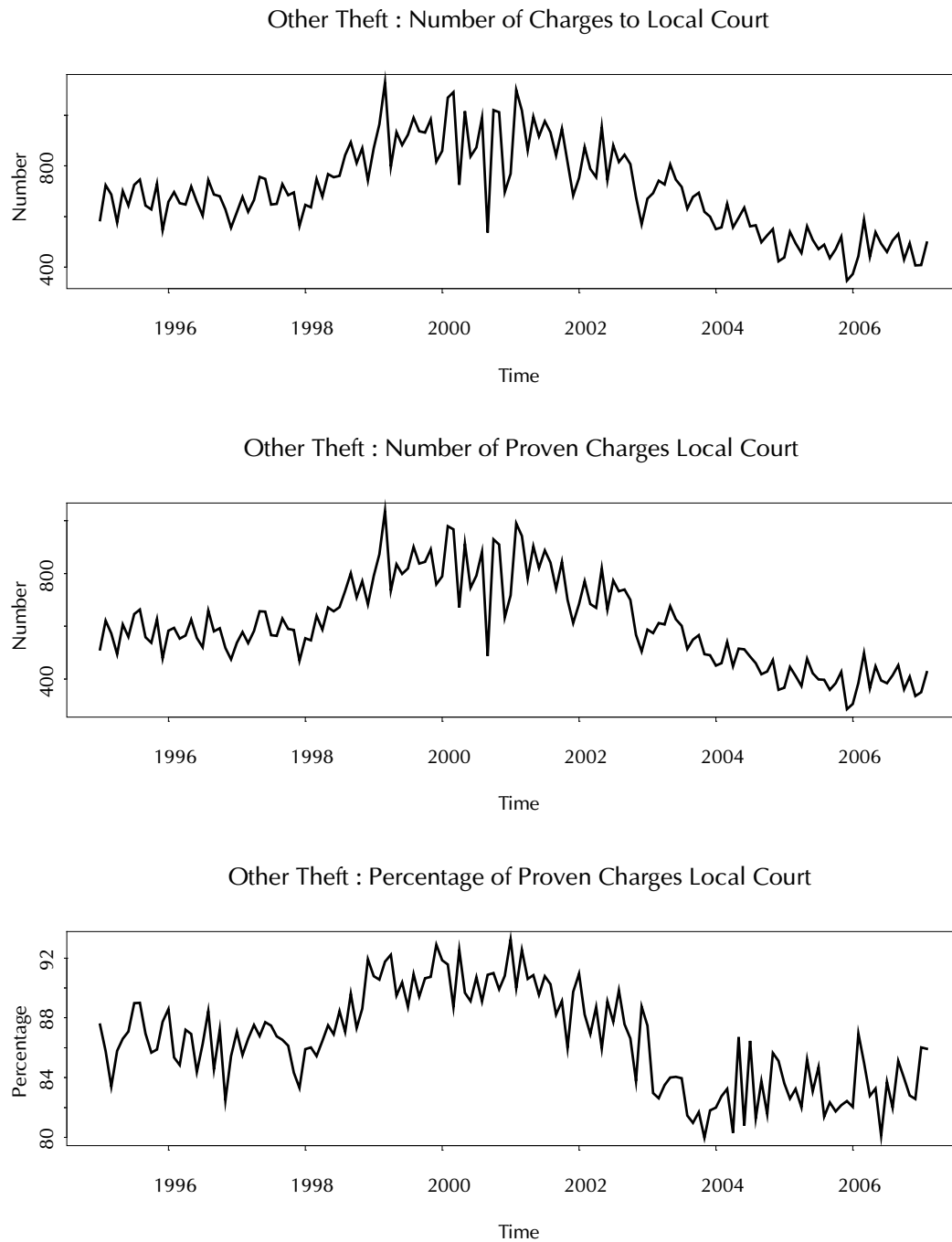
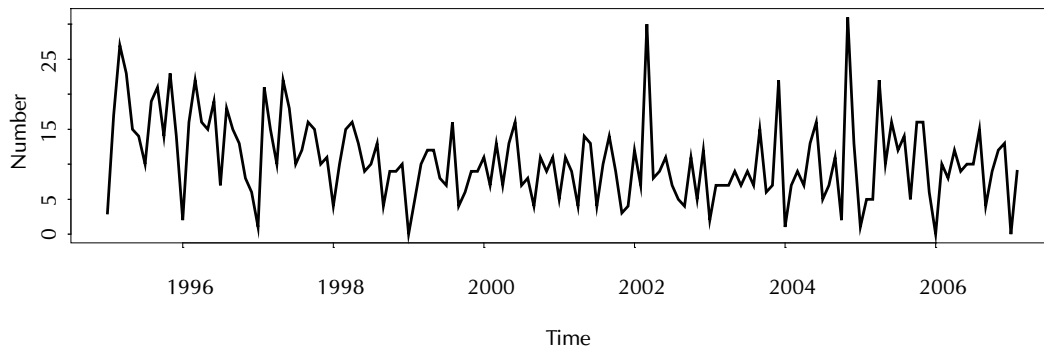
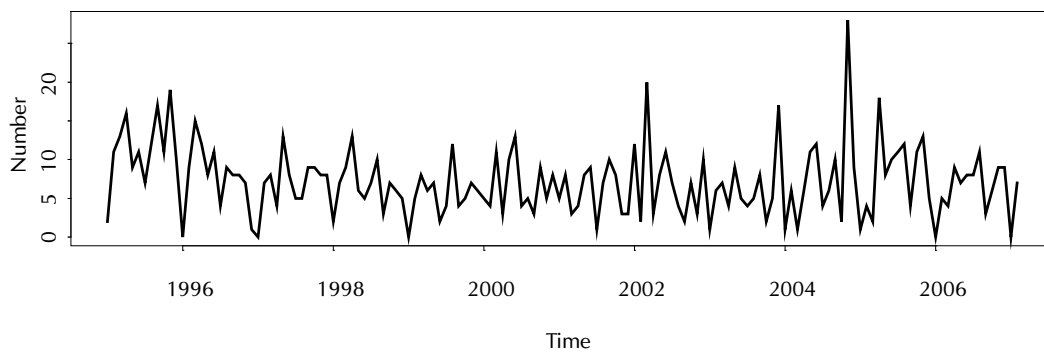


