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ECONOMIC ASPECTS OF MARIJUANA*

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1. INTRODUCTION

The marijuana industry is of interest to economists for several reasons. First, although official data are lacking, the available estimates indicate that the industry is of substantial size. For example, about one-third of all Australians admit to having tried it, and a much larger proportion of young people have done so (see National Drug Strategy Household Survey, various issues, for details). Additionally, Clements and Daryal (2005a) estimate that expenditure on marijuana is about three-quarters of beer sales and twice wine sales. Although these estimates are subject to considerable uncertainties, all the indications are that the marijuana sector is of sufficient size to merit careful investigation.

A second reason making the economics of marijuana of interest is that it forms the basis of appealing teaching material, possibly because young people tend to be the more intensive users, and because its illicit nature endows marijuana with some form of edgy mystique that captures the imagination of students. Marijuana provides nice examples for lively classroom discussions of demand analysis (what are the substitutes for marijuana and what is its price elasticity of demand?); the demand and supply model (the effects of legalisation of marijuana on the price and quantity transacted); the role of technological change in lowering prices to consumers (the switch to hydroponics techniques for growing marijuana in the 1990s); and the economics of packaging (why are there substantial discounts for bulk purchases of marijuana?).

A third reason for interest in marijuana relates to public finance issues. As its production and consumption are illegal, marijuana escapes the tax net. Can producers of alcoholic beverages -- substitutes for marijuana -- legitimately argue that on the basis of competitive neutrality, marijuana should be legalised and taxed in a similar manner to them? If so, exactly how should marijuana be taxed? The possibilities include a uniform rate applied to marijuana and alcohol; Ramsey optimal taxes that balance revenue requirements with deadweight losses; and using taxes to correct any externalities in consumption. There are also related public policy issues associated with marijuana: Exactly what are the health consequences of marijuana usage and to what extent are these external effects justifying policy intervention? What is the case for regulating consumption and what are the least-cost policy instruments?

Finally, the illicit nature of marijuana presents both intriguing challenges and opportunities for research. As producers and consumers have incentives to conceal their activities, information on the marijuana industry is not readily available and has to be complied using unconventional and indirect methods and sources. The criminal aspect of marijuana opens up research possibilities regarding the impact of expected penalties on consumption, issues of asymmetric information about product quality, risk-return tradeoffs, etc. We could also usefully ask, can conventional microeconomic analysis be applied to marijuana that is not only illicit, but also has mind-altering effects on users? In this sense, the economic analysis of marijuana can be viewed as a form of "stress-testing" of theory.

This paper provides an overview of economic dimensions of the marijuana industry and in a number of ways, compares and contrasts economic characteristics of marijuana with other products. This comparison involves the following elements:

- We compare consumption patterns of marijuana with those of alcohol, tobacco and other drugs to reveal interesting similarities and differences. For example, it is likely that marijuana and alcohol are substitutes in consumption, so that policies that serve to reduce marijuana usage by increasing its price (such as a police crackdown on production), would be likely to encourage drinking. A further example is that to a first approximation at least, the price sensitivity of the demand for marijuana is the same as that of beer, wine and spirits -- each of these products has a price elasticity of about minus one-half.
- An analysis of marijuana prices in different regions of Australia reveals a surprising degree of dispersion which is much larger than that of regional incomes, but of the same order as the dispersion of house prices. This finding points to the importance of local processing and distribution costs, in addition to the cost of the "raw" product, in determining marijuana prices.
- Over time, the relative price of marijuana has fallen substantially, much faster than the prices of many other primary products which tend to fall at about 1-2 percent p. a. on average. We argue that this fall in prices is likely to be due to part of the benefits of productivity improvement in the growing of marijuana (associated with the adoption of hydroponic techniques) and/or a softening of community attitudes to marijuana usage that has lead, in one way or another, to a lowering of the risk of incurring substantial criminal penalties.
- The unit price of marijuana declines by as much as 50 percent when purchased in the form of an ounce rather than a gram. We show that once this discount is formulated in a manner that is comparable across widely different types of products (in the form of what we call the "discount elasticity"), it is more or less the same as that available for grocery products, as well as other illicit drugs. This leads to the elegantly simple pricing rule that a 10 percent rise in the package size of a product is associated with a

2.5 percent reduction in the unit price. That such a pricing rule applies to a number of products in addition to marijuana seems to reflect the same basic economic forces at work in a variety of different situations.

- In the late 1990s, taxation of alcohol and tobacco consumption in Australia generated almost $700 per capita p. a. If marijuana were legalised and subject to taxation, the revenue-maximising rate of about 50 percent would increase tax collections by roughly $95 per capita, or 14 percent.

Thus while marijuana does have some unique characteristics associated with its illicit status, these do not seem to be sufficient to put the product in a special category requiring special treatment for the purposes of economic analysis.

The structure of the paper is as follows. Sections 2 and 3 present detailed empirical evidence from nationally-representative drug surveys on marijuana consumption patterns, as well as econometric analyses of the socioeconomic determinants of marijuana consumption. The identification of those groups in society who have a high propensity to use marijuana is valuable for designing better-targeted drug education programs. We also investigate in Section 3 the correlation between marijuana usage and that of other legal and illegal drugs, emphasising the importance of cross-drug relationships via unobservable personal characteristics. Such information could help to understand the indirect effects of an education campaign or policy pertaining to one drug within a multi-drug context. The next two sections of the paper -- Sections 4 and 5 -- discuss intriguing patterns in marijuana prices, viz., pronounced regional price differences, the substantial fall in prices over time and quantity discounts. Sections 6 and 7 deal with the price sensitivity of marijuana consumption, and its interrelationship with drinking patterns. We then turn in Sections 8 and 9 to something a bit more speculative, the likely impacts of the legalisation of marijuana consumption. This material includes survey information on the possible changes in marijuana usage, as well as the indirect effects on usage of substitute products, alcoholic beverages. We also investigate the possibilities afforded by legalisation for the government to tax marijuana consumption. Section 10 contains some concluding comments.

2. WHO USES MARIJUANA?

This section provides a descriptive analysis of marijuana consumption patterns in Australia. An econometric analysis of these patterns is carried out in the subsequent section. We commence with a description of data sources.

The most comprehensive data source in Australia for individuals' consumption of recreational drugs is the National Drug Strategy Household Surveys (NDSHS). These are nationally representative surveys of the non-institutionalised civilian population aged 14 and above in Australian households, and contain information on individuals' knowledge, attitudes and behaviour in relation to drugs. The NDSHS have been conducted eight times since 1985, the latest referring to 2004. Households were selected by a multi-stage, stratified area sample design to provide a random sample within each geographical stratum. Once a household was contacted, the respondent selected was the person with the next birthday. While the earlier surveys covered a few thousand individuals each time, almost 30,000 people were involved in each of the 2001 and 2004 surveys. The questionnaire used has also become more and more comprehensive over the years, with many more questions added to more recent surveys. More rigorous measures have also been put in place in the more recent surveys to ensure confidentiality and to reduce under reporting. For example, in the last two surveys in 2001 and 2004, the self-completed "drop-and-collect" method and the computer-assisted telephone interview method were employed.

Recent Trends

According to the most recent NDSHS conducted in 2004 (AIHW, 2005), 11.3 percent of the respondents have used marijuana at least once in the past 12 months and the average age at which the Australians first used marijuana is 18.7 years old. Around one-fifth (20.6 percent) of the population said they were offered or had the opportunity to use marijuana in the 12 months preceding the survey. This availability measure is lower than the 24.2 percent in the 2001 survey. Support for the legalisation of marijuana has decreased, with 27.0 percent of the population (or 30 percent of males and 24 percent of females) in support in 2004, compared to the 29.1 percent in 2001. Interestingly, support for tougher penalties for the sale or supply of marijuana has also decreased slightly from 61.1 percent in 2001 to 58.2 percent in 2004.

Table 2.1 gives the participation rates for marijuana and several other legal and illegal drugs from the five surveys since 1993. As can be seen in the first row, about one-third of the population said they have tried or used marijuana at some time of their life, and this percentage has fluctuated only slightly in the past ten years. The figures in the second row give the prevalence of recent/current usage of marijuana. The percentage of Australians who used marijuana in the preceding 12 months declined to below 12 percent for the first time in 2004. As can be seen from the other rows of Table 2.1, participation rates for other illicit drugs are much lower than that for marijuana. Non-medical uses of speed (meth/amphetamine) and ecstasy ("designer drugs") are the next popular, with participation rates rising over the past decade. Over 3 percent used either speed or ecstasy during the previous 12 months in 2004. The prevalence rates for heroin and cocaine have declined since 1998, which may in part be due to the "heroin drought" experienced in Australia since late 2000, caused by a shortage in world supply relating to opium production in Afghanistan and the crackdown on several major trafficking groups supplying Australia.

Being legal, tobacco and alcohol are the most commonly used recreational drugs. The trends over time of participation rates for tobacco and alcohol, together with that of marijuana, are plotted in Figure 2.1. One in five Australians smoked cigarettes in 2004, but smoking has decreased by a significant 4 percentage points since 1998. On the other hand, more Australians are drinking alcohol, with the percentage drinking having increased over the past decade by 10 percentage points. These trends contrast the slight fall for marijuana participation, as shown in Figure 2.1. Participation rates for all drugs for 2004 are depicted in Figure 2.2.

Socioeconomic Characteristics of Marijuana Users

The NDSHS collected detailed information on socioeconomic and demographic characteristics of individual respondents, allowing us to study the correlations between individuals' drug-related behaviour and personal characteristics. Such information is invaluable for highlighting important factors relating to drug taking behaviour and identifying more vulnerable groups. This is crucial to the effective design and implementation of well-targeted public health and drug education programs and policies. In what follows, we present descriptive statistics on the various socioeconomic and demographic aspects of marijuana consumption. Unfortunately at the time of writing this paper, only the major summary statistics from the 2004 survey have been published, but the unit-record data have not been released, which prevents a more detailed analysis of the most recent data. Pooled data from the 1998 and 2001 surveys are used that involves over 36,000 individuals in the combined sample. We first look at the participation in marijuana usage, which relates to a binary "yes/no" type of variable, before turning to the frequency of consumption for users who have consumed marijuana in the 12 months prior to the surveys. For simplicity, we shall refer to the frequency of consumption as the "level" of consumption, but it is to be understood that the two concepts coincide only if the quantity consumed each time remains unchanged.

Marijuana Participation

Table 2.2 presents marijuana participation rates by socio-economic and demographic groups, as well as the same measure for several other licit and illicit drugs. It highlights the differences in marijuana prevalence by factors such as gender, education and income. These differences are also illustrated in Figure 2.3.[1] As can be seen, while marijuana participation among the overall Australian population is 14.4 percent, 17.1 percent of males and 12.4 percent of females use marijuana. Single individuals (22.1 percent) are significantly more likely to have used marijuana in the past 12 months than the married or de facto partnered (8.6 percent). In terms of the main activity, the group comprising those who are retired, pensioners or have home duties have a significantly lower participation rate (5.9 percent) than those who work (16.4 percent), study (24.9 percent), or who are unemployed (28.8 percent). The prevalence rates for different education levels show that those with a year-12 education have a higher chance of using marijuana (over 19 percent) than those with different levels of education (between 12.3 percent and 14.5 percent).

An individual is also more likely to participate if he/she is of Aboriginal or Torres Strait Islander (ATSI) origin and lives in a capital city. A single-parent with dependent child/children has a 25.4 percent chance of being a recent marijuana user, as compared to the 13.7 percent for the rest. In terms of personal income, low-income individuals with annual income between \$20,000 and \$30,000 show the highest participation rate relative to those with higher income or people with very low income. For incomes beyond \$30,000, the higher the personal income, the less likely a person is to use marijuana. The relationship between the participation and age is illustrated in Panel C of Figure 2.3. Young Australians between the ages of 17 to 23 are most likely to use marijuana, with the 19-year-olds having the highest participation rate of nearly 40 percent. The prevalence rate beyond the age of 19 mostly declines as individuals get older.

Next, we look at how user characteristics for other drugs compare with those for marijuana. Overall, all three illicit drugs in Table 2.2 and tobacco are associated with similar groups, while alcohol is rather different. Males are more likely to use all five drugs than

[1] Note that the figures in Table 2.2 are computed using the pooled unit record data for 1998 and 2001 and refer to the proportions of the relevant groups who have used a particular drug in the past 12 months. They are comparable to the "recently used" and "recent use" figures reported in Table 2.1 for all drugs except for tobacco and alcohol. The "recent use" figures for the two legal drugs in Table 2.1 refer to daily, weekly and less-than-weekly users, which are not strictly comparable to those in Table 2.2, where users of once or twice a year are also included.

females. Single parents are also more likely than others to use all drugs, though this occurs to a lesser extent for alcohol. Single and ATSI individuals are more likely than others to use all drugs except alcohol. People in capital cities are more likely to use all three illicit drugs and alcohol, but non-capital city residents are slightly more likely to smoke tobacco. It is also interesting to compare the income relationships for the five drugs. While marijuana and tobacco are clearly more likely to be associated with low income and alcohol participation is associated with higher income, the effects of income on cocaine and heroin usage are less straightforward. Heroin participation is highest among people with personal income between \$40,000 and \$50,000 and people with lower than \$10,000 annual income. On the other hand, cocaine is more associated with people with very high incomes of over \$60,000 and those on lower middle incomes of between \$20,000 and \$40,000.

The associations between drug participation and main activity, education and age are illustrated in Figure 2.4. In terms of main activity (Panel A), unemployed individuals exhibit the highest participation rate for marijuana, tobacco and heroin. Interestingly for cocaine, the student group has the highest participation, while those who work or are unemployed are ranked second highest. In contrast to the other drugs, alcohol participation is highest among people who are employed, while the unemployed have the second highest participation.

Turning to education, Panel B of Figure 2.4 shows that alcohol again exhibits a pattern different to the other drugs in that its participation is positively related to education attainment. For all four other drugs, those with a year-12 education have the highest participation rates. Broadly speaking, marijuana and tobacco share a similar pattern of participation in relation to education. Note that for cocaine, tertiary degree holders are the second highest users after the year-12s.

Lastly, we turn to participation rates by age for all five drugs, as shown in Panel C of Figure 2.4. For marijuana and cocaine, participation rates are highest among young people, with marijuana peaking around late teens to early twenties before declining more or less steadily and cocaine peaking over a later and wider age range of the early to late twenties. For heroin, age is less important than the other illegal drugs; while there is some volatility, the participation rate for heroin does not start to decline until the age of thirty-five or forty. Turning to the legal drugs, participation for alcohol is more of less steady after the age of twenty and only starts to decline slowly after the age of forty-five. For tobacco, the highest participation rate is for the twenty to thirty age group, then there is a slight decline for the thirty to forty age group, before a more significant decline at around the age of forty-five.

The Level of Marijuana Consumption

For respondents who have used marijuana in the preceding 12 months, the survey also asks for information about the frequency of consumption. This information is important as individuals using marijuana once or twice a year are very different from those using everyday in terms of both health consequence and targeting drug education programs. Table 2.3 presents the observed percentages for different levels (frequencies, to be precise) of marijuana participation for the whole sample, as well as by gender, main activity, education, socioeconomic and demographic groups, using the combined data of 1998 and 2001. Figure 2.5 presents graphically some of this information, as well as frequency of consumption by age.

As indicated in Table 2.3, 85.6 percent of individuals have not used marijuana over the past 12 months. Within the 100 - 85.6 = 14.4 percent who have used marijuana, 2.3 percent of the population use every day, 3.4 percent use less than daily but at least once a week, 1.9 percent use less frequently than every week but at least once a month, and 6.9 percent use less frequently than monthly but at least once in the past 12 months. Men are more likely to be in all levels of consumption than women, particularly for the heavy usage categories. Non-partnered individuals have higher proportions in all levels of consumption than married or de facto partnered. In terms of main activity, unemployed individuals are significantly over-represented in all four levels of usage especially the heavy user groups. It is also interesting to observe that while students have much higher participation rate than the employed (Table 2.2), employed individuals show a higher propensity for daily consumption than students. In terms of the highest achieved education level, individuals with a year-12 education are more likely than others to be users at all levels of marijuana consumption. Individuals with a non-tertiary diploma or trade certificate have the second highest proportions for the heavy consumption levels of weekly and daily. The results for the tertiary-educated group are interesting. With respect to infrequent and monthly use, people with degrees have higher marijuana participation rates than the group at the other end of the education scale, those with less than a year-12 education. But the reverse is true for weekly and daily use -- degree holder users are mostly infrequent users and they have a significantly lower chance than others of being daily users.

Panel E of Figure 2.5 illustrates the relationship between the levels of marijuana participation and income. The prevalence of infrequent use does not vary greatly with income, with people earning \$20,000 to \$50,000 p. a. having a slightly higher probability of being such a user. However, there seems to be a clear pattern for the weekly and daily categories whereby the proportion of users decreases as income rises beyond \$20,000. Low income earners receiving between \$10,000 and \$30,000 have the highest probability of being daily users.

Finally, turning to the relationship between consumption levels and age in Panel F of Figure 2.5, there seems to be a sharp peak around the 19 years of age for the proportion of infrequent usage, which then declines more or less consistently as age increases. However, for the frequent-usage categories, the consumption profiles are flatter and seem to plateau over the whole age range of late teens to mid-late twenties.

Marijuana and Other Drugs

Anecdotal observation suggests that marijuana consumption is closely related to other recreational drugs. For example, marijuana is frequently mixed with tobacco to smoke. In the minds of consumers, other drugs and marijuana may satisfy similar needs. In this sub-section, we present empirical evidence in the form of cross-drug descriptive statistics using data from the NDSHS. This allows us to quantify the intrinsic relationships between the consumption of marijuana and other legal and illegal recreational drugs. We first analyse the relationship between marijuana and the two legal drugs, tobacco and alcohol, and then turn to marijuana, cocaine and heroin.

Tables 2.4 and 2.5 present the sample frequencies and the estimated conditional and unconditional probabilities of the joint consumption patterns of marijuana, alcohol and tobacco. Column 5 of Table 2.4 shows that whilst 14.2 percent of the total population is estimated to have participated in marijuana consumption, 0.3+6.0+7.7=14.0 percent use marijuana in conjunction with tobacco and/or alcohol, and only 0.2 percent use marijuana by itself. The estimated conditional and unconditional probabilities in Table 2.5, based on the information in Table 2.4, highlight the correlations across the three drugs. These probabilities show that the chance of an individual participating in marijuana consumption is much higher if he or she is known to be also participating in one of the other two drugs. For example, the chance of marijuana participation is 14.2 percent for the general Australian population (first entry of column 2 of Table 2.5), but this probability increases to 16.5 percent among alcohol drinkers (third entry of this column) and to 33.8 percent among the group of tobacco smokers (last entry of this column). On the other hand, while 23.7 percent of the general population smoke tobacco, the percentage of tobacco smokers among marijuana users is much higher at 56.3 percent (column 4). These results confirm the anecdotal observation that marijuana is closely related to tobacco and alcohol in consumption.

The NDSHS data also indicate a close relationship between marijuana consumption and that of other illegal drugs. For example, Tables 2.6 and 2.7 show even stronger correlations between the consumption of marijuana, cocaine and heroin. From column 2 of Table 2.7, while

14.6 percent of individuals use marijuana, 86.2 percent of cocaine users and 90.1 percent of heroin users also consume marijuana. If an individual is known to use both cocaine and heroin, he/she is almost certainly a marijuana user with a probably of 94.8 percent, much higher than the unconditional probability of 14.6 percent. Similarly, while only 1.4 percent of the general population uses cocaine, the chance of cocaine use increases to 8.0 percent for the group of marijuana users, and to 66.9 percent among those who use both marijuana and heroin (column 3 of Table 2.7).

3. A MICROECONOMETRIC ANALYSIS OF MARIJUANA CONSUMPTION

In the previous section, we analysed some of the *observed* sample descriptive statistics pertaining to the correlations between marijuana consumption and socioeconomic and demographic factors, and between the usage of marijuana and other drugs, both legal and illegal. However, as personal characteristics are often correlated, descriptive statistics such as those presented in Tables 2.2 and 2.3 cannot isolate the effects of individual factors on drug-taking behaviour and can sometimes even be misleading. For example, while we observe a significantly higher marijuana participation rate among the unemployed, it is often the case that these individuals also have lower levels of education, lower incomes, are single, and perhaps are of an ATSI background. So the observed high prevalence among the unemployed may be partly due to the effects of these other factors, rather than being unemployed per se. Econometric models allow us to distinguish between the total and partial effects, so that the observed differences in participation can be uniquely attributed to the individual characteristics.

Similarly, while we observe high correlations between marijuana and other drugs through the conditional and unconditional frequencies in Tables 2.5 and 2.7, some of these may be explained by underlying common factors relating to observable personal characteristics (such as education levels) or prices, while others may be due to unobservable characteristics such as those related to addictive personalities. By their very nature, these unobserved factors are difficult to quantify, but can play a major role in an individual's decision to use drugs. For example, if we know that an individual is a 20-year-old single male who is unemployed, the chance of his using marijuana in a year and location where the marijuana price is cheap is higher than that of an average Australian at a time and location of low marijuana prices. However, if we also know that he is using both cocaine and heroin, we would predict an even higher probability for his use of marijuana. As indicated below, a multivariate econometric model, comprising a system of related equations, allows us to examine the extent to which the cross-drug correlations can be explained by observed personal characteristics, and the extent to which these correlations are due to unobservable factors, after controlling for differences in individuals' socioeconomic and demographic characteristics.[2]

In this section, we present econometric approaches to the analysis of marijuana consumption. In the first sub-section, we decompose the impact of a number of determinants of consumption by presenting the marginal effect of each individual characteristic on the probability of marijuana participation, controlling for all other factors, using a probit model. In the next sub-section, we analyse correlations between marijuana participation and that of other drugs due to unobservable factors, controlling for observable personal characteristics, using multivariate probit models. In the third and final sub-section, we move our focus to different levels of marijuana consumption, and investigate the partial effects of individual covariates on the probabilities of various levels of consumption, using a sequential ordered probit model. Throughout, we use the Australian National Drug Strategy Household Surveys (NHDSS), discussed in the previous section.

Modelling Marijuana Participation

Ramful and Zhao (2004) estimated a probit model that relates the probability of marijuana participation to individual socioeconomic and demographic characteristics and drug prices, using pooled data from the two surveys of 1998 and 2001. Table 3.1 presents the estimated coefficients of the model and the corresponding marginal effects on participation of the individual covariates. The marginal effects show that, holding all other explanatory variables fixed at sample means, Australian males are 4.7 percent more likely to have recently used marijuana than females. All other factors being equal, married or de facto partnered individuals have 6.9 percent lower probability of using marijuana relative to those without a partner. It is interesting to compare this marginal effect with the observed sample statistics in Table 2.2: The *observed* frequency of marijuana usage in Table 2.2 for the married or partnered

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[2] Previous econometric studies of marijuana consumption are limited due to the scarcity of data on consumption and prices. Many authors have used marijuana decriminalisation as a proxy in an attempt to estimate its price elasticity (Chaloupka et al., 1998, Farrelly et al., 2001, Model, 1993, Saffer and Chaloupka, 1998, 1999, Thies and Register 1993). Some have also investigated the economic relationship between marijuana and alcohol (Chaloupka and Laixuthai, 1997, DiNardo and Lemieux, 2001, Pacula, 1998), tobacco (Farrelly et al., 2001), and cocaine (Chaloupka et al., 1998, Desimone and Farrelly, 2003). A limited number of studies, most of which have been conducted in the US, have investigated the demand for other psychoactive substances such as cocaine and heroin (Chaloupka et al., 1998, Desimone and Farrelly, 2003, DiNardo, 1993, Grossman and Chaloupka, 1998, Petry, 2001, Saffer and Chaloupka 1995, 1999, van Ours, 2003). In Australia, despite its extensive use and abuse, only limited economic research has been undertaken on marijuana consumption. This includes Cameron and Williams (2001), Clements and Daryal (2005a), Williams (2004) and Zhao and Harris (2004).

individuals is 8.6 percent, which is more than 13 percentage points lower than that for the non-partnered (22.1 percent). This difference in the results points to the importance of controlling for other factors.

A comparison of the marginal effects of the other explanatory variables in Table 3.1 to the observed sample frequencies by personal attributes in Table 2.2 further illustrates how an econometric model allows for the partial effects of individual factors to be isolated when other factors are held fixed. Individuals with an Aboriginal or Torres Strait Island (ATSI) background have a marginal effect of 3.5 percent higher participation probability than the non-ATSIs, and single-parents are 2.3 percent more likely to use marijuana than others. These marginal effects are significantly lower than the observed differences in the sample statistics in Table 2.2. In terms of an individual's main activity, only those who are unemployed have a significantly non-zero marginal effect (4.9 percent higher probability) relative to the base group of retirees and homemakers, while the sample statistics of Table 2.2 show that all three groups of employed, students and unemployed have at least a 10 percent higher observed probability than the base group. A similar pattern emerges for educational attainment -- once other factors are controlled for, only tertiary degree holders have a significantly different participation probability (1.3 percent lower) in comparison with the base group of a less-than-year-12 education. Contrast this with the observed probabilities of Table 2.2 that show the middle two groups of year-12 and diploma educated have the highest disparities from the lowest educated base group. In fact, we actually observe a 1 percent higher participation rate for the degree holders relative to the base group, but the econometric model tells us that the marginal effect of tertiary education is significant and negative once other factors are controlled.

To further illustrate the partial effects of individual explanatory variables, Figure 3.1 gives the predicted probabilities associated with various attributes when all other factors are controlled for by setting them at sample means. Comparing Figure 3.1 with the relevant parts of Figure 2.3 for the observed sample frequencies, it can be seen that there are obvious differences.

Before concluding this sub-section, one final aspect of the results of Table 3.1 is worth mentioning. The effect of the price of marijuana on its consumption is negative, so that this good obeys of the law of demand. Additionally, the prices of heroin and cocaine both exert a positive influence on marijuana consumption, making them substitutes for marijuana. Although the coefficient of the own price is not significantly different from zero, the two cross-price coefficients are significant.

Correlation Across Drugs

The cross-drug sample statistics in Tables 2.5 and 2.7 indicate close correlations between the participation of marijuana and tobacco, alcohol, cocaine and heroin. Part of the observed correlations may be explained by the dependence of the participation probabilities on observed personal characteristics. However, unobserved personal characteristics are also likely to play an important role in determining the correlations. Personality traits such as those related to addiction are difficult to quantify, but may play a vital role in an individual's decisions relating to participation in all drugs. While it is well accepted that marijuana is closely related to other drugs in consumption, in studies explicitly addressing this relationship, it has mostly been examined through the cross-price responses of consumption (see, for example, Cameron and Williams, 2001). However, although the responsiveness of marijuana participation to changes in other drug prices has been examined previously, the correlation across decisions involving the use of different drugs for the same individual through unobservable characteristics has often been ignored.

Studies that allowed cross-drug correlations via unobservable factors are Zhao and Harris (2004) and Ramful and Zhao (2004). Ramful and Zhao (2004) estimated a trivariate probit model for the joint decision of participation in the three illicit drugs marijuana, cocaine and heroin, using pooled data from the 1998 and 2001 surveys. The trivariate approach allows for correlations across the error terms of all three probit equations, and then the three equations are estimated jointly as a system. Panel A of Table 3.2 shows the estimated correlation coefficients of the errors from the model for the three illicit drugs. These indicate that after accounting for the observable covariates, the correlations among the three drugs are still very high: 0.84 between the two hard drugs of cocaine and heroin, 0.65 between marijuana and cocaine, and 0.59 between marijuana and heroin, all of which are significantly different from zero.

Using a similar model for marijuana, tobacco and alcohol with the combined data from the three NDSHS surveys of 1995, 1998 and 2001, Zhao and Harris (2004) estimated the three correlation coefficients after controlling for observed covariates. These are given in Panel B of Table 3.2. The results show that, after accounting for the observed personal characteristics and prices, there are significant correlations between marijuana and the two legal drugs via unobserved factors, with the correlation of marijuana with tobacco being as high as 0.5.

Knowledge of these correlations can help greatly in the prediction of an individual's marijuana participation probability when knowledge of his/her participation in other drugs is available. Similarly, information on marijuana participation will also help with predicting probabilities of participation in other drugs. Table 3.3 presents some predicted unconditional, conditional and joint probabilities using both the univariate probit (UVP) models and the multivariate probit models (MVP). The UVP models ignore the cross-drug correlations via the unobserved error terms, while the MVP models account for such correlations. For example, the left-hand part of Table 3.3 shows that not using information on the correlations, the UVP model implies that for an individual with personal characteristics controlled for by setting them at sample means, the probability of him/her being a marijuana user are predicted is 9.5 percent, independent of knowledge of his/her participation in other drugs. However, when such correlations are accounted for using the MVP model, the predicted probability of marijuana usage increases to 79 percent if the person is known to be a cocaine user, while the probability increases still further to 87 percent if he/she is a user of both cocaine and heroin. The right-hand part of Table 3.3 reports the results of applying the probit models to marijuana, alcohol and tobacco. As can be seen, the predicted probability for marijuana participation for an 'average' Australian changes from 11 percent to 27 percent if the extra information is available that the person uses both alcohol and tobacco. This probability decreases to only 1.5 percent if the person is known to be abstaining from both of the two legal drugs.

The predicted joint probabilities are also different. Accounting for the cross-equation error correlations, the joint probability for an average individual with mean values of personal characteristics to be using marijuana, alcohol and tobacco is predicted to be 5.2 percent, while the univariate model predicts a mere 2.2 percent probability (see the last entries of the two columns on the far right of Table 3.3). This compares to an observed frequency of 7.7 percent in Table 2.4 when personal characteristics are not controlled for.[3]

Consider the effect on the probably of an individual using marijuana of a change in an independent variable, such as the employment status of the person. When the UVP model is used, this marginal effect is the same whether or not the individual uses any other drug. That is to say, the UVP model implies that the marginal effect is independent of other drug usage. But this is not the case with the MVP model, where the marginal effect depends on other drugs. This aspect of the multivariate approach is illustrated in Table 3.4 in the context of the probit model for marijuana, cocaine and heroin. As can be seen, many of the marginal probabilities

[3] Note that the predicted marginal probabilities for marijuana from the two models [(i) marijuana, cocaine and heroin and (ii) marijuana, alcohol and tobacco] are rather different as they use different data, from 1998-2001 for model (i) and 1995-2001 for model (ii). Also note that there are sight differences in the predicted marginal probabilities from the UVP and MVP models. This is due to two reasons. First, there are slight differences in the included sample observations as there are more missing observations for the MVP model. Second, even though both models provide consistent estimates of the true marginal probability, differences can arise due to sampling variability. In any event, the differences are small in magnitude.

change substantially as we move across the rows. Panel A of Figure 3.2 plots the results from the row for "Unemployed" in Table 3.4. This shows that with other factors held constant by setting them at sample means, an unemployed person is about 5 percent more likely to participate in marijuana consumption than the base group of retirees, pensioners and homemakers. However, among heroin users, or the cocaine users, the effect of unemployment is to increase the probability of marijuana use by almost 10 percent. Interestingly, in the subgroup of individuals who use both heroin and cocaine, the marginal effect of unemployment on the marijuana participation probability is slightly lower at 7 percent.

As another example, consider the impact of marital status on marijuana usage. Panel B of Figure 3.2 shows that married or de facto partnered people in general have almost a 7 percent lower probability of using marijuana. But for those who are already using both heroin and cocaine, the marginal effect on marijuana usage of being partnered is much lower, with the probability being only 3.6 percent lower. This seems to suggest that, although in general partnered people are much more unlikely to use marijuana in general, among serious drug users who use both heroin and cocaine, being married or living with a de facto partner does not reduce as much the chance of the person also using marijuana. These results illustrate the extra insight afforded by the multivariate approach.

Modelling the Level of Marijuana Consumption

We now turn to the relationship between individual characteristics and the level of marijuana consumption. Table 2.3 shows how the observed sample frequencies for various levels of marijuana consumption differ by socioeconomic and demographic groups. However, as in the case of participation, an econometric model is required to isolate the partial effects of the individual explanatory factors when the influences of other factors are controlled for.

Zhao and Harris (2004) studied the determinants of different levels of marijuana by using a sequential decision-making approach. Individuals first decide whether or not to participate in consuming the illicit drug; and if they decide to participate, the decision of how much to consume is then made. Zhao and Harris use a probit model for the first decision for participation, and an ordered probit model for the conditional probabilities in the second decision. It is not unreasonable to expect that the two decisions may relate to different factors, or that the same explanatory variable may have different effects on the two decisions. Estimates of the coefficients and marginal effects for both models for marijuana consumption are presented in Table 3.5. Looking at the social and demographic effects on the two decisions, factors such as age, income and gender have similar effects on both decisions. For example, males are more likely to participate and also, conditional on participation, more likely to be consuming more frequently than females. However, for some other explanatory variables, the effects on the two decisions are different or even impact in opposite directions. Being single, unemployed, of ATSI background, or speaking English at home significantly increases the chance of participating in marijuana usage, but among the marijuana users these factors no long have a significant effect on how often the user consumes. In terms of education attainment, higher educated people are not significantly different from the less-than-year-12 educated in participation; but among users of marijuana, all higher educated groups are less likely to engage in frequent consumption than the less-than-year-12 group. Finally, while being employed increases the probability of participation, people who work are less likely to be frequent users as compared to retirees, those with home duties or who undertake volunteer work. Residency in a capital city has a significant effect for both participation and the level of consumption. But the coefficients of the residency variable in the two equations have opposite signs; individuals in capital cities are more likely to participate, but among users, heavier smokers are more likely to be residing in non-capital cities.[4]

4. TWO EMPIRICAL REGULARITIES IN PRICES

This section deals with two intriguing empirical regularities in marijuana prices, (i) the distinct regional structure of prices; and (ii) the substantial fall in prices that occurred over the last decade. In the next section we discuss a pattern that characterises relative marijuana prices, the substantial quantity discounts available for bulk purchases. We start with a brief discussion of the data on prices.[5]

The Australian Bureau of Statistics do not collect marijuana prices, but the Australian Bureau of Criminal Intelligence (ABCI) have some "unofficial" data which they generously provided to us.[6] These prices were elicited by law enforcement agencies in the various states

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[4] The econometric models discussed in this section can be generalised and extended in several directions. Harris and Zhao (2005) argue that the large proportion of zero observations, which refer to non-participants, needs to be closely examined. They propose a zero-inflated ordered probit model whereby the zeros are related to two distinct sources, each of which is determined by different systems of consumer behaviour. For example, in the case of marijuana consumption, zeros will be recorded for genuine non-participants due to health or legal concerns. However, there will also be zeros for those infrequent purchasers, or potential users, who may report zero consumption at the time of the survey, but who may become consumers if price falls sufficiently. Another issue relates to the lack of flexibility in the use of the ordered probit model. Using a single latent equation, the ordered probit is restrictive in modelling different levels of consumption. Harris et al. (forthcoming) use an ordered generalised extreme value model that is more flexible, while at the same time accounts for the ordered nature of the discrete data.

[5] This section draws on Clements (2002, 2004).

[6] An alternative source of information on drug prices in Australia is the Illicit Drug Reporting System, which is funded by the Commonwealth Department of Health and Ageing and coordinated by the National Drug and

and territories during undercover buys. In general, the data are quarterly and refer to the period 1990-1999, for each state and territory. The different types of marijuana identified separately are leaf, heads, hydroponics, skunk, hash resin and hash oil. However, we focus on only the prices of leaf and heads packaged in the form of grams and ounces, as these products are the most popular. The data are described in ABCI (1996) who acknowledge that there exist some inconsistencies with the data. The prices are usually recorded in the form of ranges and the basic data are listed in Clements and Daryal (2001) who also "consolidate" and edit the data to eliminate outliers. In summary, while these data are less than perfect, they are all we have. But even acknowledging their problems, when we average over the individual prices, there is little reason to believe that the resulting indexes systematically over- or under-estimate prices in general.

Regional Disparities in Prices

Relative to weight and volume, marijuana is a high-value product, so we would expect transport costs to be low relative to the price. Other things being equal, this would tend to make for a national marijuana market with regional prices more or less equalised. The tradeable nature of marijuana would also seem to be supported by the prominent role that anecdotal evidence accords to Adelaide as a major exporter. Radio National (1999) noted that:

> "Cannabis is by far and away the illicit drug of choice for Australians. There is a multi billion dollar industry to supply it, and increasingly, the centre of action is the city of churches."

That program quoted a person called "David" as saying:

> "Say five, ten years ago, everyone spoke of the country towns of New South Wales and the north coast, now you never hear of it; those towns have died in this regard I'd say, because they're lost out to the indoor variety, the hydro, and everyone was just saying South Australia, Adelaide, Adelaide, Adelaide, and that's where it all seems to be coming from."

In a similar vein, the ABCI (1999, p. 18) commented on marijuana being exported from South Australia to other states as follows:

> "New South Wales Police reported that cannabis has been found secreted in the body parts of motor vehicles from South Australia… It is reported that cannabis originating in South Australia is transported to neighbouring jurisdictions. South Australia Police reported that large amounts of cannabis are transported from South Australia by air, truck, hire vehicles, buses and private motor vehicles.

Alcohol Research Centre at the University of New South Wales. These data are derived from injecting-drug users and surveys of experts. For details, see http://www.health.gov.au/internet/wcms/Publishing.nsf/Content/health-pubhlth-strateg-drugs-illicit-index.htm and http://ndarc.med.unsw.edu.au/ndarc.nsf/website/IDRS.

> Queensland Police reported that South Australian cannabis is sold on the Gold Coast. New South Wales Police reported South Australian vehicles returning to that state have been found carrying large amounts of cash or amphetamines, or both. It also considers that the decrease in the amount of locally grown cannabis is the result of an increase in the quantity of South Australian cannabis in New South Wales.
>
> The Australian Federal Police in Canberra reported that the majority of cannabis transported to the Australian Capital Territory is from the Murray Bridge area of South Australia…"

In view of the above, it comes as a bit of a surprise that there are significant differences in marijuana prices in the different states and territories of Australia. This is illustrated in Panel I of Table 4.1, which gives for the four types of marijuana the results of regressing prices on dummy variables for each state and territory. In this panel, the dependent variable is $\log p_{rt}$, where p_{rt} is the price of the relevant type of marijuana in region r ($r = 1, \ldots, 8$) and year t ($t = 1990, \ldots, 1999$), and the coefficients measure the price relative to NSW, the base region. Only two of the 28 coefficients are positive, leaf/ounce in Victoria and ACT, but these are both insignificantly different from zero. The vast majority of the other coefficients are significantly negative, which says that marijuana prices are significantly lower in all regions relative to NSW. Row 4 tells us that for the product "head ounce", the most important category, NT is the cheapest region with marijuana costing about 44 percent less than that in NSW. Then comes WA (35 percent less), SA (34 percent), Tasmania (30 percent), Queensland (28 percent), Victoria (20 percent) and, finally, ACT (13 percent). The last column of the table gives a measure of the dispersion of prices around those in NSW, a measure that is approximately the percentage standard deviation. If prices are equalised across regions, then this measure is zero. But as can be seen, the standard deviation is substantially above zero, and ranges from 24 to 44 percent.

It is clear from the significance of the regional dummies that marijuana prices are not equalised nationally. But this conclusion does raise the question of what could be the possible barriers to inter-regional trade that would prevent prices from being equalised? Or to put it another way, what prevents an entrepreneur buying marijuana in NT and selling in NSW to realise a (gross) profit of more than 40 percent for head ounce? While such a transaction is certainly not risk free, is it plausible for the risk premium to be more than 40 percent? Are there other substantial costs to be paid that would rule out arbitraging away the price differential? To what extent do the regional differences in marijuana prices reflect the cost of living in the location where it is sold? Panels II and III of Table 4.1 explore this issue by using per capita incomes and housing prices as proxies for regional living costs.[7] In Panel II, we regress the logarithm of income on seven regional dummies. All the coefficients are negative, except those for the ACT. As can be seen from the last column of Panel II, the dispersion of income regionally is considerably less than that of marijuana prices, roughly about one half, which could reflect the operation of the fiscal equalisation feature of the federal system. Panel III repeats the analysis with housing prices replacing incomes, and the results in the last column show that the regional dispersion of housing prices is of the same order of magnitude of that of marijuana prices. Figure 4.1 gives a graphical comparison of the regional dispersion of prices and incomes.

To compare and contrast the prices of marijuana and housing further, Figure 4.2 plots the two sets of prices relative to NSW/Sydney by using the regional dummy-variable coefficients for head ounce (given in row 4 of Table 4.1) and those for houses (row 7 of Table 4.1). The broken ray from the origin has a 45^0 slope, so that as we move along the ray and get further away from the origin, marijuana and housing prices both fall equiproportionally relative to those in Sydney. In other words, any point on the ray represents lower prices of both goods, but the marijuana/housing relative price is the same as that in Sydney. A point above the ray, such as that for Darwin, indicates that marijuana is cheap in terms of housing in comparison to that in Sydney. Next, consider Perth where marijuana is about 30 percent cheaper than Sydney, while the cost of housing is 55 percent below that of Sydney. Relative to Sydney, although marijuana is cheap, housing is even cheaper, causing the marijuana/housing relative price to be higher in Perth than Sydney. As all cities other than Darwin lie below the ray, we could say that relative to housing, Sydney has the country's cheapest marijuana. The solid line in Figure 4.2 is the least-squares regression line, constrained to pass through the origin. The slope of this line is the elasticity of marijuana prices with respect to housing prices, estimated to be 0.59 (SE = 0.09). Since the observation for Darwin lies substantially above the regression line, we can say that marijuana prices in that city are cheap given its housing prices, or that housing is expensive in view of the cost of marijuana. Among the seven non-Sydney cities, given its housing prices, marijuana would seem to be most overpriced, or housing most underpriced, in Hobart.

The final interesting feature of Figure 4.2 is that it can be used to naturally divide up Australia into three super regions/cities: (i) NSW/Sydney -- expensive marijuana and housing. (ii) Victoria/Melbourne and ACT/Canberra -- moderately-priced marijuana and housing. (iii) The rest -- cheap marijuana and housing.

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[7] While the Australian Bureau of Statistics publish a Consumer Price Index for each of the six capital cities, these indexes are not harmonised. Accordingly, the levels of the CPI cannot be compared across cities to provide information on the level of regional living costs.

The above discussion shows that to the extent that housing costs are a good proxy for living costs, marijuana prices are at least partially related to costs in general. As a substantial part of the overall price of marijuana is likely to reflect local distribution activities, which differ significantly across different regions, this could explain the finding that the market is not a national one, but a series of regional markets that are not too closely linked. Understanding the pricing of marijuana is enhanced if we split the product into (i) a (nationally) traded component comprising mainly the "raw" product, whose price is likely to be approximately equalised in different regions; and (ii) a nontraded component associated with packaging and local distribution, the price of which is less likely to be equalised. As such services are likely to be labour intensive, their prices will mainly reflect local wages which, in turn, would partly reflect local living costs. The results of this sub-section could be interpreted as pointing to a surprising importance of the nontraded component of marijuana prices.

A final point to note is the role of regional differences in penalties for possessing marijuana. As discussed at the end of this section, there seems to be little, if any, link between penalties and regional price differences.

<u>Marijuana Has Become Substantially Cheaper</u>

Notwithstanding the likely importance of packaging and distribution costs, marijuana is an agricultural/horticultural-based product. The real prices of many primary products exhibit a long-term downward trend of about 1-2 percent p. a. due to the workings of Engel's law and productivity growth in agriculture. Are marijuana prices subject to a similar pattern? In this and the next sub-section, we show that possibly because of a surge in productivity growth due to the adoption of hydroponic techniques of production and a softening of community attitudes to the use of marijuana, prices have fallen by much more than 1-2 percent, so that the answer to this question is a definitive "No".

Figure 4.3 plots an index of nominal marijuana prices and shows that over the course of the 1990s prices fell from near \$600 per ounce to something like \$450.[8] Figure 4.4 gives the path of marijuana prices in terms of the CPI and alcohol prices and, as can be seen, prices declined in real terms on average by either 4.9 percent p. a. or 5.7 percent, depending on which deflator is used.

How do marijuana prices compare with those of other commodities? Figure 4.5 gives the price changes of 24 internationally-traded commodities plus marijuana. The striking feature of this graph is that marijuana prices have fallen the most by far. The only commodity to come

[8] This index is a weighted geometric mean of the four prices, leaf grams, leaf ounces, heads grams and heads ounces. The weights are guestimates of the budget shares. For details, see Clements (2002).

close is rubber, but even then its average price fall is one percentage point less than that for marijuana (-3.9 versus -4.9 percent p.a.) After rubber there is a substantial drop off in the price declines -- palm oil –2.3 percent, rice –2.2 percent, cotton –2.0 percent, etc. Surprisingly, the price of tobacco, which might be considered to be related to marijuana in both consumption and production, increased by 0.9 percent p.a. Note also the minerals (aluminium, copper, lead, zinc, tin and silver) tend to lie in the middle of the spectrum of prices and have agricultural products on either side. The declines in most of the commodity prices reflect the impact of productivity enhancement coupled with low income elasticities. The mineral prices could also reflect the tendency of GDP to become "lighter" and less metals intensive over time.

What about the prices of other goods that are not traded commodities? Figure 4.6 presents a selection of relative prices changes averaged over the period 1900 – 2000. As is to be expected, labour-intensive services (such as the cost of a hotel room, a butler and a theatre ticket) increase in relative terms. The prices that fall include those that are (i) predominantly agricultural or resource based (coffee, wine, eggs and petrol); and (ii) subject to substantial technological improvements in their manufacture and/or economies of scale (e.g., car, clothing, refrigerator, electricity). To illustrate, consider the price of cars: According to The Economist (2000/01) "Henry Ford's original Model-T, introduced in 1908, cost \$850, but by 1924 only \$265: He was using an assembly line, and, in a virtuous circle, was selling far more cars. Over the century the real price of a car fell by 50 percent." The quality-adjusted price of a car, and some other goods, would have fallen even further, as recognised by The Economist (2000/01). If we omit the cost of phone calls as a possible outlier (as its price falls by 99.5 percent over the entire century!), the good whose price falls the most is electricity. But even electricity prices fall by only 2.8 percent p.a., substantially below that of marijuana (4.9 percent).

In a well-known paper, Nordhaus (1997) analyses the evolution of the price of light over the past 200 years. He uses the service characteristic provided by light, illumination, which is measured in terms of lumens. He notes that a "wax candle emits about 13 lumens [and] a one-hundred-watt filament bulb about 1200 lumens", which shows that the flow of lighting service from different sources of light has increased substantially with the introduction of new products. Nordhaus constructs an index of the true (or quality-adjusted) price of light in real terms. This index falls from a value of 100 in 1800 to a mere 0.029 in 1992 (Nordhaus, 1997, Table 1.4, column 3), which represents an average price decline of 4.15 percent p.a., or a log-change $(\times 100)$ of -4.24 p.a. As the real price of marijuana has an annual average log-change $(\times 100)$ of -4.87, marijuana in terms of light on average falls by -4.87 - (-4.24) = -0.63 p.a. If past trends continue, this implies that the number of years for this relative price to fall by $k \times 100$ percent is $\left[\log\left(1\text{-k}\right)\right]/\text{-}0.0063$, so that it would take about 35 years for the price of marijuana relative to light to fall by 20 percent. In other words, as the price of marijuana relative to light is fairly constant, it could be argued that the production of both goods has been subject to similar degrees of productivity improvement.

A final well-known example of the impact of productivity improvement on prices is the case of personal computers. Berndt and Rappaport (2001, p. 268) describe the enhanced capabilities of PCs over the last quarter of a century in the following terms:

> "When introduced in 1976, personal computers (PCs) had only several kilobytes of random-access memory (RAM) and no hard disk, processed commands at speeds of less than 1 megahertz (MHz), yet typically cost several thousand dollars. Today's PCs have megabytes (MB) of RAM and gigabytes of hard-disk memory, process commands at speeds exceeding 1,000 MHz, and often cost less than $1,000. Ever more powerful PC boxes have been transformed into increasingly smaller and lighter notebooks."

Berndt and Rappaport compute quality-adjusted price index for PCs, with quality defined in terms of hard-disk memory, processor speed and the amount of RAM. Using more than 9,000 observations on about 375 models per year, they find that for desktop PCs, prices declined over the period 1976-99 at an average rate of 27 percent p.a. and that the ratio of the price index in 1976 to that in 1999 is 1,445:1. For mobile PCs, prices declined by about 25 percent p.a. on average from 1983 to 1999. Although the above-documented declines in marijuana prices are very substantial among agricultural/horticultural commodities, they are still considerably less than those for PCs, which are nothing less than spectacular. There would seem to be fundamental differences to the limits to productivity enhancement for commodities that are <u>grown</u>, and those that involve electronics such as computing, power generation and telecommunications.

<u>Why Did Prices Fall By So Much</u>?

One reason for the decline in their prices is that the growing of marijuana has been subject to productivity enhancement associated with the adoption of hydroponic growing techniques,[9] which lead to a higher-quality product containing higher THC levels.[10] For example, hydroponically-grown marijuana from northern Tasmania has been analysed as

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9 The word *hydroponic* means "water working". For details of hydroponic techniques, see, e.g., Asher and Edwards (1981) and Ashley's Sister (1997).

10 The content of the main psychoactive chemical *Delta-9-tetrahydrocannabinol* (THC) determines the potency and the quality of marijuana. This is evidenced by the fact that flowers (so-called "heads" or "buds"), which contain more THC than leaves, are considerably more expensive.

containing 16 percent of THC, while that grown outdoors in the south of the state contained 12.8 percent (ABCI, 1996). The ease of concealment, and near-ideal growing conditions that produce good-quality plants, are the main reasons for the shift to hydroponic systems. According to the ABCI (1996),

> "Hydroponic systems are being used to grow cannabis on a relatively large scale. Unlike external plantations, hydroponic cultivation can be used in any region and is not regulated by growing seasons. Both residential and industrial areas are used to establish these indoor sites. Cellars and concealed rooms in existing residential and commercial properties are also used… The use of shipping containers to grow cannabis with hydroponic equipment has been seen in many cases. The containers are sometimes buried on rural properties to reduce chances of detection."

Other anecdotal evidence also points to the rise of hydroponic activity over this period. For example, according to the Yellow Pages telephone directory, in 1999 Victoria had 149 hydroponics suppliers, NSW 115, SA 69, Queensland 59 and WA 58. One suspects that many of these operations supply marijuana growers. For a further discussion of this anecdotal evidence, see Clements (2002).

A second possible reason for the decline in marijuana prices is that because of changing community attitudes, laws have become softer and penalties reduced. Information on the enforcement of marijuana laws distinguishes between (i) infringement notices issued for minor offences and (ii) arrests. Table 4.2 presents the available Australian data on infringement notices for the three states/territories that use them, SA, NT and ACT. As can be seen, per capita infringement notices have declined substantially in SA since 1996, increased in NT, first increased and then declined in ACT, and declined noticeably for Australia as a whole, where they have fallen by almost 50 percent. This information points in the direction of a lower policing effort. Data on arrests and prosecution for marijuana offences are given in Table 4.3. Panel I shows that the arrest rate for NSW was more or less stable over the six-year period, while that for Victoria fell substantially due to a "redirection of police resources away from minor cannabis offences" (ABCI, 1998). For Queensland, the arrest rate rose by more than 50 percent in 1997, and then fell back to a more or less stable value, but in WA the rate fell markedly in 1999 with the introduction of a trial of cautioning and mandatory education to "reduce the resources previously used to pursue prosecutions for simple cannabis offences" (ABCI, 2000). For Australia, the arrest rate fell from 342 in 1996 to 232 in 2001 (per 100,000 population), a decline of 32 percent. Data on successful prosecution of marijuana cases for three states are given in Panel II of Table 4.3 (data for the other states/territories are not available). For both NSW and SA, the prosecution rate has fallen substantially. Not only has the prosecution rate fallen, lighter sentences have become much more common. Interestingly, in the early 1990s the prosecution rate was much higher in SA than in NSW, but by the end of the decade the rate was approximately the same in the two states. In WA, the prosecution rate is fairly stable, but the period is much shorter. No clear pattern emerges from the information on the percentage of arrests that result in a successful prosecution, as shown in Panel III of Table 4.3.

The evolution of enforcement of marijuana laws can be analysed in terms of a simple model that decomposes penalties into penalty type, regional and time effects (Clements, 2004). Controlling for regional and time effects, the estimated coefficient of the infringement dummy (which is the "penalty type" effect) indicates that these are significantly higher than arrests. The estimated trend term shows that all penalties are falling on average by about 8 percent p.a., a fall that is significantly different from zero. These results thus show that the "enforcement effort' with respect to marijuana was indeed falling over time. The model also allows for the identification of which regions are softer/tougher on marijuana. As compared to NSW, Victoria, NT and ACT are all low-penalty regions, while the other four have higher penalties on average. It is of considerable interest to compare this index of regional "legal attitudes" to marijuana to prices. To do this, we use the results of row 4 of Table 4.1, which refers to prices of head ounce, the most popular product type, to rank regions in terms of the cost of marijuana, a ranking which is given in the first row of the table below:

Cost (cheapest to most expensive) :	NT	WA	SA	TAS	QLD	VIC	ACT	NSW
Penalties (weakest to most severe) :	ACT	NT	VIC	NSW	TAS	SA	QLD	WA

The estimates of the penalties model yield the ranking of regions given in the second row of the above. As the relationship between the two rankings is obviously weak, with major differences for most states, regional disparities in penalties do not seem to be systematically associated with regional price differences.[11]

Taken as a whole, the above analysis seems to support the idea that participants in the marijuana industry have faced a declining probability of being arrested/successfully prosecuted; and even if they are arrested and successfully prosecuted, the expected penalty is now lower. In other words, both the effort devoted to the enforcement of existing laws and penalties imposed seem to have decreased. Accordingly, the expected value of this component of the "full cost"

[11] Estimates for the penalties model also reveal that other factors remaining unchanged, more infringement notices are associated with fewer arrests, so the two types of penalties are substitutes for one another. This, of course, must have been one of the key objectives associated with the introduction of the infringement regime.

of using marijuana has fallen. During the period considered, NSW, Victoria, WA and Tasmania all introduced marijuana cautioning programs (ABCI, 2000) and SA, NT and ACT issued marijuana offence notices. This seems to indicate changing community attitudes to marijuana associated with the reduced "policing effort". It is plausible that this has also led to lower marijuana prices. As the riskiness of buying and selling marijuana has fallen, so may have any risk premium built into prices. This explanation of lower prices has, however, been challenged by Basov et al. (2001) who analyse illicit drug prices in the United States. They show that while drug prohibition enforcement costs have risen substantially over the past 25 years, the relative prices of drugs have nonetheless declined. Basov et al. suggest four possible reasons for the decrease in prices: (i) Production costs of drugs have declined; (ii) tax and regulatory cost increases have raised the prices of legal goods, but not illicit goods such as drugs; (iii) the market power of the illicit drug industry has fallen; and (iv) technologies to evade enforcement have improved. Although hard evidence is necessarily difficult to obtain, Basov et al. argue against explanations (i) and (ii), and favour (iii) and (iv) as realistic possibilities. We will have more to say about the possible impact of softening attitudes and laws on the workings of drugs markets in Section 8.

We can summarise this material on marijuana prices as follows. First, the relative price of marijuana has fallen substantially, by much more than those of many other commodities. Second, two possible explanations for this decline are (a) productivity improvement in the production of marijuana associated with the adoption of hydroponic growing techniques; and (b) the lower expected penalties for producing, buying and selling marijuana. On the basis of the evidence currently available, both explanations seem to be equally plausible.

5. QUANTITY DISCOUNTS

In addition to the above two patterns in marijuana prices, there is a third intriguing characteristic of prices, viz., the unit price of marijuana falls noticeably as the quantity purchased rises. In the 1990s in Australia the average cost of an ounce of marijuana was about \$450 and \$35 for a gram. As there are about 28 grams in an ounce, the cost of an ounce is equivalent to 450/28 = \$16 per gram. Accordingly, the unit cost drops from \$35 to \$16 if marijuana is purchased in the form of an ounce package, rather than a gram package. Figure 5.1 plots the unit prices of marijuana purchased in an ounce in the eight Australian states and territories over the decade of the 1990s against the corresponding gram prices. As all points lie below the 45^0-degree line for both heads and leaf, it can be seen that unit ounce prices are less than gram prices, and quantity discounts pertain. Quantity discounts are quite common in many markets, and apply for instance to some grocery products, international air fares where prices for return trips can be substantially less than twice the one-way cost, and private school fees whereby a discount is given for the second and subsequent child from the same family. In this section, we explore quantity discounts in the context of the economics of packaging and show that once these discounts are formulated appropriately, marijuana is priced in a manner not too dissimilar to that of a number of other products, both illicit and licit. [12]

Theories of Quantity Discounts

There are several explanations for quantity discounts, the first of which is price discrimination. Here, lower unit prices for large purchases are interpreted as reflecting that large customers have a more elastic demand than smaller ones. Of course, producers can only practise price discrimination when competition is lacking and when it is possible to limit resale of the product. Such an explanation possibly applies to air fares where business travellers would tend to pay the high-cost fares, and tourists the cheaper fares.

A second explanation for quantity discounts is that they reflect cost differences. To illustrate, consider a stylised example, due to Telser (1978, Sec. 9.4), that focuses on the role of packaging costs in generating quantity discounts. Suppose a certain grocery product of volume s, measured in terms of cubic cm say, is sold in a package in the form a cube, which has the linear dimension of $s^{1/3}$, so that its surface area is $6 \times s^{2/3}\ \text{cm}^2$. If the packaging cost is α dollars per cm^2 and the product cost is β per cm^3, then the total cost of the product, as a function of size s, is $c(s) = \alpha 6 s^{2/3} + \beta s$, so that the elasticity of total cost with respect to size is

$$\frac{d(\log c)}{d(\log s)} = \gamma \frac{2}{3} + (1 - \gamma),$$

where γ is the share of packaging in total cost. As this elasticity is clearly less than one, total cost rises less than proportionally with product size s, so that the unit cost c/s declines as s rises. This can be clearly seen from the unit cost function, which takes the form $c(s)/s = \alpha 6 s^{-1/3} + \beta$. Another way of describing this result is that packaging is subject to economies of scale.[13] As packaging is a trivial part of the total costs of drugs, if we interpret

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[12] This section draws on Clements (forthcoming).

[13] It is to be noted that scale economies in package is a general result that does not hinge on the specific assumption that the package takes the form of a cube. To illustrate, consider a sphere of radius r, the surface area and volume

"packaging" in a narrow sense, this does not explain the observed quantity discounts for marijuana. However, it may have some explanatory power if we think of packaging as referring to all the "value added" in going form larger to smaller drug packages.

The role of risk in the drug business is another explanation of quantity discounts. As each transaction involves the exposure to the probability of being busted, there are incentives to increase the average size of transactions and reduce their number as a risk-management strategy. This could lead to higher unit prices for smaller lot sizes as a reflection of a risk premium.[14] Additionally, as holding an inventory of drugs is risky, quantity discounts for large transactions could also represent compensation for bearing this risk.

The fourth approach to pricing and packaging is the model proposed by Caulkins and Padman (1993) that makes explicit the key structural parameters of the packaging industry in the relationship between price and package size.[15] As this model has been applied to illicit drugs, and as we shall refer back to it subsequently, it is appropriate to provide some details. Suppose there is a log-linear relationship between price of package size s, $p(s)$, and package size,

$$\log p(s) = \alpha + \beta \log s, \qquad (5.1)$$

where α is an intercept and β is the size elasticity. Thus

$$p(s) = a s^{\beta}, \qquad (5.2)$$

where $a = \exp(\alpha)$. Suppose that initially an ounce of marijuana is purchased and that we measure size in terms of grams, so that $s = 28$ and $p(28)$ is the price of this ounce. If this ounce is then split into 28 gram packages, so that $s = 1$ now, the revenue from these 28 packages is $28 \times p(1)$, where $p(1)$ is the price of one gram. Define the ratio of this revenue to the cost of an ounce as the <u>markup factor</u>, $\delta = 28 \times p(1) / p(28)$, or $28 \times p(1) = \delta \times p(28)$. More generally, let $\phi > 1$ be the <u>conversion factor</u> that transforms the larger quantity s into a smaller one s / ϕ, so that in the previous example $\phi = 28$. Thus we have the following general relationship between prices of different package sizes, the markup and conversion factors:

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of which are $A = 4\pi r^2, V = (4/3)\pi r^3$. The area per unit of volume is $A/V = 3/r = \alpha V^{-1/3}$, where α is a constant, so that unit packaging costs again decline with package size.

[14] When the penalties increase with volume, this argument for higher unit prices continues to hold as long as penalties increase proportionately less than volume.

[15] For a further elaboration and application of this model, see Caulkins (1997).

(5.3) $$\phi \times p\left(\frac{s}{\phi}\right) = \delta \times p(s).$$

Our objective is to use equations (5.2) and (5.3) to derive an expression for the size elasticity β that involves the markup and conversion factors δ and ϕ. To do this, we use equation (5.2) in the form $p(s/\phi) = a(s/\phi)^{\beta}$, so that the left-hand side of equation (5.3) becomes $\phi a(s/\phi)^{\beta}$. Using equation (5.2) again, we can write the right-hand side of (5.3) as $\delta a s^{\beta}$. Accordingly, equation (5.3) can be expressed as $\phi(s/\phi)^{\beta} = \delta s^{\beta}$, or $\phi^{(1-\beta)} = \delta$, which implies

(5.4) $$\beta = 1 - \frac{\log \delta}{\log \phi}.$$

As the markup $\delta > 0$ and is presumably less than the conversion factor ϕ, the size elasticity β is a positive fraction. Equation (5.4) also shows that the size elasticity falls with the markup δ and rises with the conversion factor ϕ. If there is no markup, $\delta = 1$ and the size elasticity $\beta = 1$, so that price is just proportional to package size and there would be no quantity discount for buying in bulk. When $\delta > 1$, the unit price falls with the quantity purchased, so that discounts would apply. As the markup rises, so does the quantity discount and the (proportionate) increase in the total price resulting from a unit increase in package size is lower. In other words, the size elasticity β falls with the markup. Other things equal, the greater the conversion factor ϕ, the more the product can be "split" or "cut" and the higher is the profit from the operation. The role of the conversion factor in equation (5.4) is then to normalise by deflating the markup by the size of the conversion involved (e.g., in going from ounces to grams), thus making the size elasticity a pure number.

To illustrate the workings of equation (5.4), suppose that the markup is 100 percent, so that $\delta = 2$, and we convert from ounces to grams, in which case $\phi = 28$. With these values, $\beta = 1 - \log 2 / \log 28 \approx 0.8$, so that a doubling of package size is associated with an 80 percent increase in price. Equation (5.4) is an elegant result which yields considerable insights into the interactions between price and package size, and the role of the structural parameters δ and ϕ.

<u>The Discount Elasticity</u>

At the beginning of this section, we considered marijuana prices in Australia and compared the unit price of ounces, $p(28)/28$, with that that of grams, $p(1)$, to conclude that there was a substantial quantity discount. To compare the price of a package of size s to that of a package of size one, define the unit-price ratio as $r = \left[p(s)/s \right] / p(1)$.[16] The logarithm of the ratio is

(5.5) $$d = \log \left[\frac{p(s)/s}{p(1)} \right].$$

For small values of the ratio r, $d \approx r - 1$, which is the proportionate discount from bulk buying. Accordingly, we shall refer to d as the "logarithmic discount" or the "log discount" for short. The advantages of using d instead of $r - 1$ are that it is symmetric in its base[17] and has desirable properties when averaged; additionally, the log discount is consistent with the log-linear pricing equation (5.1), which is at the root of our subsequent analysis of quantity discounts.

Figure 5.2 presents the logarithmic discount (5.5) for marijuana in Australia over the 1990s. As can be seen, on average, the log discount is about -0.8, which corresponds to about -55 percent. While this is substantial, it has to be remembered that there is also a substantial quantity increase involved in purchasing an ounce of marijuana rather than a gram. In this sense, the measure (5.5) is not really unit free, and thus cannot be compared across products for cases where the discounts involve different units. One way to rectify the problem is to normalise (5.5) by the difference in the two package sizes, s and 1. Accordingly, we define

(5.6) $$d' = \frac{\log \left[\dfrac{p(s)/s}{p(1)} \right]}{\log \left[\dfrac{s}{1} \right]} = \frac{\log \left[\dfrac{p(s)/s}{p(1)} \right]}{\log s},$$

where the second step follow from $\log 1 = 0$. To interpret the measure d', we return to equation (5.1) and subtract $\log s$ from both sides to obtain

(5.7) $$\log \frac{p(s)}{s} = \alpha + \beta' \log s,$$

[16] In the language of the Caulkins and Padman (1993) model considered above, $r = 1/\delta$. Accordingly, a value of the unit-price ratio of $r \approx 0.5$ implies a markup of about 100 percent in the Australian marijuana industry.