Figure 12

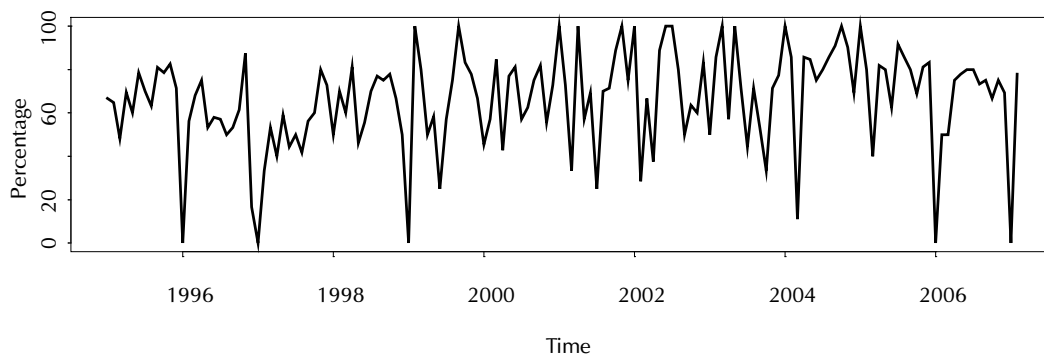
Other Theft : Number of Charges to Higher Court



Other Theft : Number of Proven Charges Higher Court



Other Theft : Percentage of Proven Charges Higher Court



OBSERVATIONS ON EACH CATEGORY OF CRIME

1.1 PRELIMINARY ANALYSIS FOR ASSAULT

Referring to Figure 1 of Appendix B, the number of charges to local courts has an upward trend in the whole period, which is fairly stable near the end of the investigation (2003-2007). May has a higher value than other months.

The total number of proven charges in local court has fairly similar pattern.

The percentage of proven charges in local court is fairly stable in the period 1995-mid 1998. It then has an upward trend in mid 1998-Jan 2001, followed by a downward trend in Jan 2001-mid 2003. After that it is fairly stable.

The number of charges to higher court is fairly stable but there is a very strong seasonal pattern. In January, July, this number drops to very low values.

The number of proven charges in higher court has a slight upward trend.

The percentage of proven charges in higher court has an upward trend in 1995-Jan 2000, with a peak in early 2000. After that, it is fairly stable and there is no evidential seasonal pattern.

The total number of charges, total number of proven charges and the percentage of proven charges to both local and higher courts are dominated by local courts and hence have similar pattern as those for local court.

1.2 PRELIMINARY ANALYSIS FOR SEXUAL ASSAULT

The number of charges to local has an upward trend in the period 1995 to early 1997, it then stays stable in 1997-mid 2000. Mid 2000-late 2001 is a period of high fluctuation with high peaks in early 2001. There is no obvious trend in the later period, which is fairly stable near the end of the investigation (2003-2007).

The total number of proven charges in local court has fairly similar pattern with high peaks in early 2001.

The percentage of proven charges in local court fluctuates around 40 percent in the period 1995-mid 2000. After that, there is a slight upward trend.

The number of charges to higher court has an upward trend in the period 1995-mid 1997. After that, there is a downward trend until early 2002. The total number drops from around 170 to around 59. It starts increasing slightly until the end of the investigation period. In January, July this number drops to very low values. In November the number of charges to higher court is higher than other months.

The number of proven charges in higher court follows roughly the same pattern as the number of charges to higher court.

The percentage of proven charges in higher court is fairly stable in the period 1995-2002... After that, there is a slight upward trend.