[17] That is,

$$d = \log \left[\frac{p(s)/s}{p(1)} \right] = -\log \left[\frac{p(1)}{p(s)/s} \right],$$

which means that if relative to a package of unit size, a package of size s sells at a discount of $-\alpha$, then the unit package sells at a premium relative to s of α. This is a property not shared by the proportionate discount $r - 1$.

where $\beta' = \beta - 1$ is the size elasticity of the unit price, or the "discount elasticity" for short. Thus if there are quantity discounts, the size elasticity β in equation (5.1) is less than unity, the discount elasticity in (5.7) is negative and the unit price $p(s)/s$ falls with s. Applying equation (5.7) to the unit package size yields $\log p(1) = \alpha$, so that

$$(5.8) \qquad \log \frac{p(s)/s}{p(1)} = \beta' \log s, \text{ or } \frac{\log \dfrac{p(s)/s}{p(1)}}{\log s} = \beta' .$$

This establishes that the unit-free measure d' in equation (5.6) is interpreted as the discount elasticity β'. That d' is this elasticity can also be seen from the second member of equation (5.6), which is the ratio of the logarithmic change in the unit price to that of the package size:

$$d' = \frac{\log\left[\dfrac{p(s)/s}{p(1)}\right]}{\log\left[\dfrac{s}{1}\right]} = \frac{\log\left[\dfrac{p(s)}{s}\right] - \log\left[\dfrac{p(1)}{1}\right]}{\log s - \log 1}.$$

Application to Marijuana and Other Products

To get a feel for the value of the discount elasticity, we can use in numerator of the second member of equation (5.8) the mean of the log discount -0.8 and $\log 28 \approx 3.33$ in the denominator to yield $\hat{\beta}' \approx -0.8/3.33 \approx -0.25$. In words, the discount elasticity is about minus one-quarter.[18] Equation (5.4) relates the size elasticity (β) to the markup factor (δ) and the conversion factor in going from a larger package size to a smaller one (ϕ). That equation implies that the discount elasticity is related to these two factors according to $\beta' = -\log\delta/\log\phi$. Thus, $\beta' = -0.25$ and $\phi = 28$ imply a markup factor of $\delta = \exp(0.25 \times \log 28) = 2.30$, or about 130 percent in transforming ounces into grams. This value seems not unreasonable.

It is remarkable that in broad terms at least, the above value of the discount elasticity of -0.25 is also obtained using other approaches with the marijuana data, as well as for other illicit drugs and groceries. Full details of this strong claim are provided in Clements (forthcoming), but in what follows we give some illustrative evidence. Equation (5.7) can be treated as a regression equation and the discount elasticity β' estimated as a coefficient. Using the Australian marijuana data over time, products and/or over regions yields a number of estimates

[18] This estimator of the discount elasticity is in fact exactly equivalent to the OLS estimator of β' in equation (5.7).

of this elasticity, a summary of which appears in the form of a histogram in Figure 5.3. As can be seen, the centre of gravity of these estimates is clearly very close to -0.25. Next, we give in Figures 5.4 and 5.5 estimates of the discount elasticity for heroin and other illicit drugs, and on average at least the values are not too far from minus one-quarter. Finally, Table 5.1 provides estimated elasticities for groceries and while there seems to be a bit more dispersion in this case, again we see the results are clustered around -0.25.[19] The absolute values of β' for baked beans and canned vegetables are somewhat higher than those for the other products, which may reflect larger markups and/or that packaging accounts for a larger share of total costs.

Summary

We thus conclude that quantity discounts, as measured by the discount elasticity β', seem to be more or less the same in both licit and illicit markets, at least to a first approximation. In broad terms, the results support the following pricing rule: *The unit price falls by 2.5 percent when the product size increases by 10 percent.* While such a rule has much appeal in terms of its elegant simplicity, it is probably a bit of an exaggeration to claim that it has universal applicability and it would be premature to conclude that the discount elasticity has the status of a "natural constant".[20]

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[19] The grocery-price data are from Gordon Mills, who generously provided unpublished details from his survey of grocery prices; for details, see Mills (2002, Chap. 7).

[20] It is relevant to mention here the "rule of six-tenths" according to which the production function exhibits a specific type of economies of scale. If Y is output produced with a piece of capital equipment of size K, then the production function is $Y=\alpha' K^{1/\beta}$, with $\beta \approx 0.6$, so that the implied "factor demand equation" is $K=\alpha Y^{\beta}$. For example, Whitesides (2005) recommends using this relationship to estimate the cost of equipment having capacity Y_1, on the basis of the known cost of equipment of smaller capacity Y_0, according to $K_1 = K_0 \left(Y_1/Y_0\right)^{0.6}$. Whitesides, who attributes the rule to Williams (1947), emphasises its use in the absence of more detailed information. Indeed, he provides specific examples of equipment for which $\beta \neq 0.6$, such as an industrial boiler, where output is measured in terms of lb/hr, and $\beta = 0.50$; for a bucket conveyor belt (output in feet), $\beta = 0.77$; while for a stainless steel tank or vessel (gallons), $\beta = 0.68$. According to this rule, the unit cost function is $K/Y = \alpha Y^{\beta-1}$, so that the elasticity of unit cost with respect to size is $\beta - 1 = -0.4$ when $\beta = 0.6$. Hence the unit cost falls with as capacity rises, so there are scale economies. If it is thought that six-tenths is sufficiently close to three-quarters, then our results are not inconsistent with the rule.

Consider again the expression derived at the start of this section for the elasticity of (total) cost c with respect to the package size s: $d(\log c)/d(\log s) = \gamma(2/3) + (1-\gamma)$, where γ is the share of packaging in total cost. This shows that the elasticity lies between two-thirds and unity, a range that excludes 0.6. But this result depends on the simple stylised case in which the package takes the form of a cube. Although the same result holds in the case of a sphere (see footnote 13), these simple examples should probably not be taken as serious evidence against the rule of six-tenths.

We are indebted to Steven Schilizzi, University of Western Australia, and Jean-Baptiste Lesourd, Université de la Méditerranée, for drawing our attention to the rule of six-tenths and its possible relation to our work. In personal communication, Lesourd refers to Arrow and Hahn (1971), Bruni (1965), Gazérian et al. (1991) and Park and Lesourd (2000) and describes the rule as "…not, in fact, anything like a 'universal constant' and, especially with multi-product firms, reality is quite more complex. However, in certain specific areas of production, the rule remains a good approximation."

6. THE PRICE-SENSITIVITY OF CONSUMPTION

The previous two sections analysed marijuana prices to identify their patterns. We now combine prices and quantities to investigate their co-movement. Such an investigation is required to answer questions such as, by how much would its usage change if marijuana were legalised? Could substantial government revenue be raised by taxing marijuana usage? How does its consumption interact with that of alcohol? These issues all involve the price-sensitivity of consumption. In this section, we present some evidence on the extent to which marijuana consumption is responsive to variations in its price. As alcohol and marijuana share some important common characteristics, we shall analyse their consumption jointly. We start with a discussion of marijuana consumption data and present a comparison with drinking patterns. This section also contains material on indexes of prices and consumption of marijuana and alcohol, and demand equations.[21]

<u>Prices and Quantities</u>

The marijuana consumption data are estimated by Clements and Daryal (2005a) on the basis of (i) the frequency of consumption information available in the National Drug Strategy Household Survey (various issues) and (ii) reasonable assumptions about the intensity of consumption. Although all care has been taken with the preparation of these estimates, by their very nature they are subject to more than the usual degree of uncertainties. Nonetheless, there is no reason to expect the estimates to be biased one way or another and, in broad outline, they agree with other studies such as Marks (1992).[22] The consumption and prices of the three alcoholic beverages and marijuana are presented in Table 6.1 and Figure 6.1 plots the consumption data. As can be seen, per capita consumption of beer decreases noticeably over this period, from more than 140 litres in 1988 to 117 in 1998. Wine consumption also decreases -- by almost 1.2 litres to end up at 24.6 litres in 1998. But in contrast to beer, wine consumption increases in each of the last three years. The time path of spirits is roughly similar to that of wine -- it first declines substantially, bottoms out in the early 1990s and then more than recovers to end up at 4.3 litres in 1998. Marijuana consumption starts off at 0.65 ounces in 1988, increases steadily until it reaches a peak of 0.83 oz in 1991, tends to decrease for the next several years and then increases again to end up at 0.79 oz in 1998. It can be shown that this variability in marijuana consumption is mostly due to the weekly and monthly consumers. Note

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[21] This section is based on Clements and Daryal (2005a).

[22] See Clements and Daryal (2005a) for details. Note, however, these estimates of consumption have been challenged by Jiggens (in progress).

from the last column of the bottom panel of Table 6.1 that the nominal price of marijuana is taken to be constant over this period. When this research was originally carried out, we had no detailed information on the evolution of prices over time. As the assumption of constant prices is contradicted by the evidence presented in Section 4, the results reported in this section have only a preliminary status.

Table 6.2 combines the quantity and price data and presents expenditures on, and budget shares of, the four goods. The budget share is expenditure on the good in question expressed as a fraction of total expenditure on the four goods. Several interesting features emerge from this table: (i) Marijuana absorbs about 30 percent of expenditure on the four goods. (ii) Expenditure on marijuana is almost equal to that on wine plus spirits; and it is about three-quarters of beer expenditure. (iii) Over the 11 years, the budget share of spirits rises by almost 4 percentage points, while that of beer falls by 3+ percentage points. Table 6.3 gives the quantity and price data in terms of log-changes. The upper panel of the table shows that, on average, beer consumption decreases by about 1.9 percent p.a., wine decreases by 0.5 percent, spirits increases by 0.8 percent and marijuana increases by 2.0 percent. The growth in consumption of both spirits and marijuana exhibit considerable volatility. For example, while spirits consumption grows at a mean rate of 0.8 percent p.a., in 1993 consumption of this beverage increases by more than 10 percent; and in the same year, marijuana declines by more than 8 percent, while its average growth rate is 2.0 percent.

Index Numbers

As an informal way to study the price-sensitivity of consumption, and as a way of summarising the data, we begin by presenting price and volume indexes. Let p_{it} be the price of good i in year t and q_{it} be the corresponding quantity consumed per capita. Then, if there are n goods, $M_t = \sum_{i=1}^{n} p_{it} q_{it}$ is total expenditure and $w_{it} = p_{it} q_{it} / M_t$ is the budget share of i. Let $\overline{w}_{it} = \frac{1}{2}\left(w_{it} + w_{i,t-1}\right)$ be the arithmetic average of the budget share over the years $t-1$ and t; and $Dp_{it} = \log p_{it} - \log p_{i,t-1}$ and $Dq_{it} = \log q_{it} - \log q_{i,t-1}$ be the i^{th} price and quantity log-changes. The Divisia price and volume indexes are then defined as

$$(6.1) \qquad DP_t = \sum_{i=1}^{n} \overline{w}_{it} Dp_{it} \ , \qquad DQ_t = \sum_{i=1}^{n} \overline{w}_{it} Dq_{it} \ .$$

The Divisia price index is a budget-share-weighted average of the n price log-changes and thus represents a centre-of-gravity measure of the prices. This index also has a statistical interpretation (Theil, 1967, p. 136): Suppose we draw prices at random such that each dollar of expenditure has an equal chance of being selected. Then, the budget share $\overline{w}_{it}$ is the probability of drawing Dp_{it} for the transition from year $t-1$ to t, so that the expected value of the prices is $\sum_{i=1}^{n}\overline{w}_{it}Dp_{it}$, the Divisia index. The Divisia volume index has a similar interpretation and measures the overall growth in per capita consumption.

Columns 2 and 3 of Table 6.4 contain DP_t and DQ_t for the three alcoholic beverages plus marijuana (so that $n=4$). As can be seen, on average the price index rises by about 2.6 percent p.a., while the volume index falls by 0.1 percent p.a. The indexes defined in equation (6.1) represent weighted first-order moments of the n prices $Dp_{1t},\ldots,Dp_{nt}$ and the n quantities $Dq_{1t},\ldots,Dq_{nt}$. The corresponding second-order moments are the Divisia variances:

$$(6.2) \qquad \Pi_t = \sum_{i=1}^{n}\overline{w}_{it}\left(Dp_{it}-DP_t\right)^2, \quad K_t = \sum_{i=1}^{n}\overline{w}_{it}\left(Dq_{it}-DQ_t\right)^2.$$

These variances measure the dispersion across commodities of the prices and quantities. Columns 4 and 5 of Table 6.4 give (6.2) for $n=4$. These show that for a given year there is usually more dispersion in quantities than prices. The final second-order moment is the Divisia price-quantity covariance, defined as $\Gamma_t = \sum_{i=1}^{n}\overline{w}_{it}\left(Dp_{it}-DP_t\right)\left(Dq_{it}-DQ_t\right)$. Given the tendency of consumers to move away from those goods whose prices increase faster than average, we expect Γ_t to be negative. This covariance is given in column 6 of Table 6.4 and, as can be seen, in 7 out of 10 cases it is negative. Column 7 gives the corresponding correlation, $\Gamma_t/\sqrt{\Pi_t K_t}$, the mean value of which is -0.2.

As Dp_{it} is the change in the nominal price of the i^{th} good and DP_t is an index of the change in the prices of all goods (namely, alcoholic beverages and marijuana), $Dp_{it}-DP_t$ is interpreted as the change in the relative price of i. Similarly, as $Dq_{it}-DQ_t$ is the change in the quantity consumed of i relative to the average, this can also be termed the change in the relative quantity of i. The means ($\times 100$) of these relative price and quantity changes are:

	Quantities	Prices
Beer	-1.8	1.0
Wine	-0.4	0.9
Spirits	0.9	1.8
Marijuana	2.1	-2.6

As in three out of the four cases the quantity change has the opposite sign to the price change, we see again that there is a tendency for consumption of those goods whose relative price rises to grow slower than average, and vice versa.

Consider the following way of measuring the degree of interrelationship between the consumption of the four goods. Suppose that total consumption of the four goods is held constant, and that for some reason or another (such as a heat wave) beer is subject to a random shock causing its consumption to increase. If at the same time marijuana consumption falls, then, as more of one good compensates for less of the other, it would seem that both goods are capable of satisfying the same type of want of the consumer. In such a case, as these goods are competitive, it would be natural to describe beer and marijuana as being substitutes for one another. By a similar argument, goods whose consumption is positively correlated reinforce each other and can be described as complements.[23] We implement this idea by computing the correlation coefficients between the relative quantity change in good i, $Dq_{it} - DQ_t$, and that of good j, $Dq_{jt} - DQ_t$ for all pairs $i, j = 1, \ldots, 4$; deflating the individual quantity changes by DQ_t serves to hold constant total consumption of the group of goods. The results, presented in Table 6.5, indicate that the three alcoholic beverages are all negatively correlated with marijuana and are thus substitutes. Interestingly, for each of the three rows referring to alcoholic beverages, the largest (in absolute value) off-diagonal correlation always involves marijuana; these correlations are beer-marijuana -0.7, wine-marijuana -0.7 and spirits-marijuana -0.9. Accordingly, there seems to be some strength in the substitutability relationship between alcohol and marijuana. Note also that the three within-alcohol correlations are all positive, indicating complementarity. While this sort of behaviour cannot be ruled out, as these correlations are all lower than the others, less weight should be given to this finding.

<u>Demand Equations</u>

In this sub-section we proceed more formally and present estimates for own- and cross-price elasticities for the three alcoholic beverages and marijuana which are derived from a demand system. Due to the limited number of observations available, as well as the lack of variability of the price of marijuana, this requires substantial structuring of the problem in the form of several simplifying assumptions. Because of its straightforward nature and because it is widely used, the demand system we use is the Rotterdam model due to Barten (1964) and Theil (1965).

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[23] This approach to substitutability/complementarity based on residual correlations has a long history, going back to Allen and Bowley (1935).

To keep things manageable, we take alcohol and marijuana to be a separable block in the consumer's utility function, so that we can consider the group by itself, and suppose that within the group each of the goods is preference independent in the sense that the marginal utility of consumption is independent of the consumption of the other goods.[24] Under these conditions, the i^{th} equation of the Rotterdam model takes the form

$$\text{(6.3)} \qquad \bar{w}_{it} Dq_{it} = \theta_i DQ_t + \phi\theta_i \left(Dp_{it} - DP'_t\right) + \varepsilon_{it},$$

where $\theta_i = \partial(p_i q_i)/\partial M$ is the marginal share of good i; ϕ is the own-price elasticity of demand for the group of goods as a whole; $DP'_t = \sum_{i=1}^n \theta_i Dp_{it}$ is the Frisch price index; and ε_{it} is a disturbance term. By dividing both sides of equation (6.3) by $\bar{w}_{it}$, it can be seen that $\eta_i = \theta_i / \bar{w}_{it}$ is the i^{th} income elasticity, and $\eta'_{ii} = \phi\theta_i / \bar{w}_{it}$ is the elasticity of demand for i with respect to its relative price, $Dp_{it} - DP'$, also known as the Frisch price elasticity. For $i, j = 1, ..., n,$ the compensated (or Slutsky) price elasticities, which hold real total expenditure on the group constant, take the form $\eta_{ij} = \eta'_{ii}\left(\delta_{ij} - \eta_j \bar{w}_{jt}\right)$, where δ_{ij} is the Kronecker delta $\left(\delta_{ij} = 1 \text{ if } i = j, \text{ 0 otherwise}\right)$; and the corresponding uncompensated (or Marshallian) elasticities are $\eta^*_{ij} = \eta_{ij} - \eta_i \bar{w}_{jt}$.[25] To further simplify the problem of estimating equation (6.3) for i=1,…,4, the values of the marginal shares are specified in advance on the basis of prior studies,[26] so that ϕ is the only unknown parameter. Using the Australian data, the GLS estimate of this parameter is -0.429, with standard error 0.227.[27] This is the estimated price elasticity of demand for alcohol and marijuana as a whole; the value of this elasticity is reasonable and it is significantly different from zero.

The top part of Table 6.6 gives the implied matrix of compensated price elasticities. The own-price elasticity of beer is -0.2, wine -0.4, spirits -0.6 and marijuana -0.3. Interestingly, for

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[24] For details, see, e. g., Theil (1980) and Clements (1987a, 1987b). The assumption of preference independence will be discussed in the next section.

[25] As $\sum_{i=1}^n \bar{w}_{it} = \sum_{i=1}^n \theta_i = 1$ and $\eta_i = \theta_i / \bar{w}_{it}$, it follows that $\sum_{j=1}^n \eta_{ij} = 0$ and $\sum_{j=1}^n \eta^*_{ij} = -\eta_i$, i=1,...,n, which reflect demand homogeneity.

[26] The income elasticities are taken to be 0.5 for beer, 1.0 for wine, 2.0 for spirits and 1.2 for marijuana. When the four budget shares are specified as 0.4, 0.15, 0.15 and 0.3, the implied marginal shares are 0.20, 0.15, 0.30 and 0.35 (in the same order as before). See Clements and Daryal (2005a) for details.

[27] The disturbances ε_{it} are assumed to have zero means and to economise on unknown parameters, have variances and covariances of the form $\sigma^2 \bar{w}_i (\delta_{ij} - \bar{w}_j)$, where σ^2 is a constant; and $\bar{w}_i$ is the sample mean of $\bar{w}_{it}$. This specification, which has been advocated by Selvanathan (1991) and Theil (1987b), is based on the multinomial distribution.

each alcoholic beverage, the largest cross-price elasticity is for the price of marijuana: The elasticity of beer consumption with respect to the price of marijuana is 0.1; wine-marijuana is 0.2; and spirits-marijuana is 0.3. The corresponding uncompensated elasticities are given in the bottom panel of Table 6.6. The own-price elasticities are now -0.4, -0.5, -0.9 and -0.7 for beer, wine, spirits and marijuana, respectively. An element-by-element comparison of the uncompensated elasticities with their compensated counterparts reveals two major differences: (i) When the income effects are included, due to the high budget share of beer of about 40 percent, the elasticities involving the price of beer (given in column 2) are all (algebraically) much lower than when these effects are excluded. (ii) The four uncompensated elasticities of spirits (given in the row for that good) are all much smaller algebraically than their compensated counterparts due to the high income elasticity of spirits of 2 (see footnote 26). In comparison with previous studies, the values of the own-price elasticities for the three alcoholic beverages are reasonable (for a recent survey, see Fogarty, 2005, Chap. 2). There are only two prior comparable studies of the own-price elasticity of demand for marijuana. First, Nisbet and Vakil (1972), using US data, find it to lie in the range -0.5 to -1.5, so that our estimate of the uncompensated elasticity lies within this range. Second, Daryal (2002) employs survey data to estimate the elasticity to be -0.4 for frequent users, -0.1 for occasional users and 0 for those who are not currently users. Given that the bulk of marijuana is consumed by frequent users, our estimates are not greatly at variance with his.

7. A USEFUL RULE OF THUMB: PRICE ELASTICITIES ARE ABOUT -1/2

The own-price price elasticities for alcohol and marijuana discussed in the previous section are clustered around the value of minus one half. As this center-of-gravity value applies in a number of other instances also, we shall consider in this section what theoretical justification lies behind the empirical regularity of price elasticities being approximately equal to minus one half. We commence the discussion by considering several examples.

Table 7.1 and Figure 7.1 present information from reviews regarding estimated price elasticities for a number of different commodities. Panels 1-3 of the table show that the major alcoholic beverages have mean/median elasticities not too away from the value $-\frac{1}{2}$. The means from Selvanathan and Selvanathan (2005a) are beer –0.37 (with standard error 0.09), wine –0.46 (0.08) and spirits –0.57 (0.12), so that the maximum distance from $-\frac{1}{2}$ is a mere 1.4 standard errors. The next two panels of the table, Panels 4 and 5, show that more or less the same result holds for cigarettes and residential water. For petrol (Panel 6), the long-run elasticities tend to be closer to -½ than the short-run values. A possible exception to the "rule of -½" is residential electricity (Panel 7), which has a mean short-run elasticity of demand of –0.35, while the mean long-run value is –0.85. Finally, Panel 8 of the table shows that the mean price elasticity of "branded products" is –1.76, which is substantially different from -½. But this is not unexpected as there are many good substitutes for a branded product -- other brands of the same basic product. In this sense then, branded products are fundamentally different to the others in the table: Branded products are much more narrowly defined than are products such as alcoholic beverages, cigarettes, water, petrol and electricity. In what follows, we develop a theory that is applicable to broader products only, not more narrowly defined goods like branded products.

We shall present the theory in the context of the Rotterdam model but as the arguments that follow are more general, this is only for purposes of convenience.[28] We thus return to demand equation (6.3), which we reproduce here with the disturbance term set at its expected value of zero:

$$\text{(7.1)} \qquad \bar{w}_{it} Dq_{it} = \theta_i DQ_t + \phi\theta_i \left(Dp_{it} - DP'_t\right) .$$

This is the i^{th} demand equation of the Rotterdam model under the assumption of preference independence. Initially, suppose we apply this model to an exhaustive set of n goods, rather than just a sub-set; we could then describe this as an unconditional application, whereas the sub-set case would be a conditional one. In equation (7.1), $\bar{w}_{it}$ is the budget share of good i averaged over the two years t-1, t; the n budget shares have a unit sum, that is $\sum_{i=1}^{n} \bar{w}_{it} = 1$. The term Dq_{it} is the log-change from t-1 to t in the quantity consumed of i, $Dq_{it} = \log q_{it} - \log q_{i,t-1}$, and it can be shown that the left-hand variable of equation (7.1), $\bar{w}_{it} Dq_{it}$, is the quantity component of the change in the budget share of i. The first term on the right of (7.1) is $\theta_i DQ_t$, which refers to the effect of a change in real income on the demand for i. In this term, θ_i is the i^{th} marginal share, which answers the question, if income increases by one dollar, what fraction of this increase is spent on i, with $\sum_{i=1}^{n} \theta_i = 1$ as it is assumed that the increase is spent on something. The change in real income is measured by the Divisia volume index $DQ_t = \sum_{i=1}^{n} \bar{w}_{it} Dq_{it}$, which shows that the variable on the left-hand side of equation (7.1)

[28] Underlying the Rotterdam model is Theil's (1980) differential approach to consumption theory, which will be discussed in Section 9.

is also interpreted as the contribution of good i to this index. Thus the income term of equation (7.1) is a fraction θ_i of the Divisia volume index.

The second term on the right of (7.1), $\phi\theta_i\left(Dp_{it} - DP'_t\right)$, deals with the impact of changes in the relative price of good i. The coefficient ϕ is the income flexibility (the reciprocal of the income elasticity of the marginal utility of income); θ_i is the same marginal share of i; $Dp_{it} = \log p_{it} - \log p_{i,t-1}$ is the log-change in the i^{th} price; and $DP'_t = \sum_{i=1}^{n} \theta_i \, Dp_{it}$ is the Frisch price index which uses marginal shares as weights, which has the effect of holding constant the marginal utility of income. Accordingly, in this relative price term the change in the nominal price of good i, Dp_{it}, is deflated by the Frisch index of the change in all n prices. It is to be noted that the right-hand side of equation (7.1) contains only the change in the own-relative price, not the others. This is an implication of the assumption of preference independence, whereby tastes can be characterised by a utility function that is additive in the n goods, $u\left(q_1,\ldots,q_n\right) = \sum_{i=1}^{n} u_i\left(q_i\right)$, with $u_i\left(q_i\right)$ the i^{th} sub-utility function that depends only on the consumption of good i. Preference independence (PI) implies that each marginal utility depends only on the consumption of the good in question, not the others, so that all second-order cross derivatives of the utility function vanish.

The assumption of PI means that as commodities do not interact in the utility function, utility is derived from the consumption of good 1 <u>and</u> good 2 <u>and</u> good 3, and so on, where the word "and" is underlined to emphasise the additive nature of preferences. Such a hypothesis about tastes is more applicable to broader aggregates than more finely distinguished goods such as "branded products". Another way of making the same argument is via the demand equations under PI, which for good i takes the form of equation (7.1). As only the own-relative price appears in this equation, the substitution possibilities are clearly restricted by the assumption of PI. Thus as the broader aggregates have few substitutes, it can again be seen that these types of goods are more suitable for the application of the assumption of PI.

To understand further the workings of equation (7.1), we divide both sides by $\bar{w}_{it}$ to yield

$$Dq_{it} = \eta_i \, DQ_t + \eta'_{ii}\left(Dp_{it} - DP'_t\right),$$

where $\eta_i = \theta_i / \bar{w}_{it}$ is the i^{th} income elasticity and $\eta'_{ii} = \phi\theta_i / \bar{w}_{it}$ is the elasticity of demand for good i with respect to its relative price. As this relative price uses the Frisch index as the deflator, this elasticity holds constant the marginal utility of income and is known as the i^{th}

Frisch own-price elasticity. It can be seen that these price elasticities are proportional to the corresponding income elasticities, with factor of proportionality ϕ. That is,

$$\eta'_{ii} = \phi\eta_i, \qquad i=1,...,n. \tag{7.2}$$

Accordingly, luxuries (goods with $\eta_i > 1$) are more price elastic than necessities ($\eta_i < 1$). Deaton (1974) refers to a variant of this proportionality relationship as "Pigou's (1910) law". The proportionality relationship (7.2) agrees with the intuitive idea that necessities (luxuries) tend to be essential (discretionary) goods, which have few (many) substitutes.

The budget constraint implies that a budget-share weighted average of the income elasticities is unity, that is, $\sum_{i=1}^{n} \bar{w}_{it}\eta_i = 1$, so that an "average" commodity has an income elasticity of unity. This means that for such a commodity, the Frisch price elasticity $\eta'_{ii} = \phi$. An alternative way to establish the same result is to consider an average commodity in the Frisch elasticity space; the price elasticity of this good is given by a budget-share weighted average of the n Frisch elasticities, $\sum_{i=1}^{n} \bar{w}_{it}\eta'_{ii}$. If we multiply both sides of the proportionality relationship (7.2) by $\bar{w}_{it}$, sum over $i=1,...,n$, and use $\eta_i = \theta_i/\bar{w}_{it}$ and $\sum_{i=1}^{n}\theta_i = 1$, we then obtain $\sum_{i=1}^{n} \bar{w}_{it}\eta'_{ii} = \phi$. This reveals that the average Frisch elasticity is also equal to ϕ. A substantial body of research points to the value of the income flexibility ϕ being approximately minus one half.[29] This means for an average commodity, the Frisch price elasticity will also

[29] Selvanathan (1993) uses time-series data to estimate a differential demand system for each of 15 OECD countries. For Australia, the ϕ-estimate is –0.46, with asymptotic standard error 0.08 (Selvanathan, 1993, p. 189). When the data are pooled over the 15 countries, the estimate of ϕ is –0.45, with ASE 0.02 (Selvanathan, 1993, p. 198). Using a related approach, Selvanathan (1993, Sec. 6.4) obtains 322 estimates of ϕ, one for each year in the sample period for each of 18 OECD countries; the weighted mean of these estimates is very similar to those above at –0.46 (ASE = 0.03). Two other cross-country estimates of ϕ are also relevant: Using the ICP data for 30 countries from Kravis et al. (1982), Theil (1987a, Sec. 2.8) obtains a ϕ-estimate of –0.53 (0.04). Chen (1999, p. 171) estimates a demand system for 42 countries and obtains an estimate of ϕ of –0.42 (0.05), when there are intercepts in his differential demand equations, which play the role of residual trends in consumption, and –0.29 (0.05) when there are no such intercepts. The final element of support for $\phi = -0.5$ is the earlier, but still influential, survey by Brown and Deaton (1972, p. 1206) who review previous findings and conclude that "there would seem to be fair agreement on the use of a value for ϕ around minus one half".

It should be noted that treating the income flexibility as a constant parameter is at variance with Frisch's (1959) famous conjecture that ϕ should increase in absolute value as the consumer becomes more affluent. However, most tests of the Frisch conjecture tend to reject it; see, e.g., Clements and Theil (1996), Selvanathan (1993, Secs. 4.8 and 6.5), Theil (1975/76, Sec. 15.4), Theil (1987a, Sec. 2.13) and Theil and Brooks (1970/71). Such a finding is not surprising as the Frisch conjecture refers to the third-order derivative of the utility function, and most consumption data could not be expected to be very informative about the nature of this higher-order effect. On the other hand however, evidence supporting Frisch has been reported by DeJanvry et al. (1972) and Lluch et al. (1977). Note also that according to Frisch (1959, p. 189) a ϕ-value of –0.5 would pertain to the "middle income bracket, 'the median part' of the population".

take the value of minus one half. As not all goods will coincide with the "average" exactly, we have to modify the above statement to the weaker form that the n Frisch price elasticities will be *approximately* equal to minus one half.[30] As the more common Slutsky (or compensated) own-price elasticity is equal to its Frisch counterpart minus a term of order $1/n$, in most cases the differences will be small, so the Slutsky elasticities will also be scattered around -½.[31]

The above discussion relates to the unconditional case with preference independence. If the assumption of preference independence is given up, the demand equation for good i becomes more complex with the substitution term on the right-hand side of (7.1), $\phi\theta_i\left(Dp_{it} - DP_t'\right)$, replaced by a term involving own- and cross-relative prices, viz., $\sum_{i=1}^{n} \nu_{ij}\left(Dp_{it} - DP_t'\right)$, where ν_{ij} is a new price coefficient. The demand equation thus becomes

(7.3) $$\overline{w}_{it} Dq_{it} = \theta_i\, DQ_t + \sum_{i=1}^{n} \nu_{ij}\left(Dp_{it} - DP_t'\right).$$

The price coefficient in this equation ν_{ij} is defined as $(\lambda p_i p_j / M) u^{ij}$, where $\lambda > 0$ is the marginal utility of income, p_i is the price of good i, M is nominal income and u^{ij} is the $(i, j)^{th}$ element of the inverse of the Hessian matrix of the utility function. If $\nu_{ij} > 0\ (< 0)$, then an increase in the relative price of good j causes consumption of i to increase (decrease), and the two goods are said to be Frisch substitutes (complements). These price coefficients satisfy $\sum_{j=1}^{n} \nu_{ij} = \phi\theta_i$. As $\eta_{ij}' = \nu_{ij} / \overline{w}_{it}$ is the $(i, j)^{th}$ Frisch price elasticity (marginal utility of income constant), the constraint of the previous sentence implies that $\eta_{i\bullet}' = \phi\eta_i$, where $\eta_{i\bullet}' = \sum_{j=1}^{n} \eta_{ij}'$ is

[30] In a widely cited paper, Deaton (1974) examines whether price and income elasticities are (approximately) proportional, as predicted by preference independence. On the basis of UK data, he finds no such relationship and concludes that "*the assumption of additive preferences* [preference independence] *is almost certain to be invalid in practice and the use of demand models based on such an assumption will lead to severe distortion of measurement*" (his emphasis). Deaton's rejection of preference independence (PI) on the basis of indirect evidence (the lack of proportionality of price and income elasticities) is consistent with first-generation direct tests that test the implied parametric restrictions on the demand equations; see Barten (1977) for a survey. These results can be responded to in two ways. First, Selvanathan (1993) examines elasticities from 18 OECD countries, and finds the evidence not inconsistent with the proportionality relationship, indicating that Deaton may have been premature in declaring the invalidity of PI. Second, as the first-generation tests of the hypothesis of PI have only an asymptotic justification, it is appropriate to exercise caution in taking the results at face value when the underlying sample sizes are not large. To avoid potential problems with asymptotics associated with modest sample sizes, Selvanathan (1987, 1993) develops a Monte Carlo test of PI, and the results reject the hypothesis much less frequently. For example, in applications of the methodology, Selvanathan and Selvanathan (2005b) reject PI in 9 countries out of a total of 45; Clements et al. (1997) are unable to reject PI for beer, wine and spirits in all of the 7 countries they consider; and Selvanathan and Selvanathan (2005a, p. 235) are unable to reject the hypothesis for the three alcoholic beverages in 10 countries. While there is still scope for differing views on this matter, it now seems safe to conclude that the assumption of PI should not be rejected out of hand, or at least as rapidly as the older studies would imply.

[31] The relationship between the Slutsky (η_{ii}) and Frisch own-price elasticities is $\eta_{ii} = \eta_{ii}'(1-\theta_i)$. As $\sum_{i=1}^{n} \theta_i = 1$, the order of the marginal shares is $1/n$, as is the difference between η_{ii} and η_{ii}'.

the sum of the own- and cross-price elasticities involving good i and η_i is the i^{th} income elasticity. Thus whereas PI implies that the Frisch own-price elasticities are proportional to the corresponding income elasticities, when we give up the assumption of PI the sums of own- and cross-price Frisch elasticities are proportional to income elasticities. Application of the argument in the previous paragraph then shows that these sums are approximately equal to -½.[32]

Now consider the conditional case, when we analyse the demand for a group of goods, rather than all goods simultaneously. An example of such a group is "vice" comprising beer, wine, spirits and marijuana, which was analysed in the previous section. Here ϕ is now interpreted as the own-price elasticity of demand for vice as a whole. But this version of ϕ is exactly equal to η'_{ii}, the own-price Frisch elasticity that is implied by the unconditional equation when vice is taken to be the i^{th} good among the original n, when preference independence holds. This means that in conditional applications ϕ continues be to approximately equal to minus one half. Thus under preference independence, conditional own-price elasticities are approximately minus one half. When preference independence does not hold, the sums of conditional own-and cross-price elasticities fluctuate around -½.

This section can be summarised as follows:

- The price elasticities for beer, wine, spirits and marijuana that were discussed in the previous section are clustered around the value of -½. This can be understood in terms of the underlying assumption of preference independence.
- Other studies that are not based on preference independence also point to a centre-of-gravity of about -½ for the price elasticities.
- Recent econometric testing tends to find more support for the hypothesis of preference independence, although the matter has probably still not been completely settled.
- When nothing else is known about the price-sensitivity of a good, a reasonable value of its price elasticity is minus one half.[33]

[32] Under PI, the Hessian matrix of the utility function is diagonal, so that $u^{ij} = 0$ for $i \neq j$. This means that $\nu_{ij} = 0$ for $i \neq j$, so that constraint $\sum_{j=1}^{n} \nu_{ij} = \phi\theta_i$ implies $\nu_{ii} = \phi\theta_i$, and equation (7.3) reduces to (7.1).

[33] For a more detailed presentation of the material of this section, see Clements (2005).

8. WHAT IF MARIJUANA WERE LEGALISED?

Thus far we have analysed the evolution of prices and the effects of prices on the consumption of marijuana and alcoholic leverages. That material deals with enhancing understanding of the way the market for marijuana works, or, perhaps, how the market has operated in the past. We now change the focus substantially to discuss what may happen to the operation of this market in light of a hypothetical major policy change, the legalisation of marijuana. This involves an examination of possible changes to prices, consumption and government revenues from taxation. In a certain sense, however, the investigation that follows still has the objective of trying to understand the way the world works, with the word "works" interpreted to now refer to how it might work in the future in a legalised, or more deregulated, environment. This section begins with an analysis of the likely effects of legalisation on prices, and then turns to the effects on the consumption of marijuana and alcohol. In the next section, we extend the analysis by considering the implications of legalisation for government revenue from taxing vice consumption.

Would Prices Decrease or Increase?

Following Miron (2005), we can analyse the impact on prices of legalisation by reference to the relative shifts of the marijuana demand and supply curves. For simplicity of exposition, we shall discuss this in terms of complete legalisation, but it should be understood that in qualitative terms, the same analysis applies to the less-than-complete legalisation case. According to the "forbidden fruit" hypothesis, legalisation makes marijuana less attractive and shifts the demand curve down and to the left, as in Panel A of Figure 8.1. On the other hand, as emphasised by Niskanen (1992), legalisation would reduce search costs and the risk of prosecution, and possibly also improve product quality. These effects would cause the demand curve to shift up and to the right. Evidence on how the demand curve shifts based on the experience with decriminalisation, which could be thought of as a weak form of legalisation, in (predominantly) the states of the US is mixed: Studies using data pertaining to the whole population (Cameron and Williams, 2001, Model, 1993, Saffer and Chaloupka, 1995, 1998) find a significant increase in marijuana consumption due to decriminalisation.[34] By contrast, three other studies involving youths only (Johnston et al., 1981, Pacula, 1998, Theis and Register, 1993) find that decriminalisation has no significant impact. Evidently, as the general population consume less marijuana than do the young, their consumption is more sensitive to changes in its

[34] It is to be noted, however, Cameron and Williams (2001) find the increase in consumption to be only temporary.

legal status. On the basis of a survey of university students, Daryal (2002) finds that on average consumption would increase modestly with legalisation. We will have more to say about Daryal's results in the next sub-section.

Regarding the supply curve, Miron (1998, 2005) argues on a priori grounds that legalisation could shift it either up or down, as shown in Panel B of Figure 8.1. With legalisation, producers would no longer be forced to incur costs associated with concealing their activities to avoid prosecution, causing the supply curve to shift down and to the right. On the other hand however, legalisation would also mean that producers become part of the legitimate sector of the economy and would have to pay taxes and charges, and comply with all regulations that conventional businesses are subject to. Additionally, marijuana producers would possibly have to incur advertising expenses if the product were legalised. These effects would cause the supply curve to shift up and to the left.

The net effect of these shifts in the demand and supply curves on prices is ambiguous as is illustrated in Panel C of Figure 8.1 for the simplified case in which the demand curve remains unchanged. This ambiguity can only be resolved with empirical evidence. While such evidence is not easy to obtain, Miron (2005) argues that on the basis of a comparison of marijuana prices in the US, where restrictions are stronger, and Australian and The Netherlands, where they are weaker, the net effect on prices likely to be quite small. Another piece of evidence that points in the same direction is Miron's (2003) finding on the basis of an extremely detailed and careful analysis, that markups from "farmgate" to consumers of heroin and cocaine are substantially smaller than previously thought. He finds while these markups are high, they are not massively larger than those of legal goods such as chocolate, coffee, tea and barley/beer. On the basis of other evidence, Miron (2003, p. 529) estimates "that the black market price of cocaine is 2-4 times the price that would obtain in a legal market, and of heroin 6-19 times. In contrast, prior research has suggested that cocaine sells at 10 to 40 times its legal price and heroin at hundreds of times its legal price." While there are other factors determining markups, the smaller-than-previously-thought markups could be taken to imply that the illicit nature of these drugs per se has only a limited (or a more limited that previously thought) impact on prices. Under this interpretation, the price effects of legalisation would likewise be limited.[35] Consistent with this line of thinking is research showing that increased enforcement of drug laws does not seem to

[35] Miron (1999) provides some further evidence with his study of the impact of prohibition on alcohol consumption in the United States during 1920-33. Using the death rate from liver cirrhosis as a proxy for alcohol consumption, he finds that prohibition "exerted a modest and possibly even positive effect on consumption." This could be because prices fell for reasons given above. But there are other possibilities including a highly inelastic demand for alcohol and/or prohibition giving alcohol the status of a "forbidden fruit" (Miron, 1999).

result in higher prices (Basov et al, 2001, DiNardo, 1993, Weatherburn and Lind, 1997, Yuan and Caulkins, 1998).

<u>The UWA Survey</u>

As discussed above, on a priori grounds it is not clear which way the demand curve could shift with legalisation. One approach to resolving this issue is to carry out as survey of consumers, as in Daryal (2002) who surveys 327 first-year economics students at the University of Western Australia. His results, for various types of consumers identified by sex and the intensity of their use of marijuana, are summarised in Table 8.1. The key results are that (i) the consumption of daily users is estimated to increase substantially (although it should be kept in mind that the corresponding standard error is relatively large); (ii) that of weekly, monthly and occasional users is estimated to increase much less, by 7-9 percent; (iii) for all individuals, legalisation is estimated to increase consumption by about 4 percent on average; (iv) legalisation has essentially no effect on encouraging non-users to take up marijuana consumption; and (v) on average, the consumption of males increases by more than that of females following legalisation.

As discussed above, since marijuana and alcohol have not dissimilar effects on users, they are likely to be closely related in consumption. Accordingly, if its legalisation causes marijuana consumption to change, consequential changes in drinking patterns could also be expected. In particular, as consumers are likely to regard marijuana and alcohol as substitutes, an increase in the usage of the former would probably coincide with a reduction of the latter. As in Daryal's (2002) survey there is only limited evidence available on the impact of legalisation of marijuana on drinking, in the next sub-section we present a model that highlights the interrelationship of marijuana and alcohol consumption. Under certain assumptions, the model can be used to provide projections of changes in alcohol consumption following legalisation.

<u>Exogenous Shocks and Related Goods</u>

The interaction of goods in the consumer's utility function, as well as the operation of the budget constraint, means that a shock that affects the consumption of one product will have ramifications for the demand for related products. Thus while hot weather may well stimulate ice-cream sales, it would probably do so at the expense of other products; similarly, low-carb diets reduce the consumption of bread, pasta, etc., but have the effect of increasing other food items. In this sub-section, we use the substitutability between goods to model the transmission to other products of a consumption shock to one product. This framework will be employed in the next sub-section to analyse the possible impact on drinking of legalisation of marijuana consumption.[36]

In conventional consumption theory, the consumer chooses the quantity vector $\mathbf{q} = [q_1,...,q_n]'$ to maximise the utility function $u(\mathbf{q})$ subject to the budget constraint $\mathbf{p}'\mathbf{q} = M$, where $\mathbf{p}' = [p_1,...,p_n]$ is the price vector, and M is total expenditure ("income" for short). This leads to a system of Marshallian demand equations of the form $\mathbf{q} = \mathbf{q}(M, \mathbf{p})$. Consider now an extended version of this theory in which some scalar shift variable s affects tastes, so that the utility function now becomes $u(\mathbf{q}, s)$. The associated demand equations now take the form $\mathbf{q} = \mathbf{q}(s, M, \mathbf{p})$, which we approximate for good i as

$$(8.1) \qquad Dq_i = \alpha_i\, Ds + \eta_i\, DM + \sum_{j=1}^{n} \eta_{ij}^{*}\, Dp_j\,,$$

where D is the log-change operator; α_i is the elasticity of the consumption of good i with respect to the shift variable s; η_i is the i^{th} income elasticity; and η_{ij}^{*} is the $(i,j)^{th}$ uncompensated price elasticity.

Let η_{ij} be the $(i,j)^{th}$ compensated price elasticity and $w_i = p_i q_i / M$ be the budget share of i, so that $\eta_{ij}^{*} = \eta_{ij} - w_j\,\eta_i$, which is the Slutsky equation. Defining the change in real income as $DQ = DM - \sum_{i=1}^{n} w_i\, Dp_i$ and using the Slutsky equation, we can then express equation (8.1) as:

$$(8.2) \qquad Dq_i = \alpha_i\, Ds + \eta_i\, DQ + \sum_{j=1}^{n} \eta_{ij}\, Dp_j\ .$$

We interpret the shift variable s as a binary variable reflecting two regimes, such that Ds takes the value 0 (for regime 1) or 1 (regime 2). We can then write equation (8.2) under the regime 2 as

$$(8.3) \qquad Dq_i = \alpha_i + \eta_i\, DQ + \sum_{j=1}^{n} \eta_{ij}\, Dp_j\ .$$

To preserve the budget constraint, the coefficients of equation (8.3) satisfy $\sum_{i=1}^{n} w_i\,\alpha_i = 0$, $\sum_{i=1}^{n} w_i\,\eta_i = 1$, $\sum_{i=1}^{n} w_i\,\eta_{ij} = 0$, $j=1,...,n$. The coefficient α_i is interpreted as the log-change in

[36] This and the next sub-section draw on Clements and Daryal (2005b) and Clements and Lan (2005).

consumption of good i resulting from the regime change when income and prices are held constant.

Let $\partial u / \partial q_k$ be the marginal utility of good k and suppose that the regime change causes this marginal utility to increase by $c \times \partial u / \partial q_k$, where $c > 0$, so that

(8.4) $$d\left(\log \frac{\partial u}{\partial q_k}\right) = c.$$

It is to be noted that the change in regime affects directly only the marginal utility of one good, that of good k. To interpret c in equation (8,4), recall that for a budget-constrained utility maximum, each marginal utility is proportional to the corresponding price, $\partial u / \partial q_i = \lambda p_i$, where λ is the marginal utility of income. Accordingly for $i = k$, $d\left[\log\left(\partial u / \partial q_k\right)\right] = d\left(\log \lambda\right) + d\left(\log p_k\right)$, or in view of (8.4), $c = d(\log p_k)$, if λ is constant. This shows that c is an "equivalent price change", the fall in the price of k that would yield the same increase in consumption of this good as would the original shock. In the Appendix we show that equation (8.4) implies that:

(8.5) $$\alpha_i = -c\, \eta_{ik}.$$

In words, the change in consumption of good i due to the regime change is proportional to that good's elasticity of demand with respect to the price of good k ,with factor of proportionality (the negative of) c. This is an attractively-simple result linking the effect on consumption of i of the shock to k that involves the degree of substitutability between the two goods. Equation (8.5) also preserves the budget constraint as $\sum_{i=1}^{n} w_i\, \alpha_i = -c \sum_{i=1}^{n} w_i\, \eta_{ik} = 0$, where the last step follows from the aggregation constraint $\sum_{i=1}^{n} w_i\, \eta_{ij} = 0$, given below equation (8.3). Accordingly, rule (8.5) serves to reallocate the fixed amount of income among the n goods following the change in regime.

Figure 8.2 illustrates the link between the substitution effect and the shift in the demand curve in the log-linear case when goods k and i are substitutes (so that $\eta_{ik} > 0$). With DD the cross relationship between consumption of i and the price of k under regime 1 , a lowering of $\log p_k$ by c leads to the movement from the point A to B, and $\Delta \log q_i = -c\, \eta_{ik}$. According to equation (8.5), the regime change causes this demand curve to shift to the left by exactly the same amount, so that the point on the new demand curve, $D'D'$, corresponding to the original price must be C , directly above B.

Legalisation and Drinking

We now use the information on the effects of legalisation on marijuana consumption, together with the price elasticities given in Table 6.6, to yield projections of changes in drinking patterns.

We first apply equation (8.5) for the case in which i = k = marijuana. The UWA survey yields a value of the change in marijuana consumption, presented in Table 8.1, which we interpret as α_i. Combining that with the own-price elasticity $\eta_{ii} = -0.33$ (from the upper panel of Table 6.6), from equation (8.5) we obtain the value of c. Next, to estimate the change in consumption of alcoholic beverages following legalisation, we use this c-value in equation (8.5) for i = beer, wine and spirits and k = marijuana, together with the cross-price elasticities given in the last column of the upper panel of Table 6.6. The results are given in Table 8.2, which for convenient reproduces from Table 8.1 the marijuana results. The key results are: (i) For each user group, the consumption of spirits always falls the most with legalisation. Next is wine, and then comes beer. (ii) The largest fall in alcohol consumption is for the daily users. The effects for weekly, monthly and occasional users are not too dissimilar. (iii) For all types of consumers (Panel H of the table), on average legalisation is estimated to cause beer consumption to fall by about 1 percent, wine by 2 percent and spirits by almost 4 percent, while marijuana usage increases by 4 percent. It should however be noted that as the standard errors are relatively large, the changes in alcohol consumption are not estimated too precisely.

9. TAXING MARIJUANA

This section proceeds on the basis that marijuana has been legalised and considers the public finance opportunities afforded by the opportunities to tax its consumption. As information regarding marijuana consumption is of necessity more uncertain than that for many other commodities, it is appropriate to recognise explicitly this uncertainty in the analysis of potential taxation revenue. This section contains four sub-sections. The first provides a review of the differential approach to consumption theory, which forms much of the basis of the subsequent investigation. Then follows a discussion of how to incorporate uncertainty into the demand responses for marijuana and the related goods tobacco and alcohol. The approach set out in that sub-section allows us to draw on the considerable prior research on the consumption of tobacco and alcohol and combine it with the much more uncertain information regarding the demand responses of marijuana. The third sub-section contains an analysis of how much taxation revenue is available from marijuana, while the fourth considers the implications of redistributing the additional revenue to drinkers in the form of lower alcohol taxes. [37]

Differential Demand Equations

The differential approach to consumption theory was introduced by Theil (1980) as a way to analyse the pattern of consumer demand with minimal a prior restrictions on behaviour. The Rotterdam demand model, which was discussed in Sections 6 and 7, is one member of the class of differential demand models.[38] This sub-section sets out the differential demand equations that will be subsequently used. In the interests of clarity, we give a more or less self-contained exposition of the approach, which means that there is some unavoidable overlap with the material of Sections 6 and 7.

Let p_i, q_i be the price and quantity consumed of good i, so that if n is the number of goods $M=\sum_{i=1}^{n} p_i q_i$ is total expenditure ("income" for short) and $w_i = p_i q_i / M$ is the i^{th} budget share. The budget constraint of the consumer is $\sum_{i=1}^{n} p_i q_i = M$, and its total differential is $dM = \sum_{i=1}^{n}\left(q_i dp_i + p_i dq_i\right)$. Using the identity $d(\log x) = dx/x$, we can write the budget constraint as $d(\log M) = d(\log P) + d(\log Q)$, where $d(\log P) = \sum_{i=1}^{n} w_i d(\log p_i)$ and $d(\log Q) = \sum_{i=1}^{n} w_i d(\log q_i)$ are price and volume indexes defined as budget-share weighted averages of the n price and quantity log-changes. As the volume index can be expressed as $d(\log Q) = d(\log M) - d(\log P)$, the excess of the change in nominal income over the price index, we can identify $d(\log Q)$ as the change in the consumer's real income. Under general conditions, we can write the utility-maximising demand equation for good i in terms of the changes in real income and the n relative prices as

$$w_i d(\log q_i) = \theta_i d(\log Q) + \sum_{j=1}^{n} \nu_{ij}\left[d(\log p_j) - d(\log P')\right]. \tag{9.1}$$

The variable on the left-hand side of this equation, the logarithmic change in the quantity demanded of good i weighted by its budget share, has two interpretations. First, it is the quantity component of the change in the i^{th} budget share, which can be confirmed by taking the differential of $w_i = p_i q_i / M$, to yield $dw_i = w_i d(\log p_i) + w_i d(\log q_i) - w_i d(\log M)$. As prices and income are taken to be exogenous in consumption theory, the quantity component of the

[37] This section is based on Clements et al. (2005).
[38] In the Rotterdam model (i) the coefficients are taken to be constants, (ii) infinitesimal changes are replaced with first differences and (iii) budget shares are replaced with their two-period arithmetic averages.

change in the budget share is the endogenous part of the overall change and thus is a reasonable choice for the dependent variable of a demand equation. The second interpretation of term $w_i d(\log q_i)$ is the contribution of good i to the change in real income, $d(\log Q) = \sum_{i=1}^{n} w_i d(\log q_i)$. The right-hand side of equation (9.1) is made up of an income term, $\theta_i d(\log Q)$, and a relative price term, $\sum_{j=1}^{n} \nu_{ij} \left[d(\log p_j) - d(\log P') \right]$. In the income term, $\theta_i = \partial(p_i q_i)/\partial M$ is the marginal share of good i which answers the question, if income rises by one dollar by how much does expenditure on i increase? As all of income is assumed to be spent, these marginal shares have a unit sum. Accordingly, the income term of the i^{th} demand equation is a fraction θ_i of the change in real income.

The term in square brackets on the right-hand side of equation (9.1), $d(\log p_j) - d(\log P')$, is the change in the relative price of good j, with the nominal price change deflated by the price index $d(\log P') = \sum_{i=1}^{n} \theta_i d(\log p_i)$. This index uses as weights the marginal shares, and is thus a marginal price index, which is known as the Frisch index. Deflation by this index serves to hold the marginal utility of income constant. The coefficient attached to the j^{th} relative price change in equation (9.1) is ν_{ij}, which is defined as $(\lambda p_i p_j / M) u^{ij}$, where $\lambda > 0$ is the marginal utility of income and u^{ij} is the (i, j)th element of the inverse of the Hessian matrix of the utility function. If $\nu_{ij} > 0$ (< 0), then an increase in the relative price of good j causes consumption of i to increase (decrease), and the two goods are said to be Frisch substitutes (complements); and if $\nu_{ij} = 0$, the two goods are independent. These ν_{ij} are known as Frisch price coefficients and satisfy $\sum_{j=1}^{n} \nu_{ij} = \phi\theta_i$, where $\phi = (\partial \log \lambda / \partial \log M)^{-1}$ is the reciprocal of the income elasticity of the marginal utility of income, which is known as the income flexibility for short. A sufficient condition for a budget-constrained utility maximum is that the $n \times n$ Hessian matrix of the utility function and its inverse $\left[u^{ij} \right]$ are both symmetric negative definite; this means that the $n \times n$ matrix of Frisch price coefficients $\left[\nu_{ij} \right]$ is also symmetric negative definite. The pattern of the matrix $\left[\nu_{ij} \right]$ is a convenient way of organising prior ideas about the manner in which the n goods interact in consumption.

Demand equation (9.1) is formulated in terms of relative prices. For some purposes it is convenient to use absolute prices by substituting $\sum_{i=1}^{n}\theta_i d(\log p_i)$ for $d(\log P')$ on the right of that equation. The relative price term then becomes

$$\begin{aligned}\sum_{j=1}^{n}\nu_{ij}\left[d(\log p_j)-\sum_{k=1}^{n}\theta_k d(\log p_k)\right] &= \sum_{j=1}^{n}\nu_{ij}d(\log p_j)-\sum_{j=1}^{n}\nu_{ij}\sum_{k=1}^{n}\theta_k d(\log p_k)\\ &= \sum_{j=1}^{n}(\nu_{ij}-\phi\theta_i\theta_j)d(\log p_j)\\ &= \sum_{j=1}^{n}\pi_{ij}d(\log p_j),\end{aligned}$$

where the second step is based on $\sum_{j=1}^{n}\nu_{ij}=\phi\theta_i$. The new term introduced in the third step of the above is $\pi_{ij}=(\nu_{ij}-\phi\theta_i\theta_j)$, the $(i,j)^{th}$ Slutsky coefficient, which measures the so-called total substitution effect of a change in the price of good j on the consumption of good i, real income remaining unchanged. The n^2 Slutsky coefficients, π_{ij}, $i,j=1,...,n$, are symmetric in i and j (Slutsky symmetry); satisfy $\sum_{j=1}^{n}\pi_{ij}=0$, $i=1,...,n$, which reflects demand homogeneity; and the $n\times n$ matrix $[\pi_{ij}]$ is symmetric negative semi-definite. We can thus rewrite equation (9.1) as

$$w_i d(\log q_i)=\theta_i d(\log Q)+\sum_{j=1}^{n}\pi_{ij}d(\log p_j), \tag{9.2}$$

which is a differential demand equation for good i in terms of absolute prices.

Dividing both sides of equation (9.2) by w_i yields a more familiar demand equation as the coefficients are now elasticities:

$$d(\log q_i)=\eta_i d(\log Q)+\sum_{j=1}^{n}\eta_{ij}d(\log p_j), \tag{9.3}$$

where $\eta_i=\theta_i/w_i$ is the income elasticity of i and $\eta_{ij}=\pi_{ij}/w_i$ is the $(i,j)^{th}$ Slutsky elasticity, the elasticity of the consumption of good i with respect to the price of good j when real income is held constant. The $n\times n$ matrix of price elasticities $[\eta_{ij}]$ is negative semi-definite; this matrix is asymmetric.

Stochastic Vice

We apply equations (9.1) and (9.3) to marijuana, tobacco, alcohol, which we dub "vice", and all other goods, so that $n=4$. As marijuana is commonly mixed with tobacco and consumed "jointly", we shall take these two products to be complements, at least on average in the sense to be described. As marijuana and alcohol both contain intoxicating properties that are similar in the minds of many consumers, they both tend to satisfy the same basic want, so we shall take them to be substitutes on average. The prior literature regarding the interrelatedness between marijuana, tobacco and alcohol is not unambiguous, but a case can be made that on balance the evidence points to marijuana and tobacco being complements, and marijuana and alcohol being substitutes. For a review of previous studies, see Clements et al. (2005). The fourth good, "other", is treated as being on average independent of the three elements of vice, which would seem to be not unreasonable for such a large heterogeneous category.

To allow for uncertainty, the budget shares and the basic parameters of the demand system given by equation (9.1) for $i=1,\ldots,4$ are all taken to be random and follow truncated normal distributions. The advantage of the approach of treating basic parameters of equation (9.1) as random is that the elasticities derived from them satisfy all the constraints of microeconomic theory. The means and standard deviations of these distributions are specified in columns 2 and 4 of Table 9.1. The values of the means reflect considerations of observed data (where available) for the budget shares; the prior literature in the case of some parameters; and/or what we judge to be "reasonable" values. The standard deviations are derived from specifying plausible confidence intervals that reflect the greater uncertainty associated with (i) marijuana and (ii) parameters as opposed to (potentially) observable budget shares.[39] These confidence bands as set out in column 3 of Table 9.1. The information in Table 9.1 provides an algorithm to compute the Frisch price coefficients, which can then be used to form the own- and cross-price Slutsky elasticities, according to equation (9.3) for $i=1,\ldots,4$, as well as the definition of η_{ij} given below that equation. As these price elasticities are non-linear functions of the budget shares and the underlying basic parameters such as the marginal shares and the income flexibility, we obtain the distributions of the elasticities with a Monte Carlo simulation approach.

We draw 5,000 values from the truncated normal distributions associated with rows 1-10 of Table 9.1 and use them to compute 5,000 values of the Slutsky price and income elasticities. Figure 9.1 gives histograms of the price elasticities in the form of a 4×4 "matrix" with rows representing quantities and columns prices. For example, the histogram in the first row and third column refers to the price elasticity for marijuana with respect to the price of alcohol. Moving down the main diagonal, it can be seen that the average own-price elasticities are -0.6 for marijuana (with standard deviation 0.4), -0.2 for tobacco (0.1), -0.7 for alcohol (0.2) and

[39] For the detailed justification of the means and standard deviations of Table 9.1, see Clements et al. (2005).

-0.04 for other (0.01).[40] The average cross-price elasticities involving the consumption of marijuana are marijuana-tobacco -0.2 (SD = 0.1), marijuana-alcohol 0.2 (0.1) and marijuana-other 0.6 (0.4). Figure 9.2 shows that on average marijuana and alcohol both have income elasticities a bit above unity, so they are mild luxuries, tobacco is a necessity with an average income elasticity of 0.4, and other has an income elasticity of about unity.

Consider the demand curve for marijuana. Per capita expenditure on marijuana in 1998 was \$372, while consumption was 0.7873 ounces per capita, so that the implicit price is 372/0.7872 = \$473 per ounce. These price-quantity values are represented by the point A in Figure 9.3, and we take this point as lying on the demand curve. The other points on the demand curve can be derived as follows. It follows from equation (9.3) for $i = 1$ (for marijuana) that $d(\log q_1) = \eta_{11} d(\log p_1)$, when real income and all non-marijuana prices are held constant. Denote the observed price and quantity by a second "0" subscript, so that $p_{10} = 473,\ q_{10} = 0.7872,$ and unobserved "new" values by p_{1*} and q_{1*}. Accordingly, $\log(q_{1*}/q_{10}) = \eta_{11}\log(p_{1*}/p_{10})$, so that $q_{1\bullet} = q_{10}\exp\left[\eta_{11}\log(p_{1\bullet}/p_{10})\right]$. As this equation expresses the new quantity in terms of the new price p_{1*}, the other points on the demand curve are obtained by varying p_{1*}. To allow for uncertainty in the parameters and data, for each value of p_{1*} we use the 5,000 values of the elasticity η_{11} described above, and we plot the averages over the 5,000 trials. The role of uncertainty is shown in Figure 9.4, which reveals that the precision of the demand curve decreases substantially as we move away from the observed price-quantity configuration. This can be seen even more clearly in the associated distributions of consumption conditional on the price, which are given in Figure 9.5. As can be seen from Panel B, when the price is \$500, which is close to that prevailing in 1998, the consumption distribution is fairly compact around the mean of 0.76 oz, and the standard deviation is 0.02 oz. But when the price rises to \$800 (Panel C), 60 percent above the status quo, the distribution moves to the left, with mean consumption falling to 0.57, while its dispersion increases substantially, as indicated by the standard deviation of 0.11.

[40] The mean price elasticities for marijuana and alcohol do not depart greatly from the "rule of -½ " of Section 7. The absolute value of the price elasticity for tobacco is more than three standard deviations below ½, so it could possibly be argued that this elasticity is on the low side. On the other hand however, the mean income elasticity for tobacco is about 0.4, much less than unity, which is the value underlying the rule of -½.

How Much Revenue Could be Raised?

In Section 8 we discussed the possibility that legalisation may have the effect of shifting the supply and demand curves for marijuana, and lead to a reallocation of consumers' "vice budget". To keep matters as simple as possible, in this and the remaining sub-sections we shall ignore these possible "legalisation effects" on production and consumption and focus on the opportunities to tax marijuana and the implications of such taxation. This analysis is thus not completely comprehensive and should be considered to be illustrative of the issues involved and the capabilities of the methodology. In a similar spirit, we also assume that any tax on marijuana is borne entirely by consumers.