The number of proven charges to courts combined has an average of around 150. There is an upward trend in 1995-late 1997. In late 1998-late 2001, there is a slight downward trend. Afterward, it stabilises.

The number of proven charges in courts combined has an average of around 60. It has similar trend as the number of charges until late 2003. From late 2003 to the end of the investigation period, there is an upward trend in the number of proven charges in courts combined.

The percentage of court proven charges fluctuates around 40% without any obvious trend until early 2001. It then has an upward trend.

1.3 PRELIMINARY ANALYSIS FOR ROBBERY

The number of charges to local court has an upward trend in 1995-early 2000, rising from around 10 to 40. This is then followed by a sharp drop in 2001 and then a slight downward trend to below 10 charges until late 2003. After that, the number of charges begins to rise until the end of the investigation period.

The number of proven charges in local court has similar pattern as the number of charges.

The percentage of proven charges in local court peaks in 1995, which then increases slightly from around 20% to around 35%. There is an sharp increase in 2001 to around 60%; which gradually decreases to around 46% in late 2005. The figure starts to rise until the end of the investigation period.

The number of charges to higher court increases steadily from around 75 to 125 in mid 2002. It then has a downward trend until the end of the investigation period (to around 50). In January, July, this number drops to very low values.

The number of proven charges in higher court is fairly stable in the period 1995-mid 1997. It sharply rises in late 1997, then have similar pattern as the number of charges.

The percentage of proven charges higher court is fairly stable until late 1997. It then sharply rises in early 1998. After that, the rate is fairly stable at around 75%.

The number of charges to courts combined has an upward trend in 1995- late 1997; followed by a period of high fluctuation but no obvious trend until mid 2002. The number has a downward trend until 2006. It then has a upward trend until the end of the investigation period. There seems to be a seasonal pattern.

The number of proven charges in courts combined is fairly stable in the period 1995-mid 1997. It sharply rises in late 1997, then have similar pattern as the number of charges.

The percentage of proven charges higher court is fairly stable until late 1997. It then sharply rises in early 1998. After that, the rate is fairly stable at around 70%.

1.4 PRELIMINARY ANALYSIS FOR BREAK AND ENTER

The number of charges to local court is stable in 1995-late 1997 (around 300); followed by an upward trend in late 1997-early 2001 (around 500). After that, the number decreases to around 250 in the end of the investigation period.

The number of proven charges in local court has similar pattern as the number of charges.

The percentage of proven charges local court has an upward trend in 1995-early 2001 (65% -95%). After that, it has a sharp downward trend in 2001-early 2002. It then stays fairly stable at around 70%.

The number of charges to higher court has a slight downward trend in 1995-early 2001. It then has a sharply upward trend in 2001-early 2004; rising from around 40 to 100. After that it gradually decreases until the end of the investigation period to around 70. In January, July, this number drops to very low values.

The number of proven charges in higher court has similar pattern.

The percentage of proven charges higher court has a stable period 1995-late 1998 with a peak in mid 1995. After that there was a sharp increase in late 1998-early 1999; raising from around 60% to around 80%. It then slightly increases until early 2003. In 2003 there was a sharp drop in this figure to around 75%. It then has a slightly upward trend until the end of the investigation period.

Those figures for courts combined have similar pattern to those of local court since local court has much higher number of charges (average of 350 vs 60)

1.5 PRELIMINARY ANALYSIS FOR MOTOR THEFT AND RELATED

The number of charges to local court has a slight upward trend in 1995-late 1999 (from around 225-250). In 2000, there was a strong rise to more than 400, it stays at that level until mid 2002 and then dropped to around 250 in 1 year. It then gradually decreases to 150 in the end of the investigation period.

The number of proven charges seems to have similar pattern.

The percentage of proven charges local court also has similar pattern but with higher fluctuation (around 70%-85%)

The number of charges to higher court is much smaller (average of less than 20). Overall there seems to be a downward trend from around 20 to around 10 in the end of the investigation period. In January, July, this number drops to very low values. The number of proven charges has similar pattern.

The percentage of proven charges higher court has an upward trend from around 65% to around 75% in the end of the investigation period.

Overall, the figures for courts combined have similar patterns to local court since the majority of crimes were sent to local court (250 vs 20).

1.6 PRELIMINARY ANALYSIS FOR OTHER THEFT

The number of charges to local court has a stable period 1995-early 1998. After that, there is an upward trend in 1998 (from around 600 to 900); which then stays at that level in the period 1998-mid 2001. This figure has a downward trend until late 2004; drops to around 500. It then stays fairly stable until the end of the investigation period.

The number of proven charges has similar pattern.

Interestingly, the percentage of proven charges local court also has similar pattern (around 80-92%).

The number of charges to higher court is much smaller (average of around than 15). It has higher fluctuation from 0 to 30. In January, July, this number drops to very low values.

The number of proven charges has similar pattern.

The percentage of proven charges higher court fluctuates from 0 to 100%

Those figures for courts combined have similar patterns to local court since the majority of crimes were sent to local court (600 vs 15).