Table 9.2 gives the basic information on pre-existing taxation and consumption. As can be seen, tax accounts for about 54 percent of the consumer price for tobacco and 41 percent for alcohol. The introduction of a marijuana tax would have the direct effect of decreasing its consumption, as well as indirect effects on the consumption of related products and tax revenue derived there from. As marijuana and tobacco are complements, the consumption of the latter product falls with the marijuana tax and as it is subject to a pre-existing tax, revenue falls on this count. On the other hand, as marijuana and alcohol are substitutes, taxing marijuana stimulates drinking and increases tax revenue from this source. To analyse these effects in detail, let p_i' be the producer (or pre-tax) price of good i, which is assumed to be constant throughout, p_i be the corresponding consumer (or post-tax) price and t_i' be the tax rate expressed as a proportion of p_i', so that $p_i = (1+t_i')p_i'$. Taxation revenue from i is $R_i = t_i' p_i' q_i = t_i p_i q_i$, where $t_i = t_i'/(1+t_i')$ is the tax rate as a proportion of the consumer price, while total tax revenue from vice is $R = \sum_{i=1}^{3} R_i$. We need to consider two situations, before and after the change in taxation arrangements, to be denoted by the superscript $\tau = 0$ and $\tau = 1$, respectively. To keep the notation as clear as possible, the τ superscript will be placed in parentheses, so that $R_i^{(\tau)}$ is revenue from taxing good i in situation (or period) τ, $\tau = 0, 1$. If $t_i'^{(\tau)}$ is the tax rate on i in τ, and $q_i^{(\tau)}$ is the corresponding quantity demand, then $R_i^{(\tau)} = t_i'^{(\tau)} p_i' q_i^{(\tau)}$ is revenue from i, and total revenue is $R^{(\tau)} = \sum_{i=1}^{3} R_i^{(\tau)}$. It follows from $d(\log q_i) = \sum_{j=1}^{3} \eta_{ij} d(\log p_j)$ and $d\left(\log p_j\right) = d\,t_j' \big/ \left(1+t_j'\right) = \left(t_j'^{(1)} - t_j'^{(0)}\right) \big/ \left(1+t_i'^{(0)}\right)$ that consumption of good i after the tax change can be expressed as

(9.4) $$q_i^{(1)} = q_i^{(0)} \exp\left[\sum_{j=1}^{3} \eta_{ij} \left(\frac{t_j'^{(1)} - t_j'^{(0)}}{1 + t_j'^{(0)}} \right)\right].$$

As marijuana is initially untaxed, $t_1'^{(0)} = 0$, and we impose a tax on it at rate $t_1'^{(1)}$, while holding the pre-existing rates on tobacco and alcohol constant, so that $t_j'^{(1)} = t_j'^{(0)}, j = 2,3$. Equation (9.4) then defines the new base, and we use various values of the marijuana tax rate to evaluate revenue with the 5,000 values of the price elasticities. Table 9.3 gives the results for revenue in the form of means over the 5,000 trials. As can be seen, the tax yields a nontrivial amount of revenue; for example, a 30 percent rate yields about \$86 per capita p. a., which represents additional revenue of about one quarter of the pre-existing revenue from tobacco. But as tobacco is a complement for marijuana, increasing the tax on the latter causes tobacco revenue to fall, as shown by column 3 of Table 9.3: The 30 percent marijuana tax causes proceeds from tobacco to fall from \$324 to \$303, a reduction of about 6 percent. Substitutability with alcohol causes alcohol revenue to rise with the marijuana tax, but as can be seen from column 4 of Table 9.3, this rise is quite modest at about 4 percent for a 30 percent marijuana tax. The net effect of these changes on total receipts from vice taxation is given in column 5, which following the introduction of a 30-percent marijuana tax, rises from \$684 to \$764, or about 12 percent. There are two noticeable patterns in the revenue standard deviations. Relative to mean revenue, the standard deviations all rise with the marijuana tax rate, and the marijuana standard deviations are all substantially larger than those of tobacco and alcohol. This reflects the greater uncertainty of the impacts of a tax regime that is more distant from the pre-existing one, as well as the greater uncertainty of the underlying data and parameters pertaining to marijuana. Figure 9.6 plots revenue against the marijuana tax rate and as it has a (gentle) inverted U-shape, it could be described as a type of "Laffer curve". As can be seen, the revenue-maximising tax rate is in the vicinity of 50 percent.[41] Panel B of Figure 9.6 illustrates the underlying uncertainty of the tax revenues by presenting a type of "fan chart" (Britton et al., 1998, Wallis, 1999) in which the darker colours denote values that have a higher probability of occurrence. This shows clearly how revenue uncertainty increases with the marijuana tax rate.

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[41] Revenue from marijuana is $R_1^{(1)} = t_1'^{(1)} p_1' q_1^{(0)} \exp\left(\eta_{11} t_1'^{(1)}\right)$, so that the first-order condition for a maximum is $\partial R_1^{(1)} \big/ \partial t_1'^{(1)} = \left(1 + \eta_{11} t_1'^{(1)}\right) p_1' q_1^{(0)} \exp\left(\eta_{11} t_1'^{(1)}\right) = 0$. Accordingly, the revenue-maximising tax is $t_1'^{(1)*} = -1/\eta_{11}$. The corresponding tax as a proportion of the consumer price is $t_1^{(1)*} = t_1'^{(1)*} \Big/ \left(1 + t_1'^{(1)*}\right) = 1 \big/ \left(1 - \eta_{11}\right)$. Using the mean value of the elasticity of $\eta_{11} = -0.64$, $t_1^{(1)*} = 0.6$. In view of the approximation involved in using the mean (that is, ignoring Jensen's inequality), this value is in reasonable agreement with the revenue-maximising rate of Figure 9.6.

The issue of estimating possible revenue from taxing marijuana in a legalised environment has been considered previously in several other studies (Bates, 2004, Caputo and Ostrom, 1994, Easton, 2004, Miron, 2005, and Schwer et al., 2002). In what seems to be the most widely-cited paper in this area, Caputo and Ostrom (1994) estimate that for the US it would be possible to raise $US3-5 billion from marijuana taxation in 1991. This estimate is based on conservative assumptions regarding the continued existence after legalisation of a black market that avoided the tax. For comparison, in the same year tax revenue from tobacco and alcohol combined was $22b (roughly evenly split between tobacco and alcohol). Using the mid-point of the above range of $4b, the marijuana tax would thus represent an addition of about 18 percent to revenue from vice taxation. As shown in the sixth element of column 2 of Table 9.3, we estimate that the maximum revenue from taxing marijuana in Australia is about $A105 per capita, or about $105/684 \approx 15$ percent of pre-existing revenue from vice. Accordingly, our revenue estimates seem to be in broad agreement with those of Caputo and Ostrom (1994). In a more recent US study, Miron (2005) estimates that marijuana could generate about $US2b p.a. if taxed at the same rate as other goods, or $6b if taxed at a rate comparable to that on tobacco and alcohol. Miron argues that these figures are similar to the earlier revenue estimates of Caputo and Ostrom (1994).

A Marijuana-Alcohol Tax Tradeoff

Next, we analyse some of the implications of the additional revenue by considering an offsetting reduction in alcohol taxes that serves to keep constant total tax collections from vice. That is, we shall keep tobacco taxes unchanged and consider a revenue-neutral reduction in alcohol taxes associated with the new tax on marijuana, so that the marijuana tax dividend is given to drinkers in the form of lower taxes.

Our problem is to specify the marijuana tax rate at some fixed value, say $t_1'^{(1)} = \hat{t}_1'$, and solve for the revenue-neutral reduction in alcohol taxes. More formally, the problem is to find the new tax on alcohol, $t_3'^{(1)}$, that satisfies the following conditions:

(i) $t_1'^{(0)} = 0$ [Marijuana is initially tax free]

(ii) $t_1'^{(1)} = \hat{t}_1'$ [Marijuana is now taxed at rate $\hat{t}_1'$]

(iii) $t_2'^{(1)} = t_2'^{(0)}$ [Tobacco continues to be taxed at the same rate]

(iv) $R^{(1)} = R^{(0)}$ [Total tax revenue is unchanged] .

Details of the numerical solution to this problem are contained in Clements et al. (2005). Panel

A of Figure 9.7 gives this tradeoff by averaging over the 5,000 trials as before. As can be seen, the tradeoff is negatively-sloped, but since the curve tends to get flatter as the marijuana tax increases, the tradeoff worsens as we move down the curve. This is due to two reasons. (1) Because the higher marijuana tax causes its consumption (the tax base) to be lower, a further increase in the rate generates a smaller increment to revenue; and this smaller amount of additional revenue is then redistributed in the form of a smaller reduction of alcohol taxes. When the marijuana tax exceeds the revenue-maximising rate, the slope of the tradeoff switches to positive (but this cannot be easily seen from Figure 9.7). (2) As it is a substitute for marijuana, alcohol consumption rises with a higher marijuana tax, so that the reduction in the alcohol tax rate required to just absorb the additional revenue from marijuana becomes smaller.[42] The slope of the tradeoff (again averaged over the 5,000 trials) is given in Panel B of Figure 9.7. This reveals that for rates of taxation of marijuana of about 20 percent for example, the tradeoff is approximately 1:2, so that a two-percentage-point increase in the marijuana tax is associated with almost a one-percentage-point reduction in the alcohol tax. This reflects primarily the differences in the tax bases of the two goods, and to a lesser extent, differences in their price elasticities. But as the marijuana tax increases from 20 percent to, say, 30 percent, the slope of the curve falls (in absolute value), from 0.47 to 0.42.

As the tradeoff of Figure 9.7 is the mean over the 5,000 trials, it represents the centre-of-gravity effects. But to understand the underlying uncertainty of these effects, we need to examine other aspects of the simulation results, such as the frequencies given in Figure 9.8. These show that the nature of the tradeoff is reasonably well defined for low rates of marijuana taxation, but uncertainty increases with the tax rate. This, of course, is to be expected as increased marijuana taxation involves a move away from its current tax-free status to something that has not been previously observed. Note that from Panel B of Figure 9.8 there is a hint that high rates of taxation cause the slope to become positive, as the revenue-maximising rate is exceeded. Finally, we consider the distribution of the alcohol tax conditional on the marijuana tax by analysing cross sections of the “vice mountain” of Figure 9.8. The left-hand side of Panel A of Figure 9.9 presents the conditional distribution when marijuana is taxed at 10 percent. As can be seen, the mean alcohol tax is about 35 percent, while the standard deviation

[42] It is to be noted that along the tradeoff not only does consumption of alcohol and marijuana change, but so also does that of tobacco. As tobacco and marijuana are complements, an increase in the marijuana tax lowers tobacco consumption and taxation revenue from this good; and because tobacco and alcohol are substitutes, a lowering of the alcohol tax also leads to reduced revenue from tobacco. Accordingly, as we move down the tradeoff, revenue from taxing tobacco falls unambiguously. By construction, along the tradeoff these changes in revenue from tobacco are “neutralised” by offsetting changes in the alcohol tax that serve to keep overall taxation revenue constant.

of the 5,000 trials is 1 percentage point. As the marijuana tax is increased to 20 and 30 percent, the mean alcohol tax falls to 30 and 26 percent, respectively, and the standard deviation rises to 1.5 and 2.6 percentage points, as shown in Panels B and C of the figure. The increased dispersion of the distribution clearly reflects the greater uncertainty of the alcohol tax as we move further away from the status quo of not taxing marijuana. This phenomenon is also reflected in the conditional distribution of the slope of the tradeoff, given on the right-hand side of Figure 9.9.

10. CONCLUDING COMMENTS

By all accounts, marijuana is a popular product. But it is not a product that is well understood from an economic perspective. What is the size of the marijuana industry? Is it a substitute or complement for other drugs? What is the price elasticity of demand for marijuana? By how much would marijuana prices and consumption change in the event that it were legalised. How much tax revenue could be raised from marijuana? These would seem to be some of the major issues in the economic analysis of marijuana. In this paper we considered in detail a number of economic dimensions of the marijuana industry, including:

- The nature of consumers of the product and how the consumption of marijuana and other drugs are interrelated.
- Intriguing patterns in prices, including quantity discounts, regional disparities in prices, and the extent to which marijuana prices have fallen over time.
- The likely size of the industry.
- The price-sensitivity of consumption, and the degree of substitution between marijuana, beer, wine, spirits and tobacco.
- The possible implications of legalising marijuana, including the amount of revenue that the government could raise by subjecting it to taxation in a manner similar to that for tobacco and alcohol.

As a way to provide an overview of much of this material, Table 10.1 compares and contrasts marijuana with other products on the basis of a number of economic dimensions. Regarding pricing practices, consider first quantity discounts (line 1.1 of the table). We showed that the price per gram of marijuana falls by something like 50 percent when purchased in ounce lots, rather than grams. But when we standardise for the quantity difference in going from grams to ounces, by using what we term the "discount elasticity", this apparently large discount is of the same order of magnitude as that available for other products, both legal and illegal. In this sense, marijuana is similar to other products.

Regarding regional disparities in marijuana prices in Australia (line 1.2 of Table 10.1), we showed that these were approximately the same as differences in housing prices, but larger than regional income differences. This finding points to the importance of local distribution costs in determining marijuana prices. Unlike "raw" marijuana, these distribution services are likely to be of the nature of "nontraded" goods, the prices of which would not be equalised regionally.

The substantial fall in the relative price of marijuana over the decade of the 1990s in Australia seems to be exceptional. The annual average fall in marijuana prices of about 5 percent is much larger than that of many primary products whose prices tend to fall by about 1-2 percent p. a. on average. The fall in marijuana prices is likely to be due to the widespread adoption of hydroponic growing techniques and/or changing community attitudes leading to less stringent drug laws and a lower level of their enforcement. Accordingly, in terms of the change in its price over time, as indicated in line 1.3 of Table 10.1, marijuana would seem to be substantially different to other products.

The preliminary evidence that is available regarding the price elasticity of demand for marijuana is that it is of the order of minus one-half. This is a reasonable value from two perspectives: (i) The value -1/2 is consistent with the economic theory of the consumer under the conditions of preference independence (or additive utility). (ii) A large number of prior studies (at least several hundred) of the price sensitivity of consumption of several other commodities also point to -1/2 as the centre-of-gravity value of the price elasticity, a result which could be termed the "rule of -1/2". Marijuana is not the exception to this rule, as indicated by line 2 of Table 10.2. In view of the all of the above, it is probably fair to say that there are more similarities than differences between marijuana and other products.

Its current illicit status means that marijuana escapes the tax net. This discriminates against producers and consumers of legal products that are substitutes for marijuana such as alcoholic beverages, as these products are subject to substantial taxes. Additionally, as the government foregoes revenue from marijuana, taxes on other products are higher than would otherwise be the case. In other words, the tax system provides marijuana with a hidden subsidy that puts it in a special category (line 3 of Table 10.1). But should marijuana be legalised, our analysis reveals that considerable taxation revenue could be generated from this source. According to our estimates, the Australian government could extract maximum revenue by taxing marijuana at a rate of about 50 percent, which is about the same as the tobacco tax and a bit above the average tax rate on alcohol. Such a tax on marijuana would generate an increase in revenue approximately equivalent to 14 percent of the pre-existing revenue from tobacco and alcohol.

The final two elements of Table 10.1 refer to externalities and legal status (lines 4 and 5). Although these have not been analysed in the paper, they have important economic implications. Examples of the issues raised by these considerations include, are there external effects associated with marijuana consumption, and if so, are these similar to those for alcohol and tobacco consumption? What is the least-cost policy of dealing with the externalities? The economic effects of the legal status of marijuana involve issues of risk, uncertainty and product quality. The current illicit status of marijuana means that consumers (i) are subject to the risk of incurring legal penalties, and (ii) face considerable uncertainty about the quality of the product. It is also possible that product innovation is inhibited by marijuana being illegal. These questions could form the basis for future research.

APPENDIX

To derive result (8.5) we use an extended version of Barten's (1964) fundamental matrix equation in consumption theory. The consumer chooses the quantity vector $\mathbf{q}$ to maximise utility $u(\mathbf{q}, s)$, where s is the exogenous shock to preference, subject to the budget constraint $\mathbf{p}'\mathbf{q} = M$, $\mathbf{p}$ being the price vector and M income. The first-order conditions are the budget constraint and $\partial u / \partial \mathbf{q} = \lambda \mathbf{p}$, where λ is the marginal utility of income.

Differentiation of the first-order conditions with respect to M, $\mathbf{p}$ and s yields

$$\text{(A1)} \qquad \begin{bmatrix} \mathbf{U} & \mathbf{p} \\ \mathbf{p}' & 0 \end{bmatrix} \begin{bmatrix} \partial \mathbf{q} / \partial M & \partial \mathbf{q} / \partial \mathbf{p}' & \partial \mathbf{q} / \partial s \\ -\partial \lambda / \partial M & -\partial \lambda / \partial \mathbf{p}' & -\partial \lambda / \partial s \end{bmatrix} = \begin{bmatrix} \mathbf{0} & \lambda \mathbf{I} & -\mathbf{u} \\ 1 & -\mathbf{q}' & 0 \end{bmatrix},$$

where $\mathbf{U} = \partial^2 u / \partial \mathbf{q} \partial \mathbf{q}'$, $\mathbf{I}$ is the identity matrix and $\mathbf{u} = \partial^2 u / \partial \mathbf{q} \partial s$. Solving (A1) for the second matrix on the left yields

$$\text{(A2)} \qquad \begin{bmatrix} \partial \mathbf{q} / \partial M & \partial \mathbf{q} / \partial \mathbf{p}' & \partial \mathbf{q} / \partial s \\ -\partial \lambda / \partial M & -\partial \lambda / \partial \mathbf{p}' & -\partial \lambda / \partial s \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} \left(\mathbf{p}'\mathbf{U}^{-1}\mathbf{p}\right)\mathbf{U}^{-1} - \mathbf{U}^{-1}\mathbf{p}\left(\mathbf{U}^{-1}\mathbf{p}\right)' & \mathbf{U}^{-1}\mathbf{p} \\ \left(\mathbf{U}^{-1}\mathbf{p}\right)' & -1 \end{bmatrix} \begin{bmatrix} \mathbf{0} & \lambda \mathbf{I} & -\mathbf{u} \\ 1 & -\mathbf{q}' & 0 \end{bmatrix},$$

where $\Delta = \mathbf{p}'\mathbf{U}^{-1}\mathbf{p}$. Accordingly,

$$\text{(A3)} \qquad \frac{\partial \mathbf{q}}{\partial M} = \frac{1}{\Delta} \mathbf{U}^{-1}\mathbf{p},$$

$$\frac{\partial \mathbf{q}}{\partial \mathbf{p}'} = \frac{1}{\Delta} \left\{ \left[\left(\mathbf{p}'\mathbf{U}^{-1}\mathbf{p}\right)\mathbf{U}^{-1} - \mathbf{U}^{-1}\mathbf{p}\left(\mathbf{U}^{-1}\mathbf{p}\right)' \right] \lambda - \mathbf{U}^{-1}\mathbf{p}\mathbf{q}' \right\}$$

$$\text{(A4)} \qquad = \frac{1}{\Delta} \left[\left(\mathbf{p}'\mathbf{U}^{-1}\mathbf{p}\right)\mathbf{U}^{-1} - \mathbf{U}^{-1}\mathbf{p}\left(\mathbf{U}^{-1}\mathbf{p}\right)' \right] \lambda - \frac{\partial \mathbf{q}}{\partial M} \mathbf{q}',$$

in view of (A3). It also follows from (A2) that

$$\frac{\partial \mathbf{q}}{\partial s} = -\frac{1}{\Delta}\left[\left(\mathbf{p}'\mathbf{U}^{-1}\mathbf{p}\right)\mathbf{U}^{-1} - \mathbf{U}^{-1}\mathbf{p}\left(\mathbf{U}^{-1}\mathbf{p}\right)'\right]\mathbf{u},$$

which, when combined with (A4), becomes

(A5) $$\frac{\partial \mathbf{q}}{\partial s} = -\frac{1}{\lambda}\left[\frac{\partial \mathbf{q}}{\partial \mathbf{p}'} + \frac{\partial \mathbf{q}}{\partial M}\mathbf{q}'\right]\mathbf{u}.$$

Equation (8.4) implies that the only non-zero element of **u** is the k^{th}, which equals $c\left(\partial u / \partial q_k\right) = c\lambda p_k$. As the term in square brackets in (A5) is the substitution matrix, it follows that

(A6) $$\frac{\partial q_i / q_i}{\partial s} = -c\eta_{ik} \qquad i = 1, \ldots, n,$$

where $\eta_{ik} = \partial\left(\log q_i\right) / \partial\left(\log p_k\right)$, real income remaining constant. Interpreting the left-hand side of (A6) as the proportionate growth in q_i resulting from the regime change, α_i, this establishes result (8.5). For a further discussion, see Barten (1977) and Theil (1975/1976, pp. 205-206).

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TABLE 2.1

DRUG USAGE IN AUSTRALIA

(Percentage of population aged over 14)

Drug	1993	1995	1998	2001	2004
Marijuana					
Ever used	34.7	31.1	39.1	33.1	33.6
Recently used	12.7	13.1	17.9	12.9	11.3
Recent use of					
Meth/amphetamine (speed)	2.0	2.1	3.7	3.4	3.2
Ecstasy (designer drugs)	1.2	0.9	2.4	2.9	3.4
Cocaine	0.5	1.0	1.4	1.3	1.0
Heroin	0.2	0.4	0.8	0.2	0.2
Tobacco	n.a.	n.a.	24.9	23.2	20.7
Alcohol	73.0	78.3	80.7	82.4	83.6

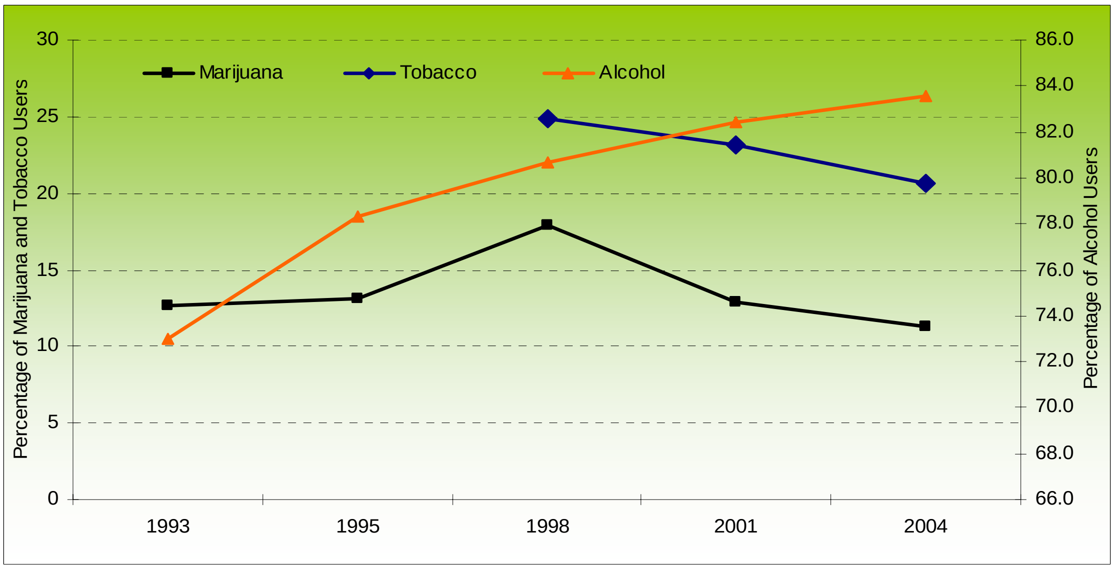
Note: For drugs other than tobacco and alcohol, the terms of "recently used" and "recent use" refer to usage in the last 12 months. For tobacco and alcohol, "recent use" means daily, weekly and less-than weekly usage.

Source: AIHW (2005).

FIGURE 2.1

PARTICIPATION RATES 1993-2004

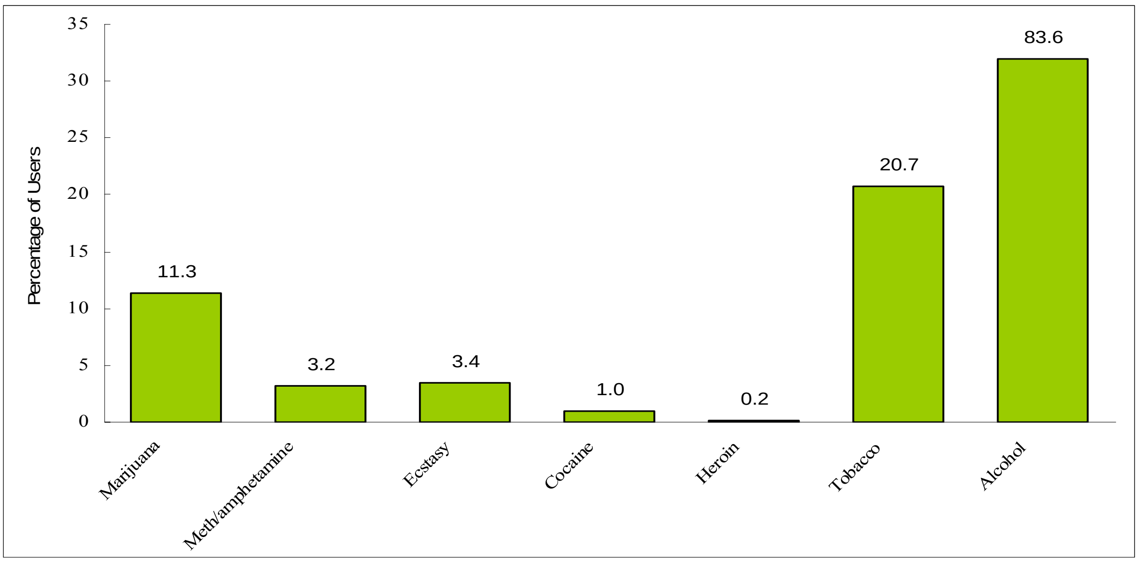
MARIJUANA, TOBACCO AND ALCOHOL



Source: Table 2.1.

FIGURE 2.2

PARTICIPATION RATES FOR 2004



Note: The bar for alcohol is not drawn to scale.

TABLE 2.2

DRUG PARTICIPATION BY GROUPS

(Percentage of population aged 14 and over)

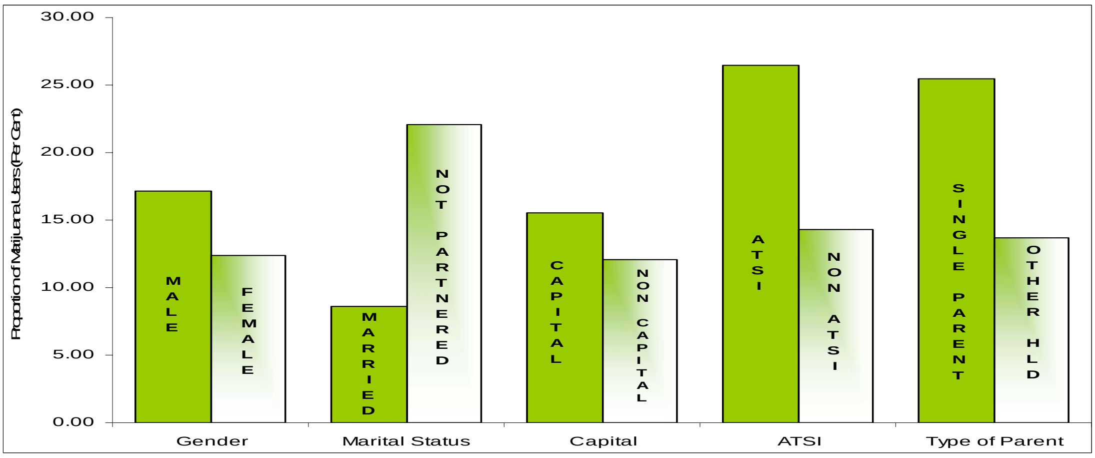
Group	Marijuana	Cocaine	Heroin	Tobacco	Alcohol
Overall	14.4	1.4	0.5	24.0	82.7
Male	17.14	1.61	0.57	25.04	85.76
Female	12.42	1.15	0.43	22.45	80.66
Married or de facto	8.61	0.68	0.25	20.03	84.68
Non-partnered	22.07	3.05	1.04	28.16	80.81
Young kids	12.98	1.27	0.32	26.62	86.52
No young kids	14.75	1.36	0.52	23.00	82.54
Capital city	15.57	1.70	0.57	23.27	83.44
Non-capital city	12.09	0.54	0.33	24.37	81.75
ATSI	26.45	2.20	1.10	44.08	76.39
Non-ATSI	14.30	1.34	0.48	23.24	83.16
Single parent	25.42	1.82	1.20	40.10	83.34
Non-single parent	13.72	1.32	0.44	22.41	83.15
Working	16.43	1.74	0.45	26.06	89.95
Studying	24.93	2.05	0.68	19.46	73.96
Unemployed	28.80	1.60	1.52	42.91	82.43
Other (retiree/pensioner/home duties)	5.87	0.40	0.39	18.76	74.87
Degree	13.35	1.76	0.33	15.58	88.21
Diploma	14.49	1.38	0.36	26.04	87.07
Year 12	19.14	1.79	0.75	27.42	85.15
Less than year 12	12.27	0.73	0.55	24.29	76.56
Income					
$0-$9,999	14.78	0.99	0.65	23.07	75.54
$10,000-$19,999	16.60	1.38	0.34	28.38	85.74
$20,000-$29,999	17.56	1.94	0.52	27.99	89.54
$30,000-$39,999	14.40	1.98	0.32	23.57	91.66
$40,000-$49,999	14.21	1.02	0.76	23.61	93.72
$50,000-$59,999	12.34	1.26	0.21	19.38	92.75
$60,000 or more	11.49	1.92	0.14	17.59	94.26

Note: The percentages refer to participation in the past 12 months, based on the pooled sample from the 1998 and 2001 surveys (NDSHS, 2001).

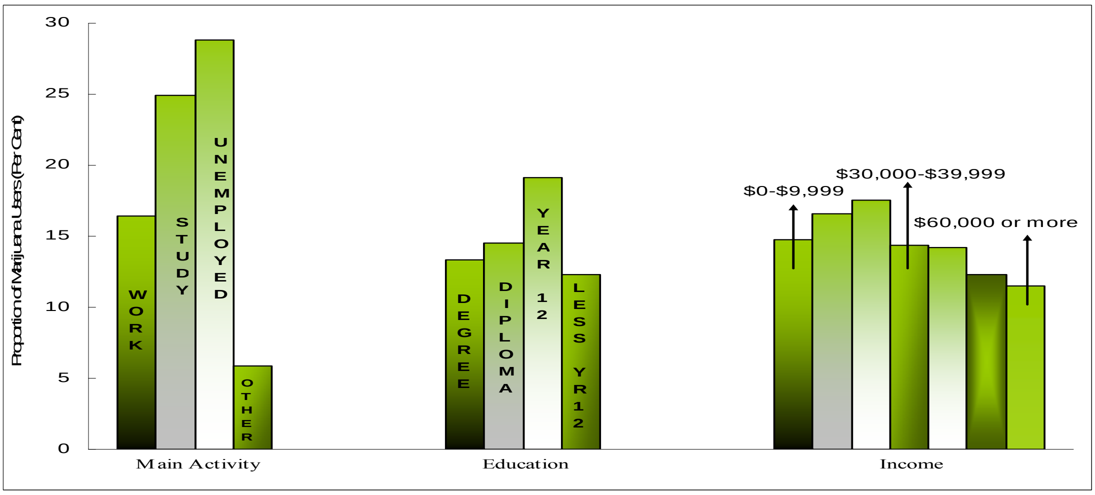
FIGURE 2.3

MARIJUANA PARTICIPATION RATES

A. By Demographic/Social Groups



B. By Socioeconomic Groups



C. By Age

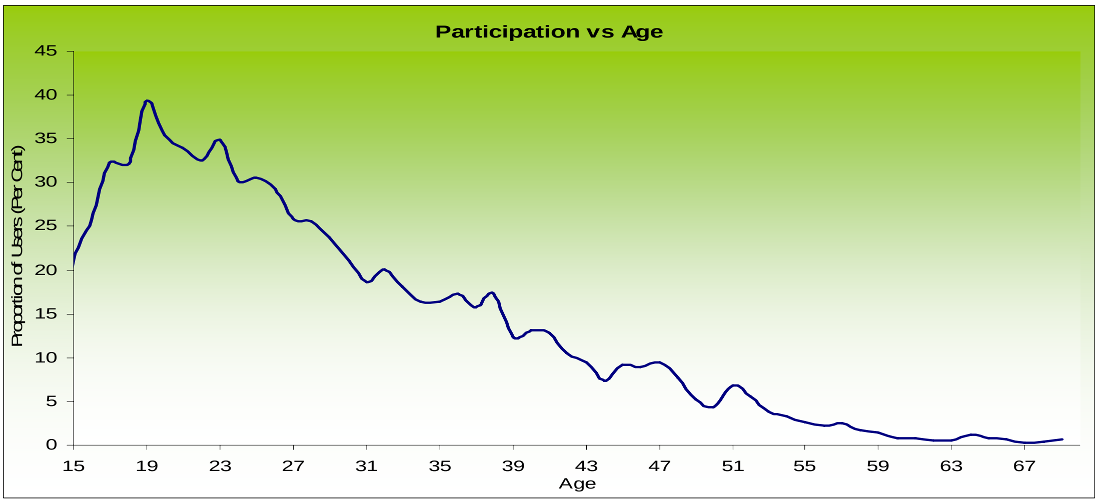
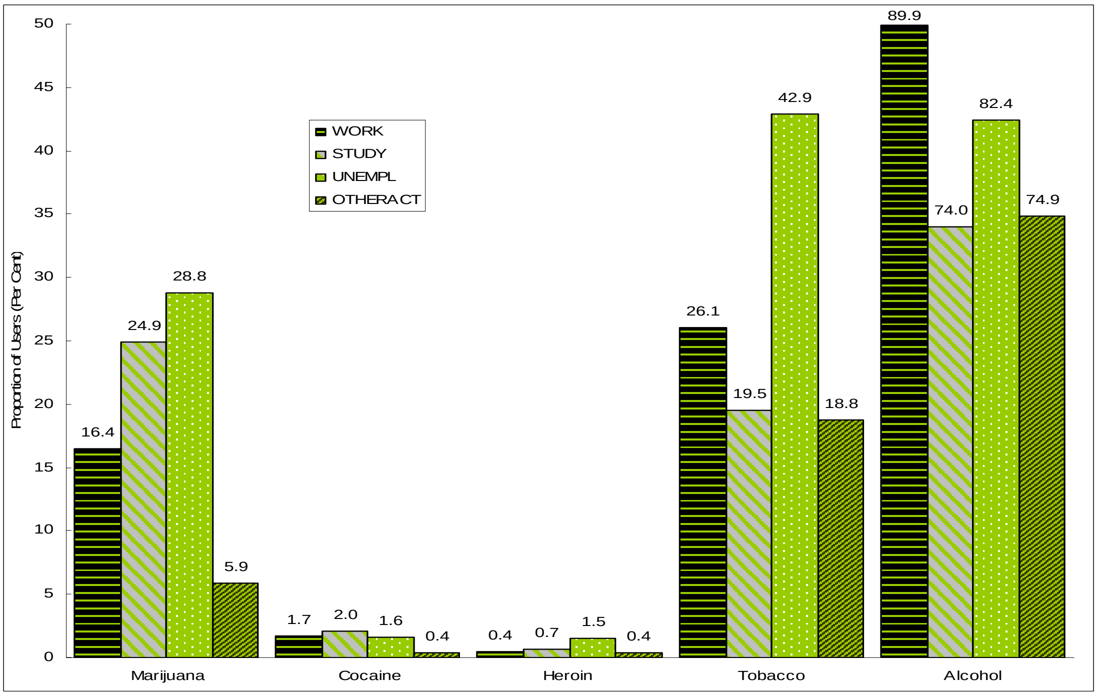


FIGURE 2.4

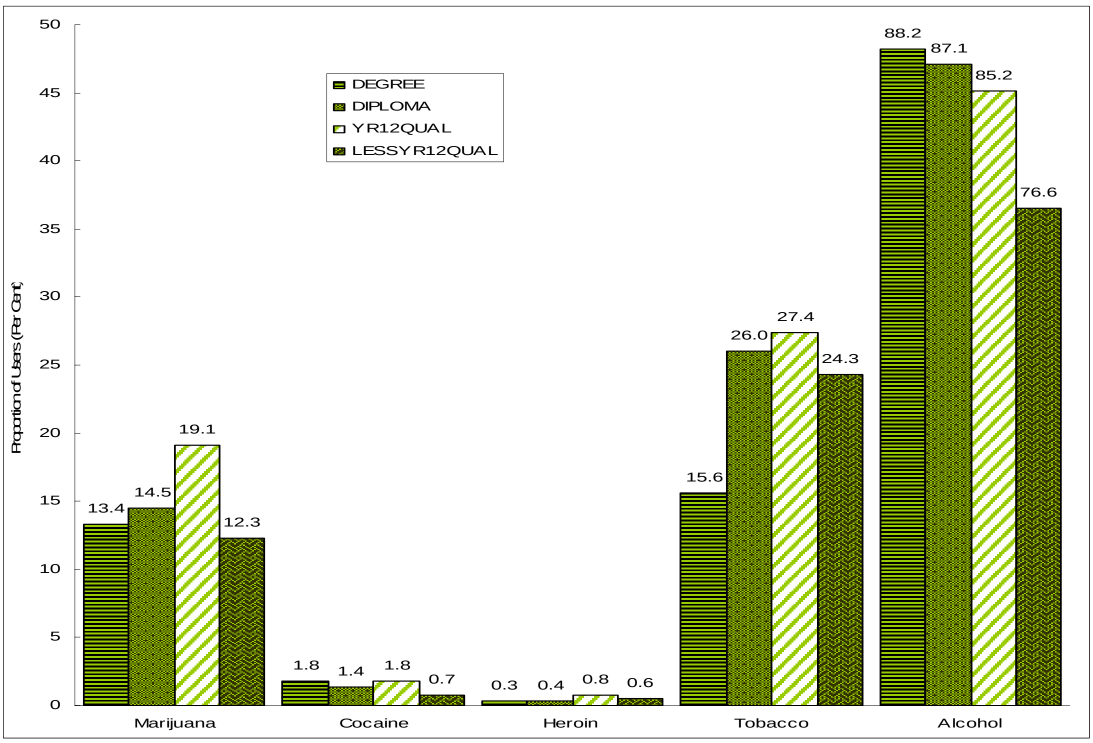
PARTICIPATION RATES FOR FIVE DRUGS

A. By Main Activity



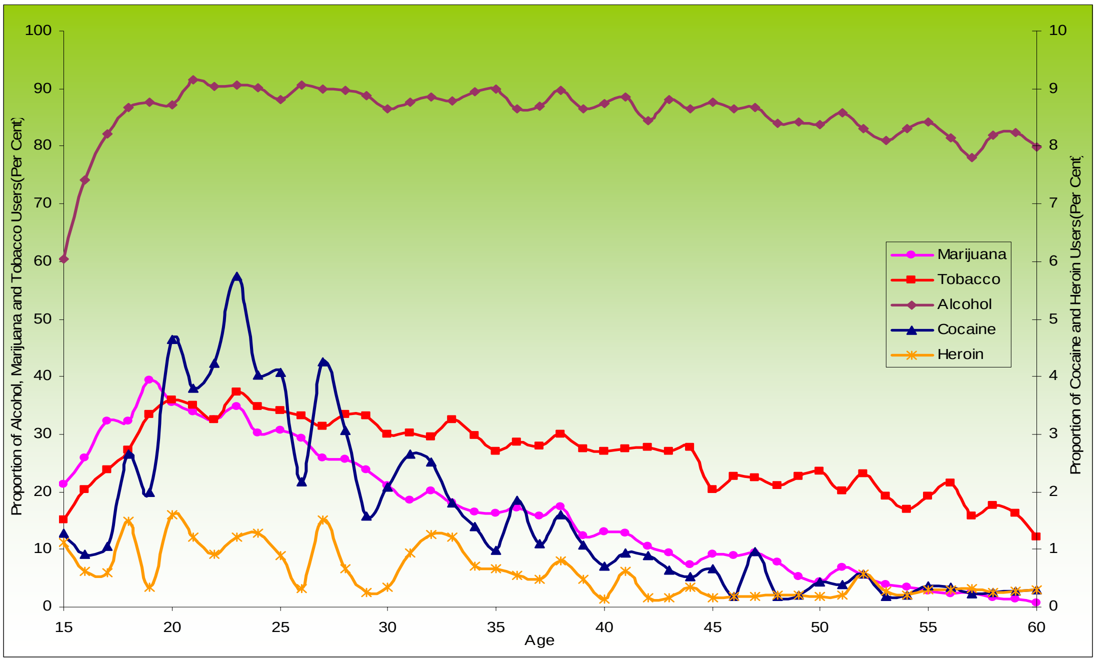
Note: The bars for alcohol are not drawn to scale.

B. By Education



Note: The bars for alcohol are not drawn to scale.

C. By Age



100
90
80
70
60
50
40
30
20
10
0
Proportion of Alcohol, Marijuana and Tobacco Users(Per Cent)
10
9
8
7
6
5
4
3
2
1
0
Proportion of Cocaine and Heroin Users(Per Cent)
Marijuana
Tobacco
Alcohol
Cocaine
Heroin
15
20
25
30
35
40
45
50
55
60
Age

TABLE 2.3

LEVELS OF MARIJUANA CONSUMPTION BY GROUPS
(Percentage of population aged 14 and over)

Group	Abstainer	Frequency of usage			
		Infrequent	Monthly	Weekly	Daily
Overall	85.60	6.89	1.91	3.41	2.32
Male	82.86	7.01	2.25	4.70	3.18
Female	87.58	6.79	1.63	2.36	1.64
Married	91.39	4.12	1.01	2.02	1.47
Non-partnered	77.93	10.43	3.04	5.18	3.41
Young kids	87.02	6.13	1.67	3.04	2.14
No young kids	85.25	7.03	1.94	3.45	2.33
Capital city	84.43	7.65	2.05	3.56	2.31
Non-capital city	87.91	5.11	1.57	3.05	2.37
ATSI	73.55	9.86	3.29	6.26	7.04
Non-ATSI	85.70	6.82	1.88	3.36	2.24
Single-parent	74.58	11.20	3.51	6.37	4.34
Non-single parent	86.28	6.58	1.81	3.17	2.16
Working	83.57	7.83	2.03	3.94	2.63
Studying	75.07	14.10	3.88	5.01	1.93
Unemployed	71.20	8.51	4.41	8.21	7.67
Other (retiree/pensioner/home duties)	94.13	2.46	0.71	1.39	1.32
Degree	86.65	7.89	1.78	2.82	0.85
Diploma	85.51	6.27	1.74	3.65	2.84
Year 12	80.86	9.16	2.59	4.44	2.95
Less than year 12	87.73	5.30	1.65	2.92	2.41
Income:					
\$0-\$9,999	85.22	7.11	2.15	3.17	2.34
\$10,000-\$19,999	83.40	6.82	2.01	4.47	3.31
\$20,000-\$29,999	82.44	8.03	2.14	4.27	3.10
\$30,000-\$39,999	85.60	7.47	1.91	3.29	1.73
\$40,000-\$49,999	85.79	7.87	1.52	3.30	1.52
\$50,000-\$59,999	87.66	7.16	1.47	2.48	1.22
\$60,000 or more	88.51	7.22	1.24	2.41	0.62

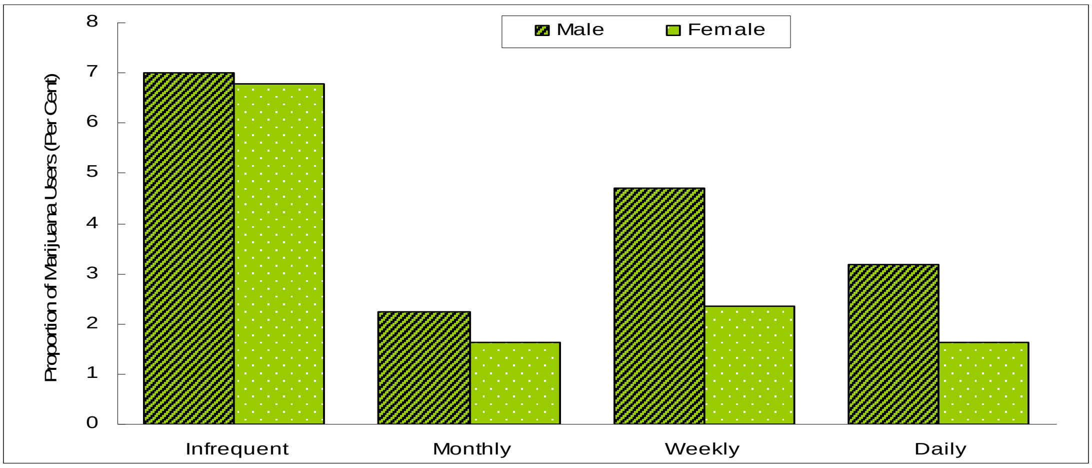
Notes: 1. These figures refer to the percentages of the relevant population groups engaging in different frequencies of consumption, based on the pooled sample from the 1998 and 2001 surveys (NDSHS, 2001).

2. Frequency of consumption is defined as follows:
Abstainers: not used marijuana in the past 12 months.
Infrequent: used less frequently than monthly, but at least once in the past 12 months.
Monthly: used at least once a month, but less frequently than weekly.
Weekly: less than daily, but at least once a week.
Daily: used every day.

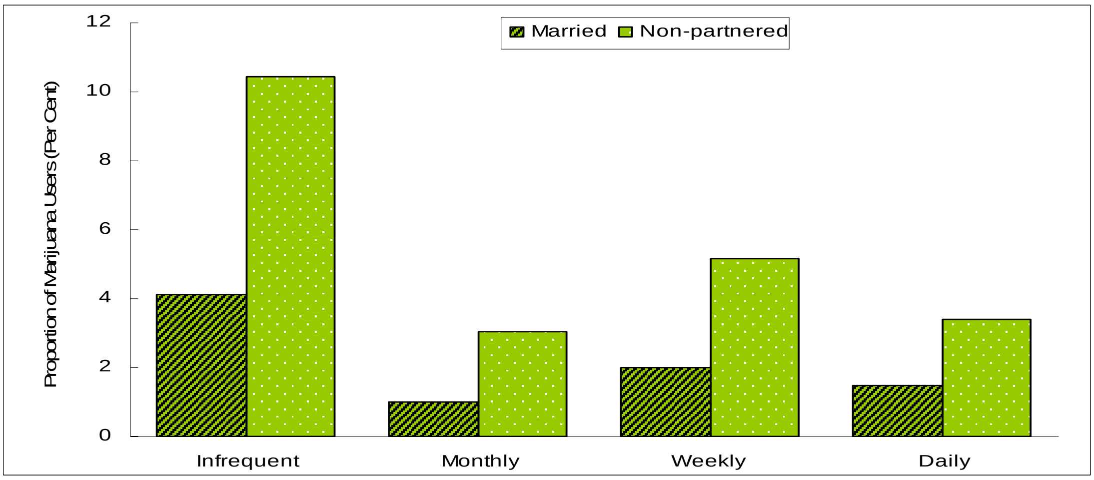
FIGURE 2.5

LEVEL OF MARIJUANA CONSUMPTION

A. By Gender

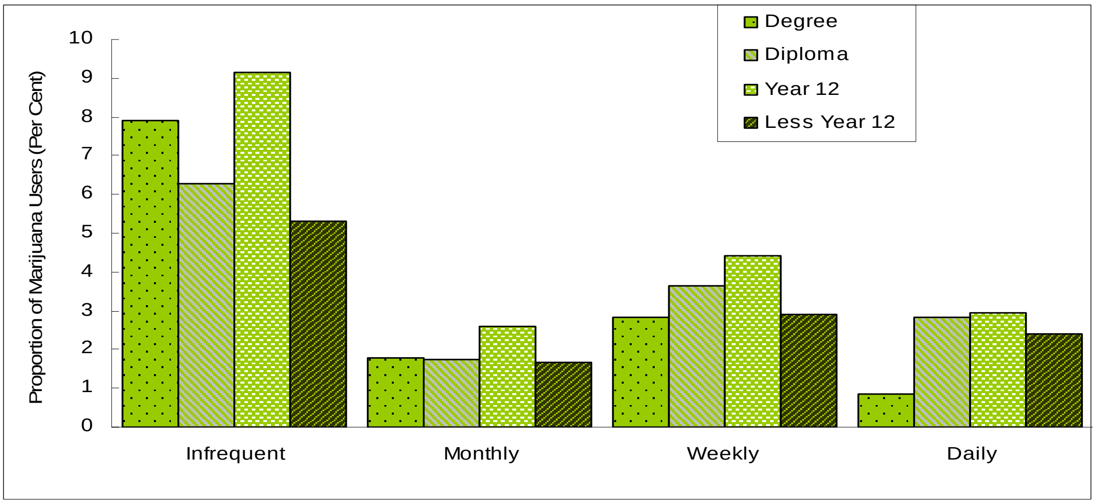


B. By Marriage Status

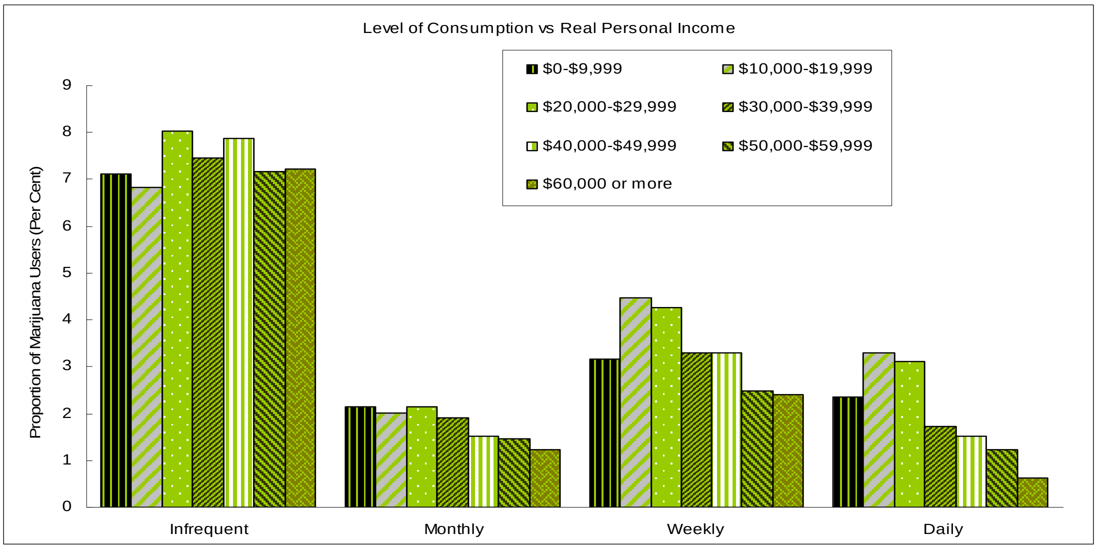


C. By Main Activity

D. By Education



E. By Income



F. By Age

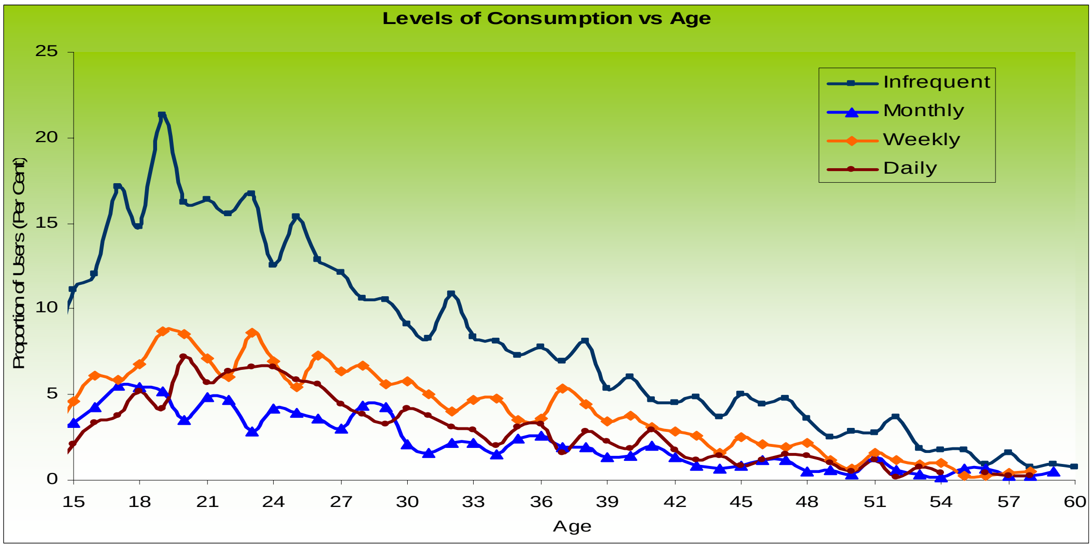


TABLE 2.4

SUMMARY STATISTICS FOR PARTICIPATION IN MARIJUANA, ALCOHOL AND TOBACCO

(Percentages)

Participation in consumption of			Probability			
Marijuana (1)	Alcohol (2)	Tobacco (3)	Joint (4)	Marijuana (5)	Alcohol (6)	Tobacco (7)
		√	1.9			1.9
	√		55.4		55.4	
√			0.2	0.2		
	√	√	13.8		13.8	13.8
√		√	0.3	0.3		0.3
√	√		6.0	6.0	6.0	
√	√	√	7.7	7.7	7.7	7.7
	NONE		14.7			
	Total		100	14.2	82.9	23.7

Source: Zhao and Harris (2004), based on pooled data from NDSHS of 1995, 1998 and 2001.

TABLE 2.5

ESTIMATED CONDITIONAL AND UNCONDITIONAL PARTICIPATION PROBABILITIES FOR MARIJUANA, ALCOHOL AND TOBACCO

(Percentages)

Probability	Drug i		
(1)	Marijuana (2)	Alcohol (3)	Tobacco (4)
$P(Y_i = 1)$	14.2	82.9	23.7
$P(Y_i = 1 \mid Y_M = 1)$	100	96.5	56.3
$P(Y_i = 1 \mid Y_A = 1)$	16.5	100	25.9
$P(Y_i = 1 \mid Y_T = 1)$	33.8	90.7	100

Note: Y_i is a binary variable representing the participation status for drug i (i = marijuana, M, alcohol, A, and tobacco, T).

Source: Zhao and Harris (2004), based on pooled data from NDSHS of 1995, 1998 and 2001.

TABLE 2.6

SUMMARY STATISTICS FOR PARTICIPATION IN MARIJUANA, COCAINE AND HEROIN
(Percentages)

Participation in consumption of			Probability			
Marijuana (1)	Cocaine (2)	Heroin (3)	Joint (4)	Marijuana (5)	Cocaine (6)	Heroin (7)
√			13.23	13.23		
	√		0.17		0.17	
		√	0.03			0.03
√	√		0.87	0.87	0.87	
√		√	0.15	0.15		0.15
	√	√	0.02		0.02	0.02
√	√	√	0.30	0.30	0.30	0.30
	NONE		85.23			
	Total		100	14.55	1.35	0.50

Source: Ramful and Zhao (2004), based on data from NDSHS of 1998 and 2001.

TABLE 2.7

ESTIMATED CONDITIONAL AND UNCONDITIONAL PARTICIPATION PROBABILITIES FOR MARIJUANA, COCAINE AND HEROIN
(Percentages)

Probability	Drug i		
(1)	Marijuana (2)	Cocaine (3)	Heroin (4)
$P(Y_i = 1)$	14.55	1.35	0.50
$P(Y_i = 1 \mid Y_M = 1)$	100.00	8.03	3.07
$P(Y_i = 1 \mid Y_C = 1)$	86.23	100.00	23.28
$P(Y_i = 1 \mid Y_H = 1)$	90.06	63.54	100.00
$P(Y_i = 1 \mid Y_C = 1, Y_H = 1)$	94.78	100.00	100.00
$P(Y_i = 1 \mid Y_M = 1, Y_H = 1)$	100.00	66.87	100.00
$P(Y_i = 1 \mid Y_M = 1, Y_C = 1)$	100.00	100.00	25.59

Note: Y_i is a binary variable representing the participation status for drug i (i = marijuana, M, cocaine, C, and heroin, H).

Source: Ramful and Zhao (2004), based on data from NDSHS of 1998 and 2001.

TABLE 3.1

DETERMINANTS OF MARIJUANA PARTICIPATION PROBABILITY

Variable	Coefficient		Marginal effect	
Constant	-16.966	(1.088)**	-2.862	(0.153)**
Year 2001	-0.065	(0.032)**	-0.011	(0.006)*
Male	0.279	(0.022)**	0.047	(0.002)**
Married	-0.410	(0.025)**	-0.069	(0.004)**
Young kids	-0.106	(0.031)**	-0.018	(0.005)**
Capital city	0.020	(0.025)	0.003	(0.002)*
ATSI	0.208	(0.072)**	0.035	(0.018)*
Single-parent	0.133	(0.038)**	0.023	(0.010)**
Working	-0.047	(0.037)	-0.008	(0.005)*
Studying	-0.051	(0.046)	-0.009	(0.009)
Unemployed	0.290	(0.058)**	0.049	(0.004)**
Degree	-0.080	(0.034)**	-0.013	(0.005)**
Diploma	0.033	(0.031)	0.006	(0.004)
Year 12	0.008	(0.032)	0.001	(0.004)
Income	0.038	(0.016)**	0.006	(0.001)**
Relative price of heroin	0.162	(0.045)**	0.027	(0.009)**
Relative price of cocaine	0.233	(0.051)**	0.039	(0.013)**
Relative price of marijuana	-0.121	(0.079)	-0.020	(0.013)
Age	9.563	(0.555)**	1.614	(0.045)**
Age squared	-1.550	(0.079)**	-0.261	(0.006)**

Notes: 1. Standard errors are given in parentheses.
2. A "*" indicates significant at the 10 percent level. A "**" indicates significant at the 5 percent level.
3. For a continuous explanatory variable, the marginal effect represents the change in the participation probability in response to a unit change in the variable. For a dummy variable, the marginal effect represents the change in the probability when the variable changes from 0 to 1. All marginal effects are evaluated at sample means of all explanatory variables.

Source: Ramful and Zhao (2004).

FIGURE 3.1

PREDICTED MARIJUANA PARTICIPATION PROBABILITIES

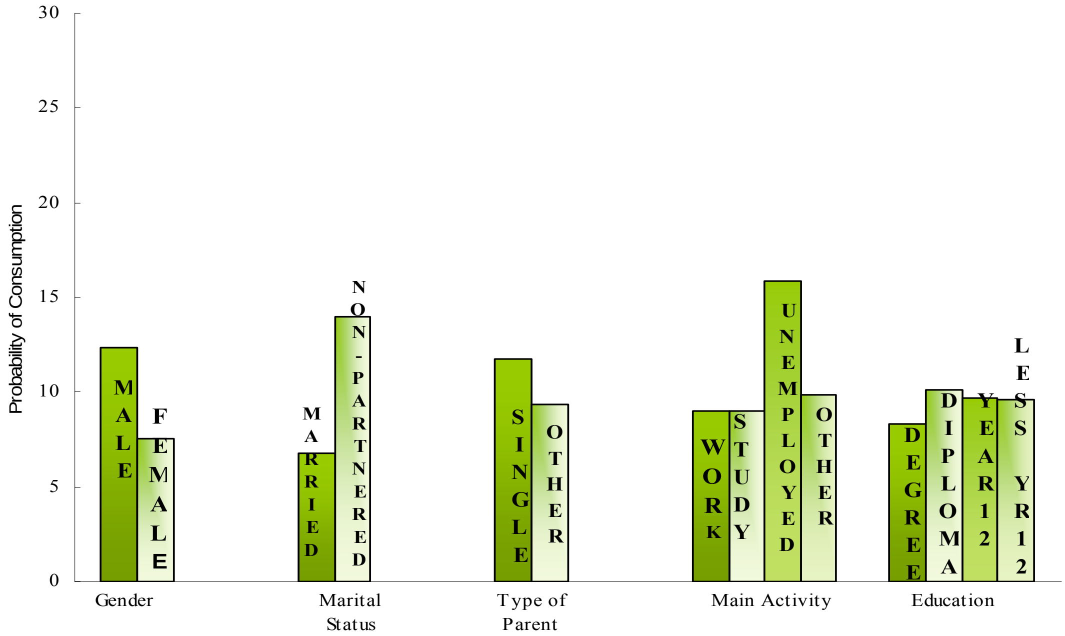


TABLE 3.2

CROSS-DRUG CORRELATION COEFFICIENTS

A. Marijuana and illegals

Drug	Marijuana	Cocaine	Heroin
Marijuana	1	0.651 (0.023)**	0.590 (0.044)**
Cocaine		1	0.835 (0.026)**
Heroin			1

B. Marijuana and legals

Drug	Marijuana	Tobacco	Alcohol
Marijuana	1	0.50 (0.011)**	0.37 (0.017)**
Tobacco		1	0.20 (0.014)**
Alcohol			1

Notes: 1. Correlations for marijuana, cocaine and heroin in Panel A refer to error terms of a trivariate probit model from Ramful and Zhao (2004). Correlations for marijuana, tobacco and alcohol in Panel B are from Zhao and Harris (2004).
2. Standard errors are given in parenthesis.
3. A "**"indicates significant at the 5 percent level.

TABLE 3.3

PREDICTED PROBABILITIES FROM FOUR PROBIT MODELS

Marijuana, cocaine and heroin			Marijuana, alcohol and tobacco		
Probability	Model		Probability	Model	
	UVP	MVP		UVP	MVP
$P(Y_M = 1)$	0.0950	0.0948	$P(Y_M = 1)$	0.1071	0.1066
$P(Y_M = 1 \mid Y_C = 1)$	0.0950	0.7943	$P(Y_M = 1 \mid Y_A = 1, Y_T = 1)$	0.1071	0.2687
$P(Y_M = 1 \mid Y_C = 1, Y_H = 1)$	0.0950	0.8697	$P(Y_M = 1 \mid Y_A = 0, Y_T = 0)$	0.1071	0.0145
$P(Y_C = 1 \mid Y_M = 1, Y_H = 1)$	0.0043	0.5692	$P(Y_T = 1 \mid Y_M = 1, Y_A = 1)$	0.2312	0.5564
$P(Y_H = 1 \mid Y_M = 1, Y_C = 1)$	0.0016	0.2308	$P(Y_A = 1 \mid Y_M = 1, Y_T = 1)$	0.8750	0.9732
$P(Y_M = 0, Y_C = 0, Y_H = 0)$	0.8997	0.9043	$P(Y_M = 0, Y_A = 0, Y_T = 0)$	0.0858	0.1064
$P(Y_M = 0, Y_C = 1, Y_H = 0)$	0.0039	0.0007	$P(Y_M = 1, Y_A = 1, Y_T = 1)$	0.0217	0.0516

Notes: 1. All predicted probabilities are evaluated at sample means of the whole population.
2. UVP denotes univariate probit; MVP denotes multivariate probit.
3. Standard errors are not presented, but can be found in the original papers.

Source: For marijuana, cocaine and heroin, Ramful and Zhao (2004); for marijuana, tobacco and alcohol, Zhao and Harris (2004).

TABLE 3.4

MARGINAL EFFECTS ON SELECTED PROBABILITIES FOR MARIJUANA

Variable	Probability				
	P(M=1)	P(M=1|C=0,H=0)	P(M=1|C=1,H=1)	P(M=1|C=1)	P(M=1|H=1)
Constant	-2.862**	-2.667**	-0.713	-1.096	-1.604
Year 2001	-0.011*	-0.011**	-0.013	-0.052**	0.028
Male	0.047**	0.046**	0.049**	0.077**	0.056**
Married	-0.069**	-0.065**	-0.036**	-0.049**	-0.064**
Young kids	-0.018**	-0.017**	-0.024*	-0.012	-0.061**
Capital city	0.003*	0.001	-0.038**	-0.069**	-0.019
ATSI	0.035*	0.034**	0.053*	0.052	0.096
Single-parent	0.023**	0.022**	0.027*	0.055**	0.012
Working	-0.008*	-0.008	0.002	-0.020	0.031
Studying	-0.009	-0.009	-0.009	-0.048*	0.036
Unemployed	0.049**	0.048**	0.071**	0.094**	0.098**
Degree	-0.013**	-0.013**	0.004	-0.034*	0.053**
Diploma	0.006	0.006	0.024*	0.001	0.070**
Year 12	0.001	0.002	0.019	0.003	0.051**
Income	0.006**	0.006**	-0.002	-0.020**	0.023*
Relative price of heroin	0.027**	0.028**	0.064**	0.109**	0.049
Relative price of cocaine	0.039**	0.039**	0.055**	0.078**	0.068*
Relative of marijuana	-0.020	-0.024*	-0.126**	-0.131**	-0.198*
Age	1.614**	1.517**	0.743**	0.934**	1.477**
Age squared	-0.261**	-0.246**	-0.134**	-0.165**	-0.259**

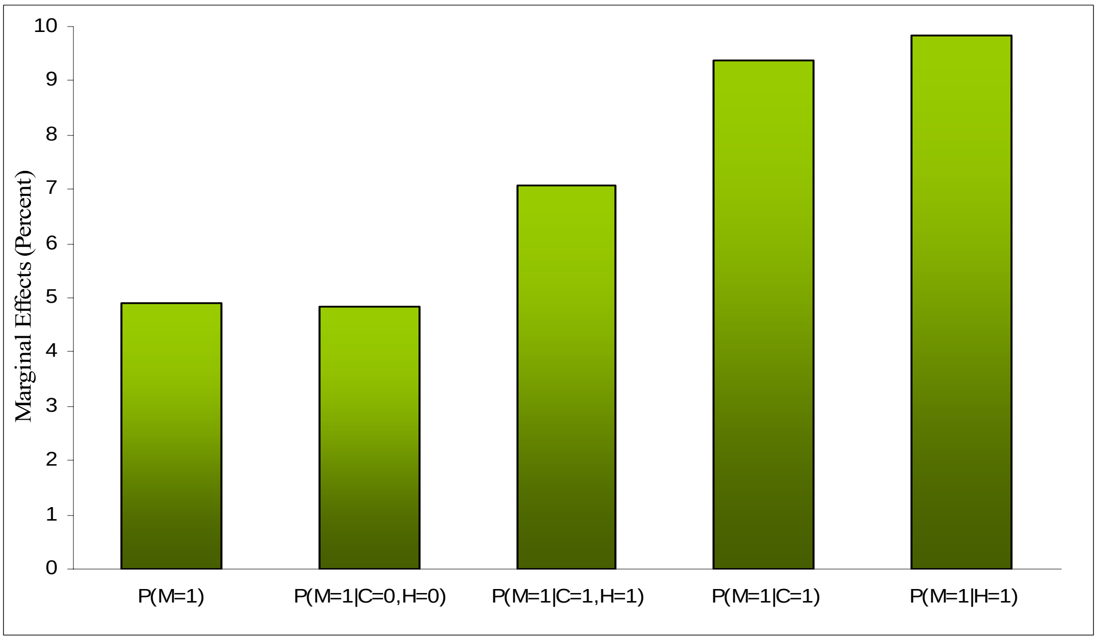
Notes: 1. A "*" indicates significant at the 10 percent level and a "**" indicates significant at the 5 percent level.
2. Standard errors are not presented, but can be found in the original paper.

Source: Ramful and Zhao (2004).

FIGURE 3.2

MARGINAL EFFECTS ON CONDITIONAL AND UNCONDITIONAL PROBABILITIES OF MARIJUANA PARTICIPATION

A. Marginal Effects of Unemployment



B. Marginal Effects of Marriage/de facto

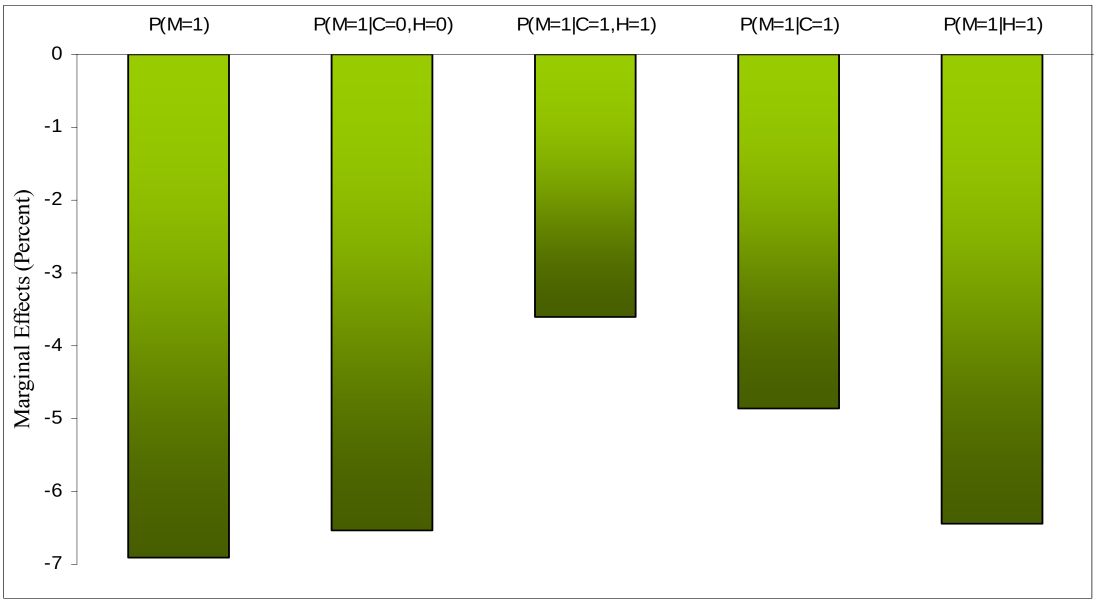


TABLE 3.5

RESULTS FOR SEQUENTIAL MODEL FOR MARIJUANA CONSUMPTION

Variable	Participation		Level of consumption (Conditional on participation)				
	Coefficient	Marginal effect		Marginal effect			
			Coefficient	Infrequent	Monthly	Weekly	Daily
Constant	8.77 *		4.77				
Year 1998	0.34 *	0.07 *	0.26 *	-0.11 *	0.00	0.04	0.06 *
Year 2001	0.42 *	0.07 *	0.39 *	-0.16 *	0.01	0.06	0.09 *
Male	0.28 *	0.05 *	0.31 *	-0.13 *	0.00	0.05	0.07 *
Married	-0.35 *	-0.07 *	0.03	-0.01 *	0.00	0.00	0.01
Capital city	0.07 *	0.01 *	-0.09 *	0.04 *	0.00	-0.01	-0.02
ATSI	0.15 *	0.03 *	-0.04	0.01 *	0.00	-0.01	-0.01
Working	0.18 *	0.03 *	-0.11 *	0.05 *	0.00	-0.02	-0.03
Studying	-0.11 *	-0.02 *	-0.37 *	0.15 *	-0.01	-0.06	-0.07
Unemployed	0.39 *	0.09 *	0.05	-0.02 *	0.00	0.01	0.01
Degree	0.04	0.01	-0.35 *	0.14 *	-0.01	-0.06	-0.07
Diploma	0.08 *	0.01 *	-0.08 *	0.03 *	0.00	-0.01	-0.02
Year 12	-0.01	0.00	-0.16 *	0.07 *	0.00	-0.03	-0.04
Log income	-0.57 *	-0.10 *	-1.68 *	0.67 *	-0.02	-0.26	-0.38 *
English at home	0.58 *	0.08 *	0.03 *	-0.01 *	0.00	0.01	0.01
School	-0.77 *	-0.09 *	-0.34 *	0.14 *	-0.01	-0.06	-0.07
Dependent child	-0.01	0.00	-0.02	0.01	0.00	0.00	0.00
DECRIM	0.13 *	0.02 *	0.16 *	-0.06 *	0.00	0.02	0.04
Log alcohol price	1.13	0.21	6.55	-2.61	0.10	1.02 *	1.49
Log marijuana price	-1.64 *	-0.30 *	-0.51	0.21	-0.01	-0.08	-0.12
Log tobacco price	-8.8 *	-1.61 *	-7.78	3.10	-0.11	-1.21	-1.77 *
Log age	-14.35 *	-2.63 *	-0.37 *	0.15 *	-0.01	-0.06	-0.08 *

Note: A “*” indicates significant at the 5 percent level.

Source: Derived from Zhao and Harris (2004).

TABLE 4.1

ESTIMATED REGIONAL EFFECTS FOR MARIJUANA PRICES, INCOME AND HOUSE PRICES

$$\log y_{rt} = \alpha + \sum_{u=2}^{8} \beta_u z_{urt}$$

(t-values in parentheses)

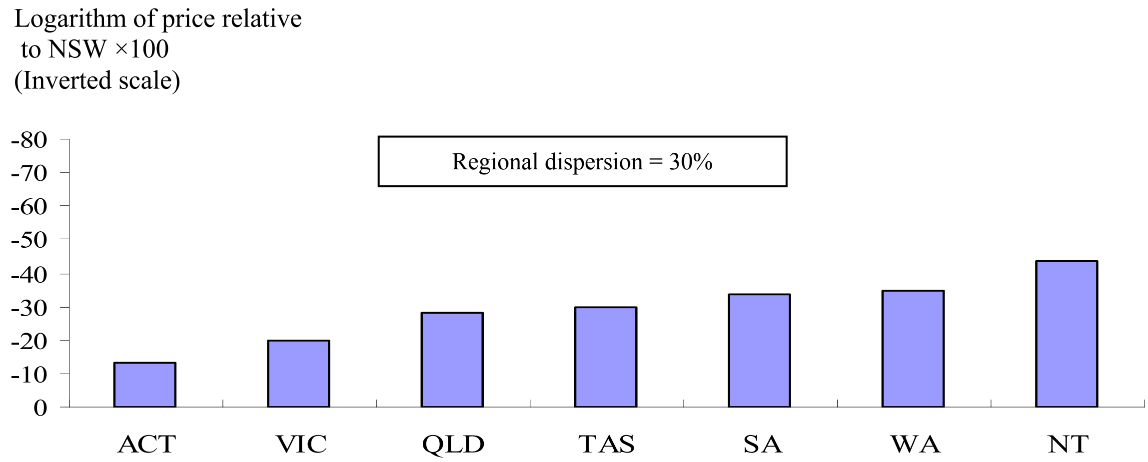
Dependent variable y_{rt}	Intercept α	Coefficients of dummy variables, $\beta_u \times 100$							$\bar{R}^2$	Regional dispersion $\{(1/7)\sum_{u=1}^{7}\beta_u^2\}^{1/2} \times 100$
		VIC	QLD	WA	SA	NT	TAS	ACT		
					I. Marijuana prices					
1. Leaf gram	6.94	-39.80	-46.70	-43.40	-47.70	-38.00	-51.20	-42.90	0.44	44.45
	(134.60)	(-5.46)	(-6.41)	(-5.95)	(-6.54)	(-5.21)	(-7.02)	(-5.89)		
2. Leaf ounce	5.88	7.00	-24.60	-34.90	-3.60	-23.70	-37.90	1.40	0.28	23.56
	(77.70)	(0.65)	(-2.30)	(-3.26)	(-0.34)	(-2.22)	(-3.54)	(0.13)		
3. Head gram	7.06	-31.10	-28.00	-40.90	-14.40	-41.40	-27.40	-24.80	0.23	30.96
	(108.30)	(-3.37)	(-3.04)	(-4.44)	(-1.56)	(-4.49)	(-2.97)	(-2.69)		
4. Head ounce	6.26	-20.10	-28.20	-34.50	-33.50	-43.60	-29.80	-13.40	0.28	30.43
	(106.00)	(-2.41)	(-3.37)	(-4.13)	(-4.01)	(-5.22)	(-3.57)	(-1.60)		
					II. Income					
5. Gross household	10.11	-2.78	-15.12	-6.98	-13.09	-9.25	-22.06	28.54	0.68	16.23
	(312.47)	(-0.61)	(-3.31)	(-1.52)	(-2.86)	(-2.02)	(-4.82)	(6.24)		
6. Gross house disposable	9.84	-2.41	-14.56	-7.69	-12.24	-4.96	-21.42	30.34	0.67	16.17
	(289.02)	(-0.50)	(-3.03)	(-1.60)	(-2.54)	(-1.03)	(-4.45)	(6.30)		
					III. Housing prices					
7. Houses	5.33	-26.94	-47.24	-55.03	-60.63	-33.36	-70.02	-31.72	0.68	48.82
	(120.30)	(-4.30)	(-7.54)	(-8.78)	(-9.68)	(-5.32)	(-11.18)	(-5.06)		
8. Units	5.11	-30.80	-38.95	-65.50	-61.85	-37.39	-72.48	-31.42	0.71	51.02
	(115.40)	(-4.92)	(-6.22)	(-10.46)	(-9.87)	(-5.97)	(-11.57)	(-5.02)		

Notes:
1. The regional dummy variable $z_{urt} = 1$ if $u = r$, 0 otherwise.
2. In all cases, the data are annual for the period 1990 to 1999, pooled over the 8 regions.
3. Gross household income and gross household disposable income are in terms of nominal dollars per capita.

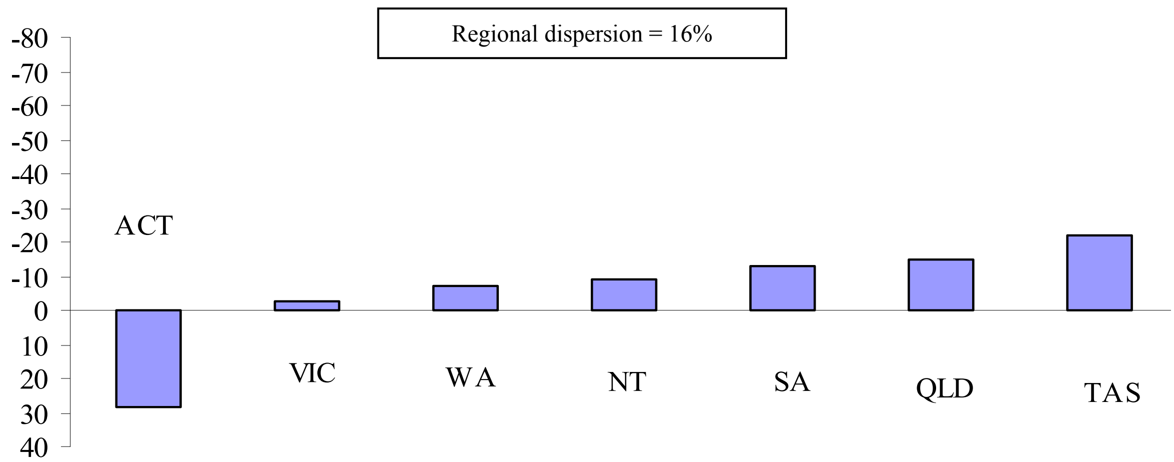
FIGURE 4.1

REGIONAL DISPERSION OF PRICES AND INCOMES

A. Marijuana Prices



B. Gross Household Income



C. Housing Prices

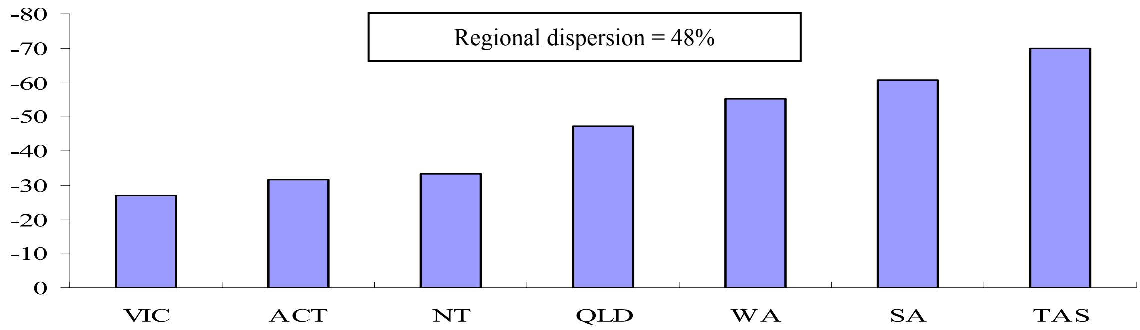


FIGURE 4.2

MARIJUANA AND HOUSING PRICES

(Logarithmic ratios to Sydney × 100; inverted scales)

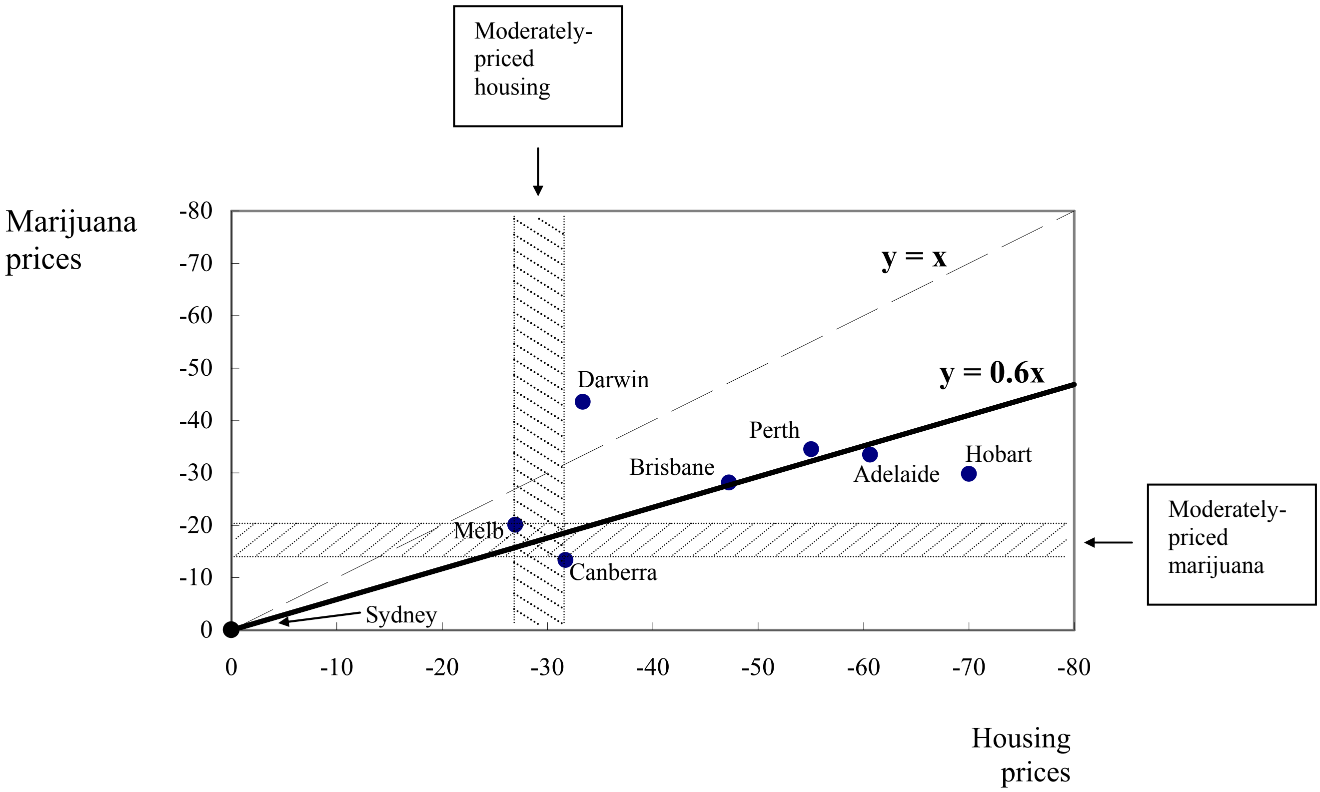


FIGURE 4.3

MARIJUANA PRICE INDEX

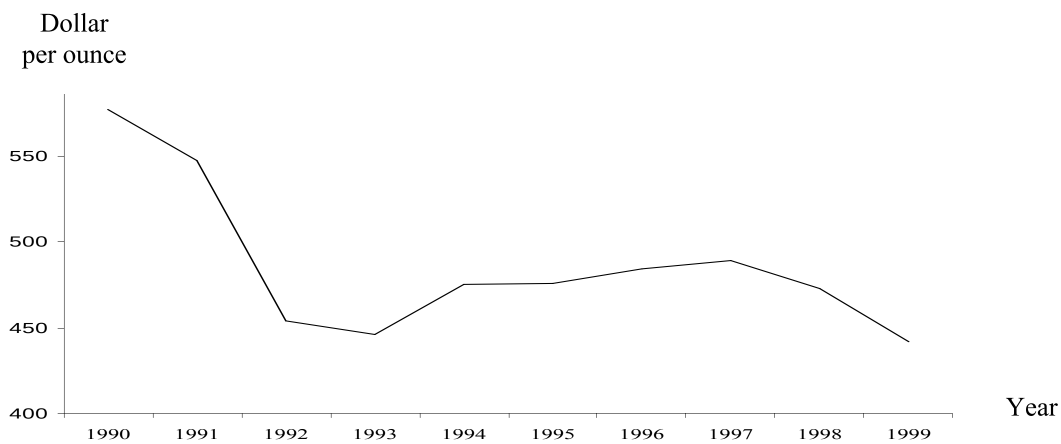


FIGURE 4.4

RELATIVE PRICES OF MARIJUANA

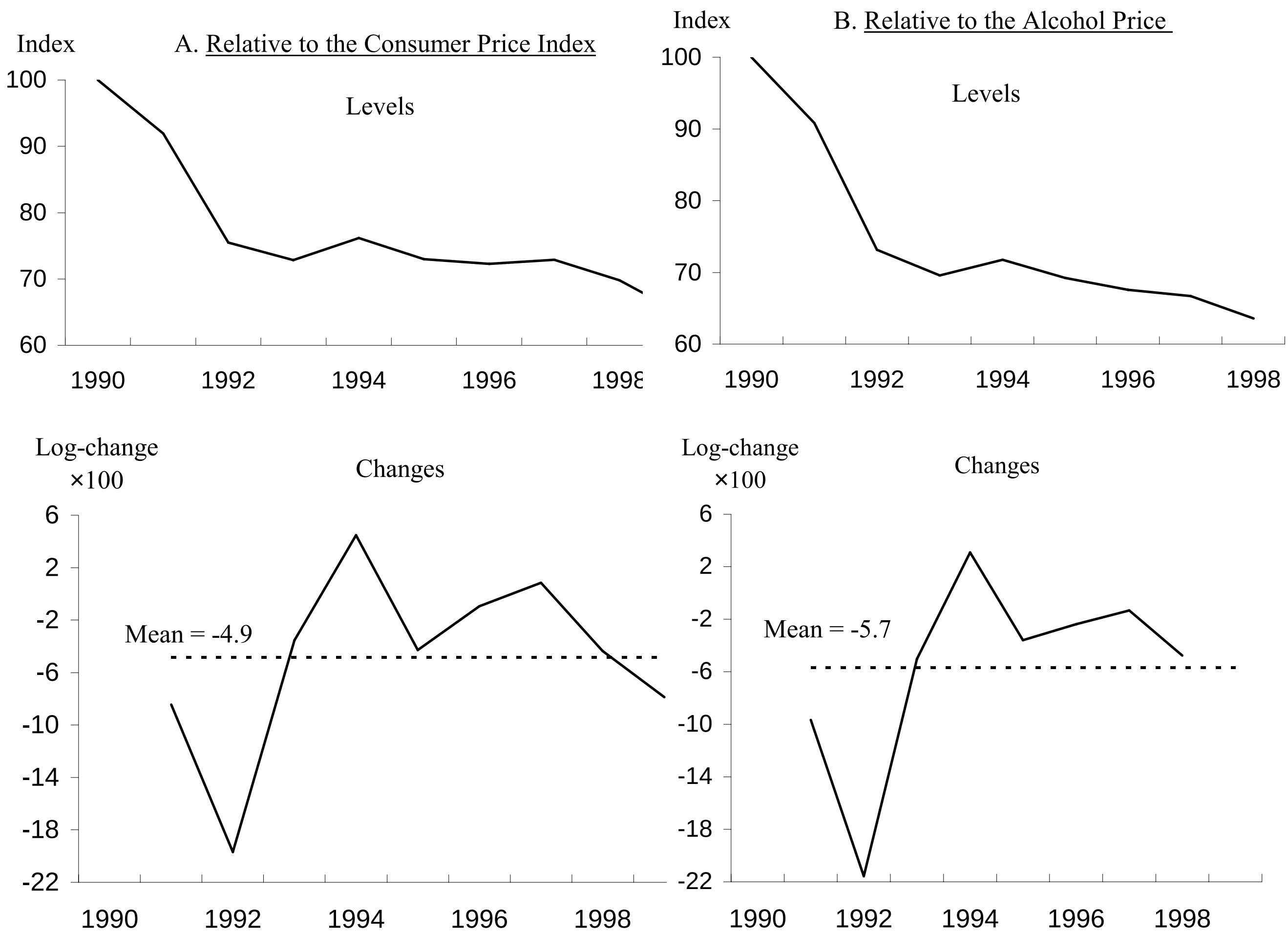
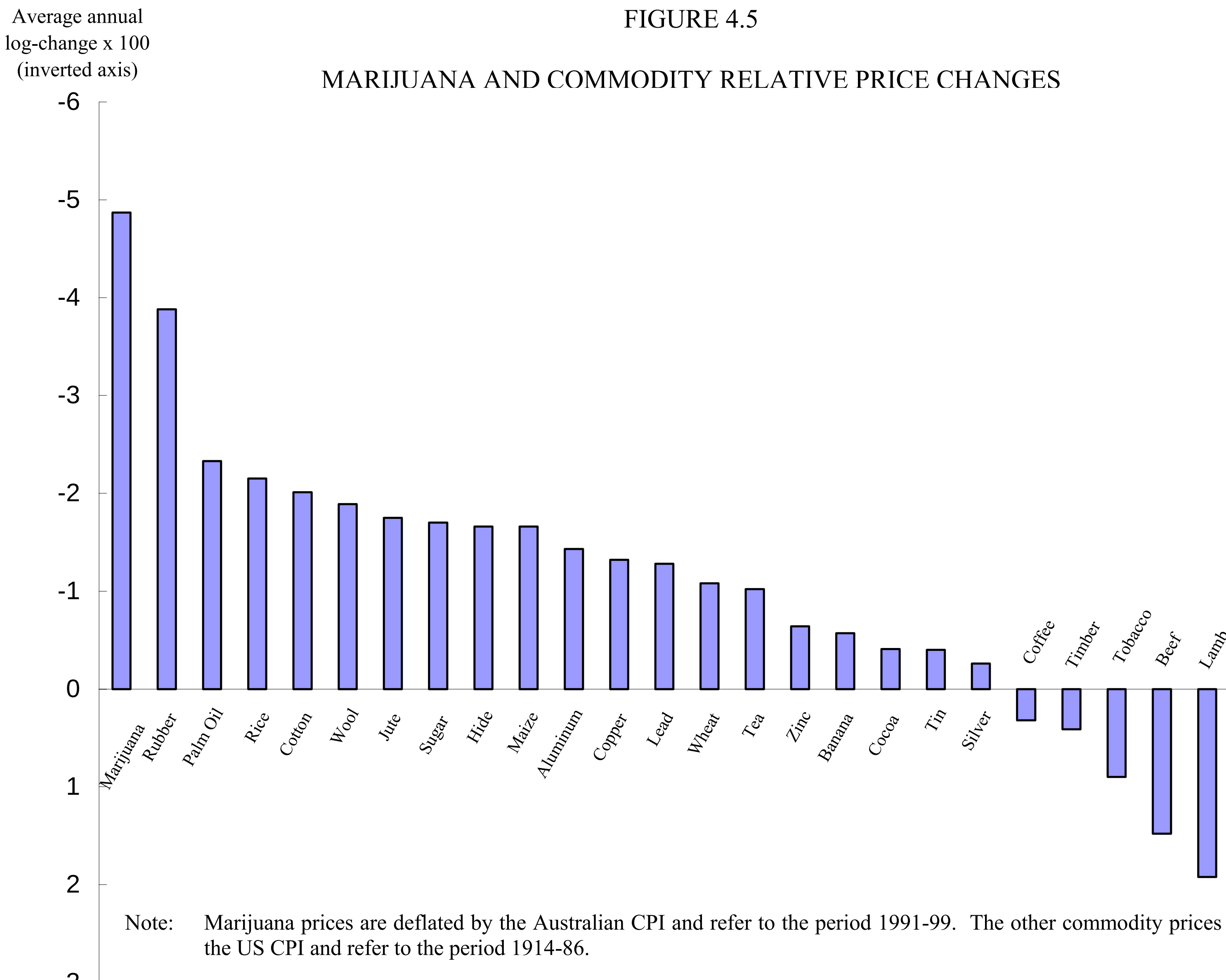


FIGURE 4.5

MARIJUANA AND COMMODITY RELATIVE PRICE CHANGES

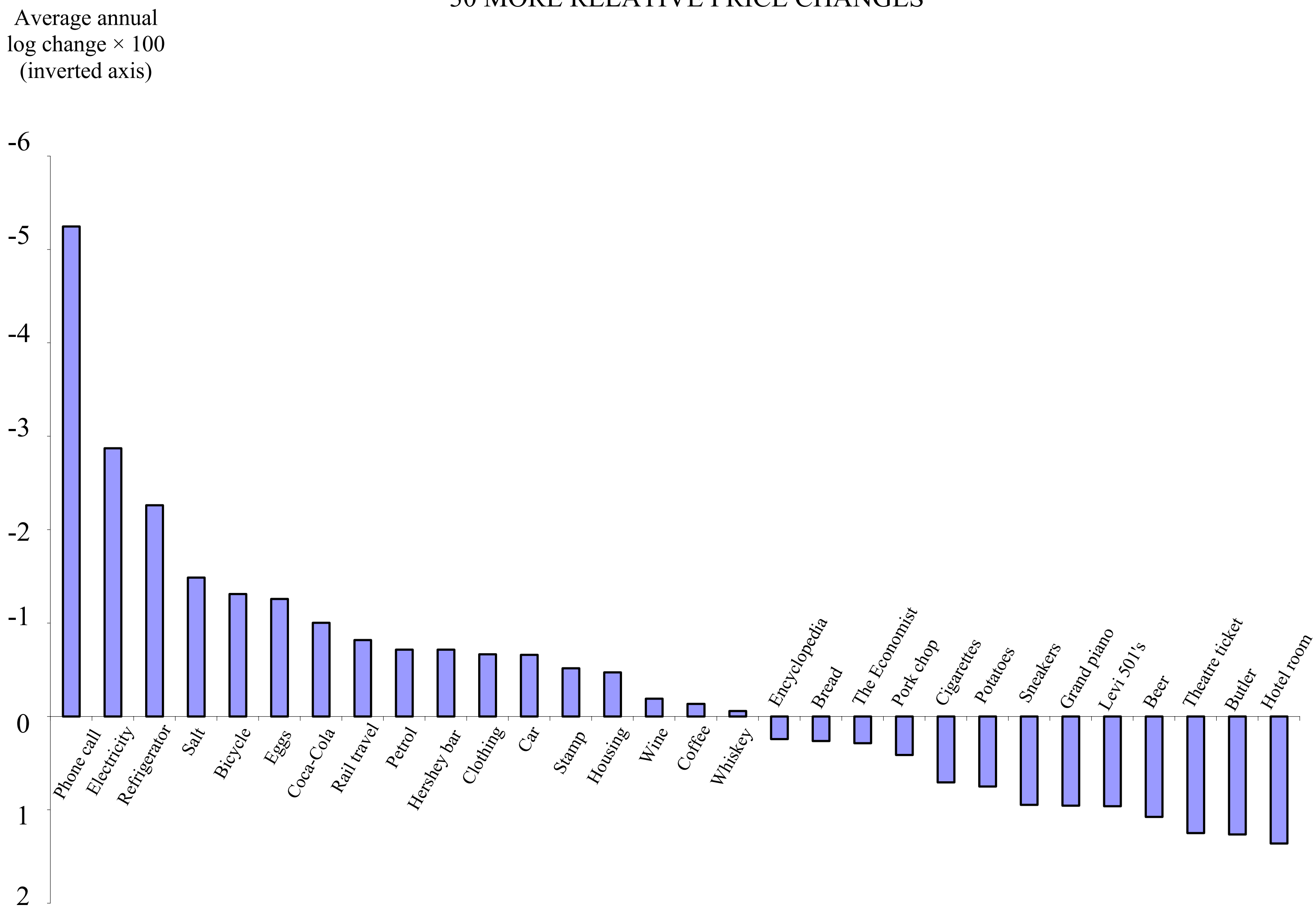


Note: Marijuana prices are deflated by the Australian CPI and refer to the period 1991-99. The other commodity prices are deflated by the US CPI and refer to the period 1914-86.

Source: Non-marijuana prices are derived from Grilli and Yang (1988). See Clements (2002) for further details.

FIGURE 4.6

30 MORE RELATIVE PRICE CHANGES



Source: The Economist (2000/01); see Clements (2002) for further details.

TABLE 4.2

INFRINGEMENT NOTICES FOR
MINOR CANNABIS OFFENCES
(Rate per 100,000 population)

Year	SA	NT	ACT	Australia
1996	1,114	-	96	92
1997	857	124	103	72
1998	725	115	76	60
1999	631	179	49	53
2000	579	401	-	50
2001	580	208	59	48
Mean	748	205	77	63

Sources: Australian Bureau of Criminal Intelligence, Australian Illicit Drug Report 2001-02, Australian Bureau of Statistics, Australian Historical Population Statistics, 2002, and Australian Bureau of Statistics, Year Book of Australia (various issues).

TABLE 4.3

ARRESTS AND PROSECUTIONS FOR MARIJUANA OFFENCES

Year	NSW	VIC	QLD	WA	SA	NT	TAS	ACT	AUST
				I. Arrests (Per 100,000 population)					
1996	238	421	286	795	141	210	531	47	342
1997	227	199	441	713	232	245	228	54	304
1998	245	195	380	633	182	222	253	45	287
1999	247	198	385	330	172	183	156	28	256
2000	220	157	386	363	210	62	170	-	242
2001	211	136	366	389	151	224	223	48	232
Mean	231	218	374	537	181	191	260	37	277
				II. Successful Prosecutions (Per 100,000 population)					
1991	112	-	-	-	-	-	-	-	-
1992	123	-	-	-	273	-	-	-	-
1993	113	-	-	-	315	-	-	-	-
1994	94	-	-	-	350	-	-	-	-
1995	83	-	-	-	326	-	-	-	-
1996	90	-	-	-	304	-	-	-	-
1997	81	-	-	-	205	-	-	-	-
1998	85	-	-	222	46	-	-	-	-
1999	92	-	-	234	38	-	-	-	-
2000	77	-	-	251	59	-	-	-	-
2001	73	-	-	238	76	-	-	-	-
Mean	93	-	-	236	199	-	-	-	-
				III. Prosecutions/Arrests (Percentages)					
1996	38	-	-	-	215	-	-	-	-
1997	36	-	-	-	88	-	-	-	-
1998	35	-	-	35	25	-	-	-	-
1999	37	-	-	71	22	-	-	-	-
2000	35	-	-	69	28	-	-	-	-
2001	35	-	-	61	51	-	-	-	-
Mean	36	-	-	59	72	-	-	-	-

Notes: 1. Arrests exclude the issuing of Cannabis Expiation Notices, Simple Cannabis Offence Notices and Infringement Notices, which are used in SA, NT and ACT. For details of these, see Table 4.2.

2. The arrests data for 1996 for SA seem to be problematic and need to be treated with caution. According to Australian Illicit Drug Report 2000-2001, arrests were 2,076, which when divided by the population of SA of 1,474,253 yields 141 per 100,000, as reported above. However, according to the 2001-2002 edition of the above-mentioned publication, arrests for the same state in the same year were 18,477, or 1,253 per 100,000. We used the 141 figure as it appeared to be more consistent with data for adjacent years; however, the use of this figure leads to a prosecutions/arrests rate of 215%, as reported in Panel III of this table.

Sources: Australian Bureau of Criminal Intelligence, Australian Illicit Drug Report 2000-2001, NSW Bureau of Crime Statistics and Research, NSW Criminal Courts Statistics, 1991-2001, Office of Crime Statistics and Research, Crime and Justice in South Australia, 1992-2001, The University of WA Crime Research Centre, Crime and Justice Statistics for Western Australia, 1996-2001, and Australian Bureau of Statistics, Australian Historical Population Statistics, 2002.

FIGURE 5.1

OUNCE AND GRAM UNIT PRICES OF MARIJUANA

(Australian dollars per gram)

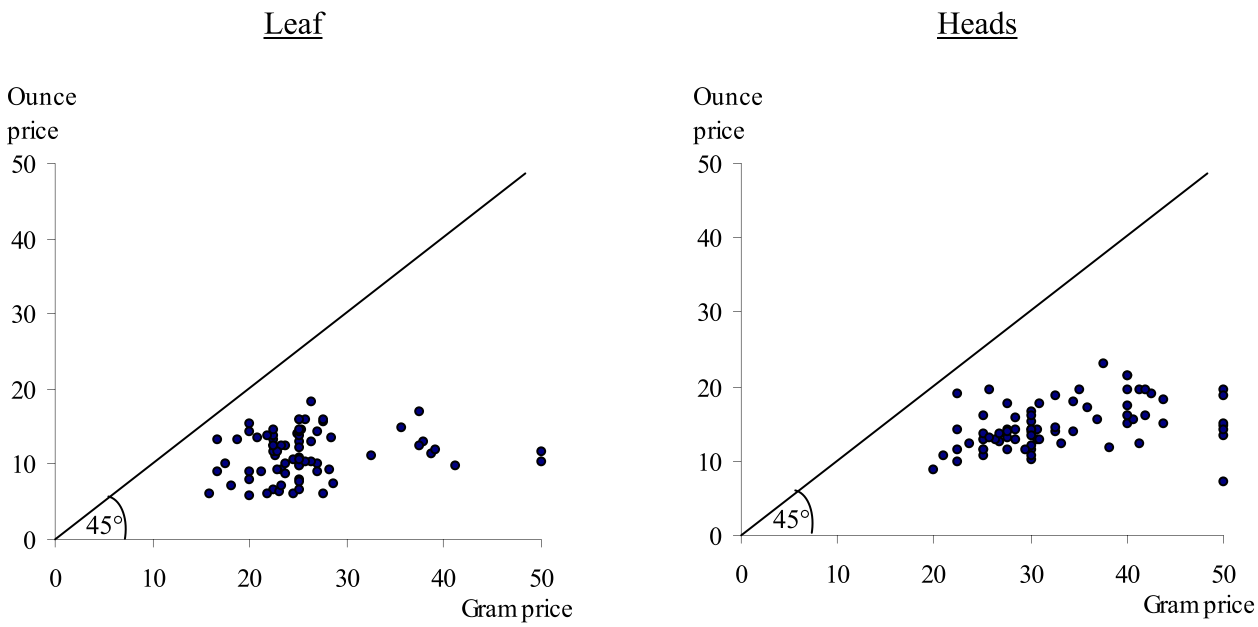


FIGURE 5.2

HISTOGRAM OF DISCOUNT FOR BULK
BUYING OF MARIJUANA

(100 × logarithmic ratios of unit ounce to unit gram prices; leaf and heads)

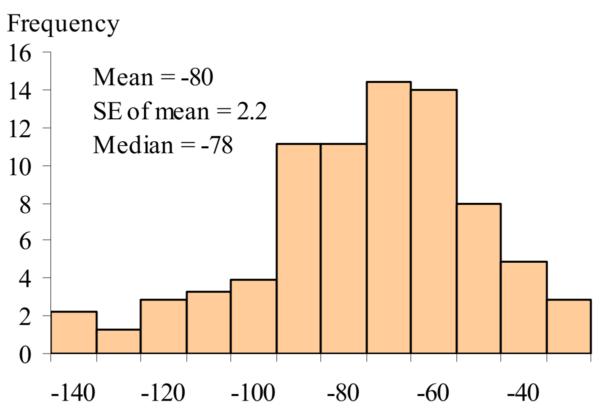


FIGURE 5.3

HISTOGRAM OF DISCOUNT ELASTICITIES
FOR MARIJUANA

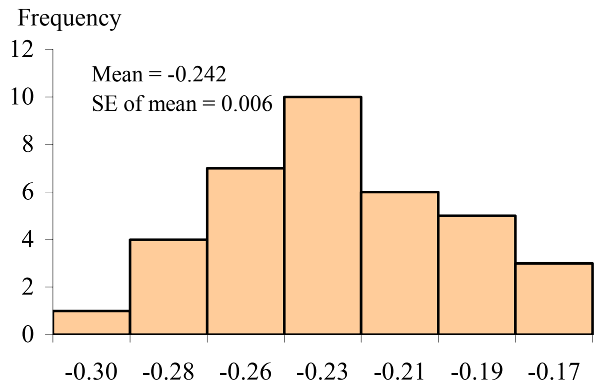
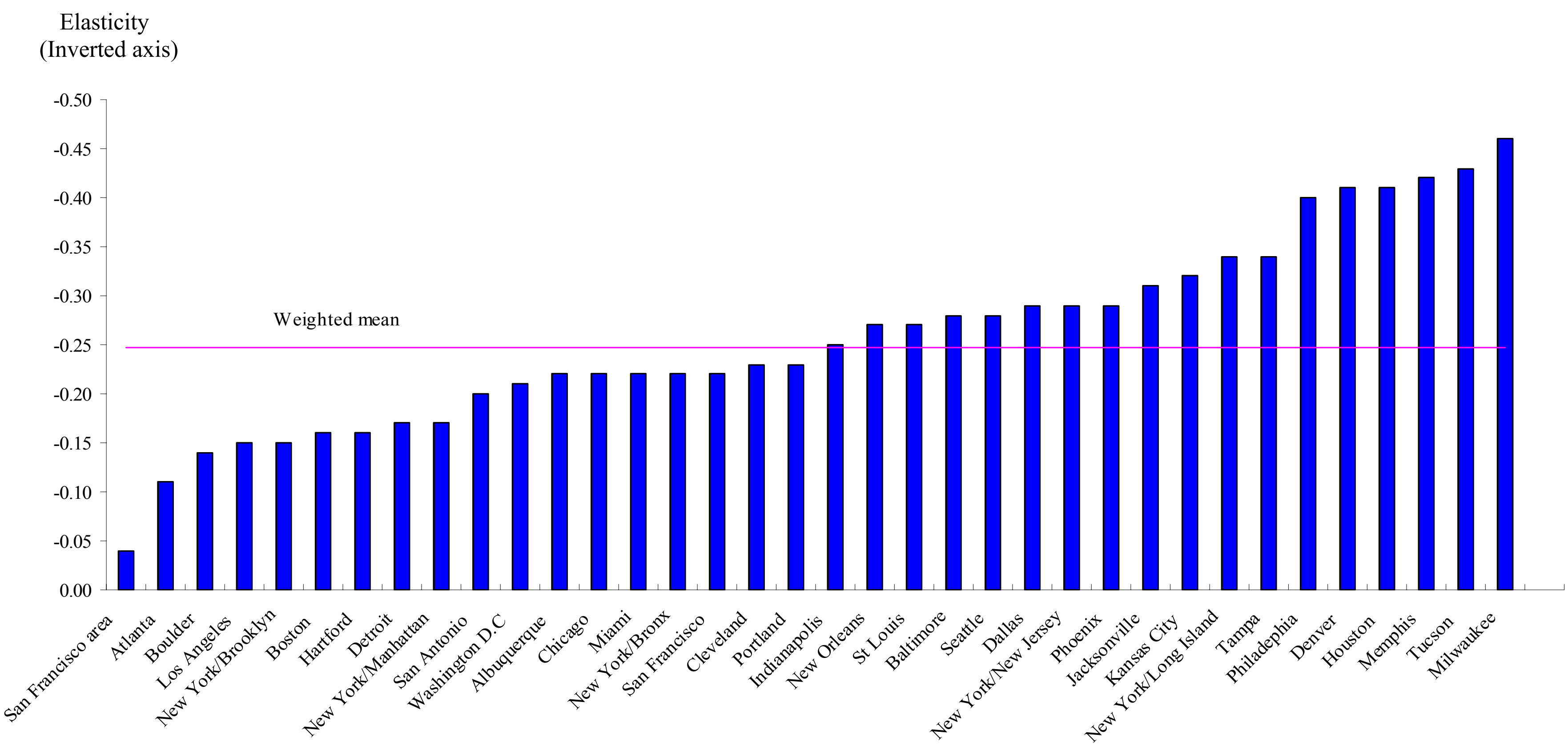


FIGURE 5.4

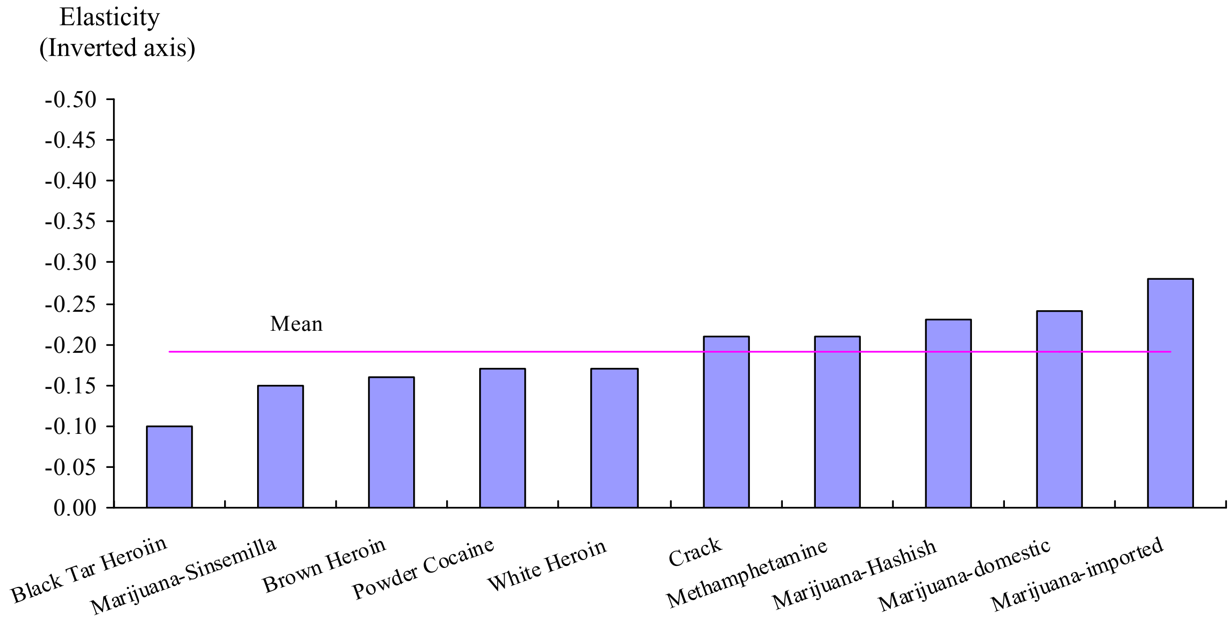
DISCOUNT ELASTICITIES FOR HEROIN



Source: Derived from Brown and Silverman (1974, Table 2).
Note: Buffalo, Minneapolis, Nashville, Pittsburgh, and Honolulu are omitted as outliers.

FIGURE 5.5

DISCOUNT ELASTICITIES FOR ILLICIT DRUGS



Source: Derived from Caulkins and Padman (1993, Tables 3 and 4).

TABLE 5.1

DISCOUNT ELASTICITIES FOR GROCERIES

(Standard errors in parentheses)

Product group	Discount elasticities			
	With product dummies		Without product dummies	
(1)	(2)		(3)	
Baked beans	-0.419	(0.020)	-0.383	(0.027)
Cheese	-0.183	(0.016)	-0.176	(0.020)
Flour	-0.259	(0.052)	-0.232	(0.079)
Milk	-0.151	(0.024)	-0.149	(0.040)
Rice	-0.122	(0.012)	-0.140	(0.018)
Sugar	-0.148	(0.033)	-0.296	(0.048)
Canned vegetables	-0.308	(0.019)	-0.388	(0.037)
Mean-unweighted	-0.227		-0.252	
Mean-weighted	-0.219		-0.237	

Notes:

1. These elasticities are estimated from the equation $\log p'_{si} = \alpha + \beta' \log s_i + \text{product dummies}$, where p'_{si} is the unit price of product i sold in the form of package size s.
2. The weights for the weighted means in the last row are proportional to the reciprocals of the standard errors.

TABLE 6.1

QUANTITIES CONSUMED AND PRICES OF

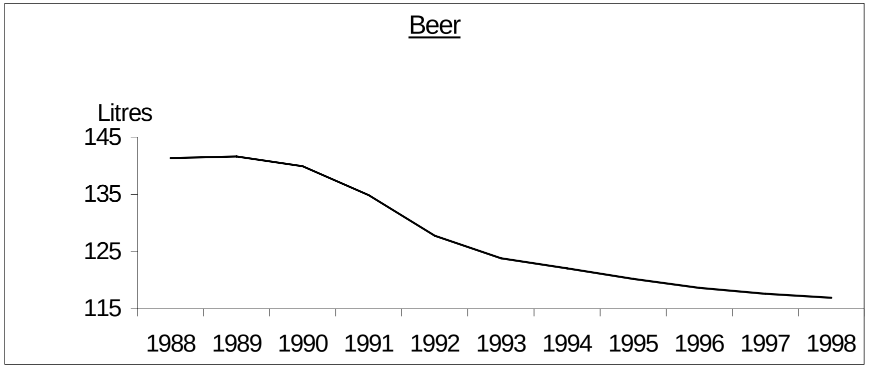
ALCOHOLIC BEVERAGES AND MARIJUANA

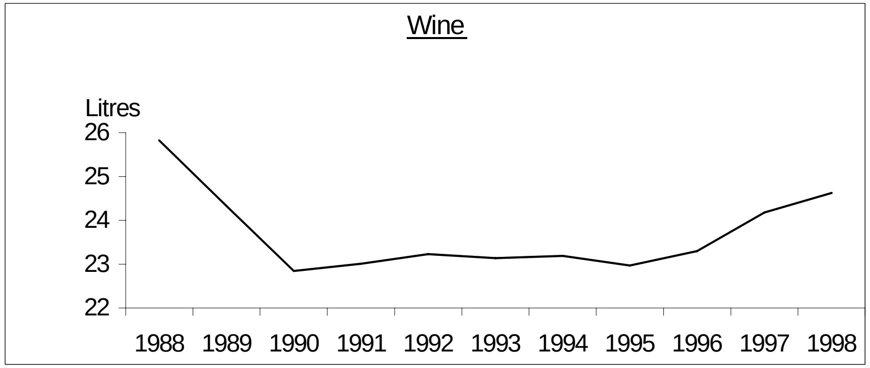
Year	Beer	Wine	Spirits	Marijuana
		Quantities		
1988	141.4	25.82	3.993	.6467
1989	141.6	24.32	4.048	.7049
1990	139.9	22.85	3.870	.7652
1991	134.9	23.01	3.614	.8278
1992	127.8	23.23	3.595	.7695
1993	123.8	23.14	3.982	.7090
1994	122.1	23.19	4.168	.7120
1995	120.2	22.96	4.130	.6913
1996	118.7	23.29	4.106	.7442
1997	117.6	24.18	4.158	.7575
1998	116.9	24.63	4.318	.7875
Mean	127.2	23.69	4.000	.7378
		Prices		
1988	2.819	6.190	30.578	450
1989	2.928	6.607	33.315	450
1990	3.116	6.801	36.601	450
1991	3.271	6.883	39.064	450
1992	3.361	7.056	40.532	450
1993	3.478	7.271	41.847	450
1994	3.583	7.597	43.044	450
1995	3.724	7.983	44.254	450
1996	3.891	8.306	45.687	450
1997	3.981	8.559	46.714	450
1998	4.020	8.755	47.088	450
Mean	3.470	7.455	40.793	450

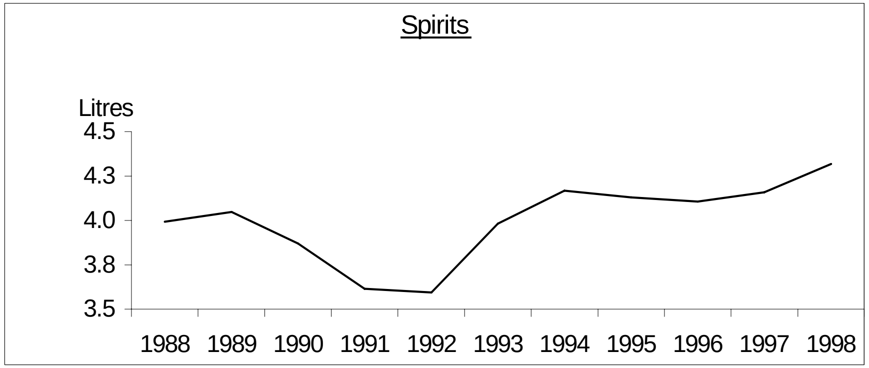
Notes:
1. Quantities are per capita (14 years and over).
2. Quantities consumed of the alcoholic beverages are in terms of litres; and that of marijuana is in ounces.
3. Prices are in dollars per litre for the alcoholic beverages and per ounce for marijuana.

FIGURE 6.1

QUANTITIES CONSUMED







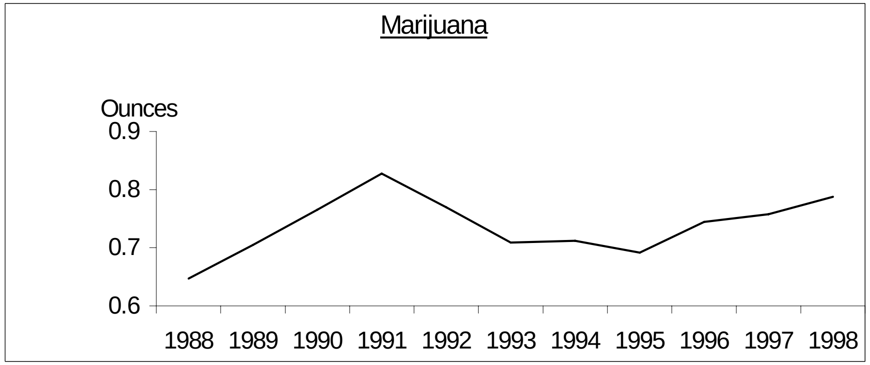


TABLE 6.2

EXPENDITURES ON AND BUDGET SHARES OF
ALCOHOLIC BEVERAGES AND MARIJUANA

Year	Beer	Wine	Spirits	Marijuana	Total
			Expenditures		
1988	398.41	159.84	122.10	291.02	971.37
1989	414.80	160.70	134.87	317.19	1,027.56
1990	435.91	155.39	141.67	344.36	1,077.32
1991	441.49	158.52	140.76	372.52	1,113.29
1992	429.43	163.93	145.70	346.27	1,085.32
1993	430.66	168.24	166.62	319.06	1,084.58
1994	437.49	176.17	179.40	320.42	1,113.47
1995	447.64	183.32	182.77	311.09	1,124.81
1996	461.75	193.48	187.60	334.90	1,177.74
1997	468.18	206.96	194.22	340.86	1,210.22
1998	470.11	215.61	203.31	354.37	1,243.41
Mean	439.60	176.55	163.59	332.01	1,111.74
			Budget Shares		
1988	41.01	16.46	12.57	29.96	100
1989	40.37	15.64	13.13	30.87	100
1990	40.46	14.42	13.15	31.96	100
1991	39.63	14.22	12.68	33.46	100
1992	39.57	15.10	13.42	31.90	100
1993	39.71	15.51	15.36	29.42	100
1994	39.29	15.82	16.11	28.78	100
1995	39.80	16.30	16.25	27.66	100
1996	39.21	16.43	15.93	28.44	100
1997	38.69	17.10	16.05	28.16	100
1998	37.81	17.34	16.35	28.50	100
Mean	39.59	15.85	14.64	29.92	100

Notes: 1. Expenditures are in terms of dollars per capita (14 years and over).
2. Budget shares are percentages.

TABLE 6.3

LOG-CHANGES IN QUANTITIES CONSUMED AND PRICES

OF ALCOHOLIC BEVERAGES AND MARIJUANA

Year	Beer	Wine	Spirits	Marijuana
		Quantities		
1989	.21	-5.98	1.38	8.61
1990	-1.23	-6.26	-4.49	8.22
1991	-3.65	.70	-6.85	7.86
1992	-5.43	.97	-.55	-7.31
1993	-3.13	-.40	10.23	-8.18
1994	-1.42	.22	4.57	.42
1995	-1.55	-.97	-.91	-2.69
1996	-1.29	1.43	-.57	7.38
1997	-.89	3.73	1.25	1.76
1998	-.57	1.83	3.78	3.89
Mean	-1.90	-.47	.78	1.97
		Prices		
1989	3.83	6.51	8.57	0
1990	6.20	2.90	9.41	0
1991	4.86	1.19	6.51	0
1992	2.72	2.49	3.69	0
1993	3.41	3.00	3.19	0
1994	3.00	4.38	2.82	0
1995	3.85	4.95	2.77	0
1996	4.40	3.97	3.19	0
1997	2.27	3.00	2.22	0
1998	.98	2.27	.80	0
Mean	3.55	3.47	4.32	0

Note: All entries are to be divided by 100.

TABLE 6.4

DIVISIA MOMENTS

Year	Price index ($\times 100$)	Quantity index ($\times 100$)	Price variance ($\times 10^4$)	Quantity variance ($\times 10^4$)	Price-quantity covariance ($\times 10^4$)	Price-quantity correlation
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1989	3.70	1.92	8.49	24.87	-11.53	-.79
1990	4.18	.55	10.97	30.06	-13.67	-.75
1991	2.96	.33	6.39	31.57	-13.71	-.97
1992	1.92	-4.47	1.92	9.34	2.84	.67
1993	2.27	-2.34	2.30	34.02	5.60	.63
1994	2.31	.32	2.45	4.05	-.23	-.07
1995	2.77	-1.75	3.39	.64	1.30	.88
1996	2.90	1.70	3.45	13.43	-6.54	-.96
1997	1.74	.98	1.27	2.81	-.17	-.09
1998	.90	1.81	.56	4.02	-.63	-.42
Mean	2.56	-.10	4.12	15.48	-3.67	-.19

TABLE 6.5

RELATIVE QUANTITY CORRELATION COEFFICIENTS

Good	Beer	Wine	Spirits	Marijuana
Beer	1.0	.15	.61	-.70
Wine		1.0	.43	-.71
Spirits			1.0	-.90
Marijuana				1.0

TABLE 6.6

PRICE ELASTICITIES OF DEMAND

Good (1)	Beer (2)	Wine (3)	Spirits (4)	Marijuana (5)
		Compensated		
Beer	-.17	.03	.06	.08
Wine	.09	-.36	.13	.15
Spirits	.17	.13	-.60	.30
Marijuana	.10	.08	.15	-.33
		Uncompensated		
Beer	-.37	-.04	-.01	-.07
Wine	-.31	-.51	-.02	-.15
Spirits	-.63	-.17	-.90	-.30
Marijuana	-.38	-.10	-.03	-.69

TABLE 7.1

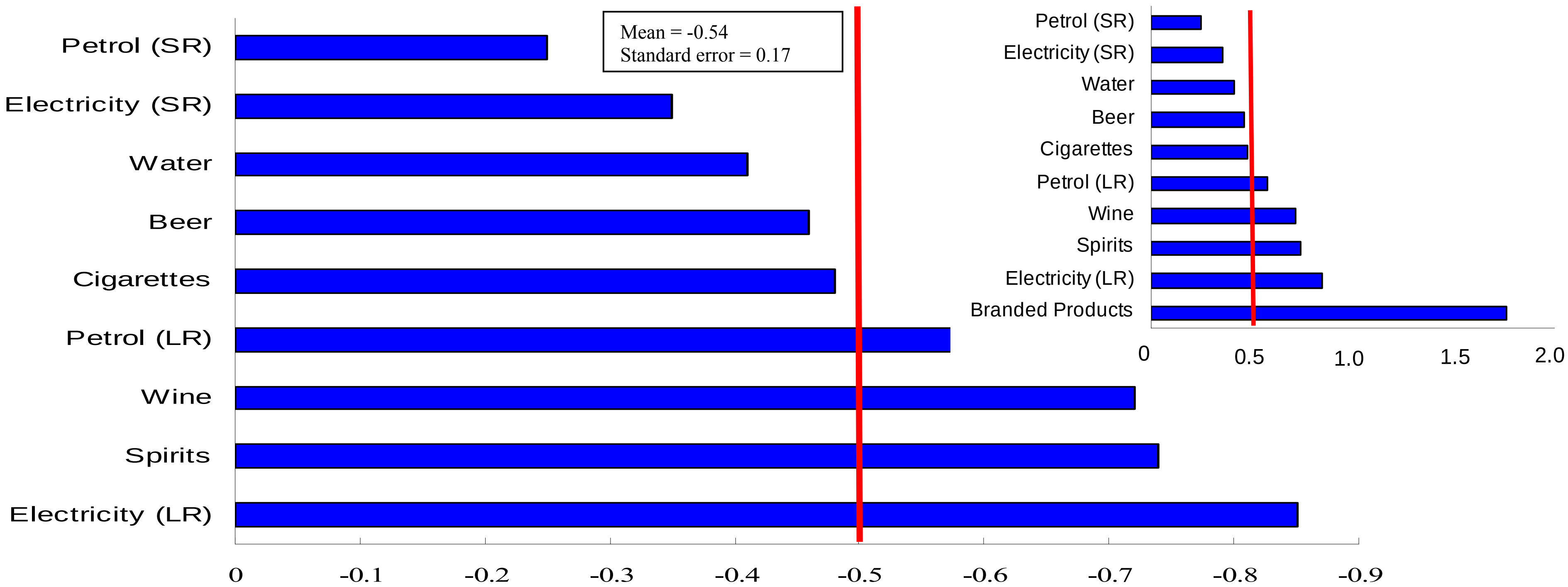
PRICE ELASTICITIES OF DEMAND FOR SELECTED PRODUCTS

Product	Mean	Median	Number of observations	Length of run	Source
1. Beer	-0.46	-0.35	139		Fogarty (2005, Chapter 2)
	-0.37		10		Selvanathan and Selvanathan (2005a, p. 232)
2. Wine	-0.72	-0.58	141		Fogarty (2005, Chapter 2)
	-0.46		10		Selvanathan and Selvanathan (2005a, p. 232)
3. Spirits	-0.74	-0.68	136		Fogarty (2005, Chapter 2)
	-0.57		10		Selvanathan and Selvanathan (2005a, p. 232)
4. Cigarettes	-0.48		523		Gallet and List (2003)
		-0.40	368	Short run	Gallet and List (2003)
		-0.44	155	Long run	Gallet and List (2003)
5. Residential water	-0.41	-0.35	314		Dalhuisen et al. (2003)
	-0.51		124		Espey et al. (1997)
		-0.38		Short run	Espey et al. (1997)
		-0.64		Long run	Espey et al. (1997)
6. Petrol	-0.26	-0.23	363	Short run	Espey (1998)
	-0.25		46	Short run	Goodwin et al. (2004)
	-0.25	-0.21	387	Short run	Graham and Glaister (2002, p. 48)
	-0.58	-0.43	277	Long run	Espey (1998)
	-0.64		51	Long run	Goodwin et al. (2004)
	-0.53		70		Espey (1996)
	-0.77	-0.55	213	Long run	Graham and Glaister (2002, p. 48)
	-0.35	-0.35	52	Intermediate	Graham and Glaister (2002, p. 54)
7. Residential electricity	-0.35	-0.28	123	Short run	Espey and Espey (2004)
	-0.85	-0.81	125	Long run	Espey and Espey (2004)
8. Branded products	-1.76		337		Tellis (1988)

Notes
1. The other average elasticities of road traffic and fuel consumption reported in Goodwin et al. (2004) and Graham and Glaister (2002) are excluded as they are not confined to the demand by final consumers.
2. Although the elasticities reported by Goodwin et al. (2004) and Graham and Glaister (2002) refer to "fuel" used by motor vehicles which is broader than "petrol" ("gasoline"), for simplicity of presentation of the table we list these under the product "petrol".

FIGURE 7.1

PRICE ELASTICITIES OF DEMAND



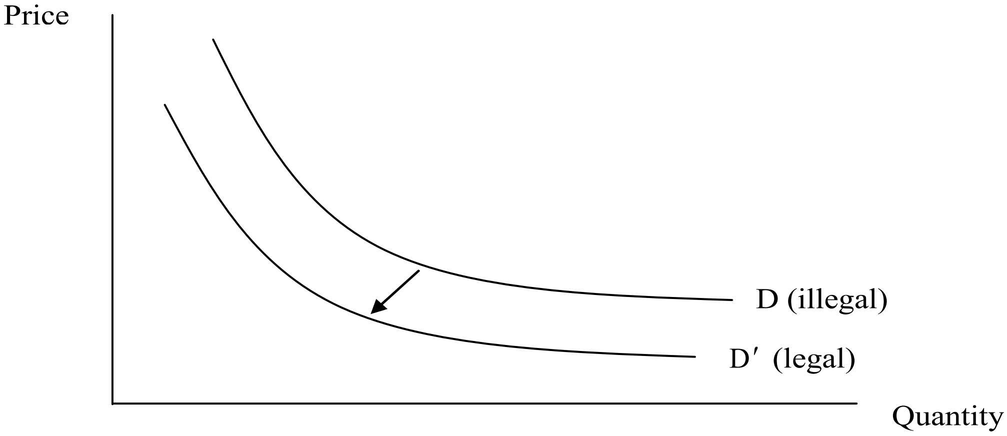
Note: The elasticity values in this figure are the means from Table 7.1. In those cases where these are multiple means for the same product, we use those with the largest number of observations. The elasticity value for petrol (SR) of -0.25 is from the third entry in Panel 6 of the table; electricity (SR) of -0.35 is from the first entry of Panel 7; water of -0.41 is from first entry of Panel 5; beer of -0.46 is from the first entry of Panel 1; cigarettes of -0.48 is from first entry of Panel 4; petrol (LR) of -0.58 is from the fourth entry of Panel 6; wine of -0.72 is from the first entry of Panel 2; spirits of -0.74 is from the first entry of Panel 3; electricity (LR) of -0.85 is from the second entry of Panel 7; and branded goods (included only in the "mini version" of the figure in the top right-hand corner) of -1.76 is from Panel 8. SR denotes short run, and LR denotes long run

.

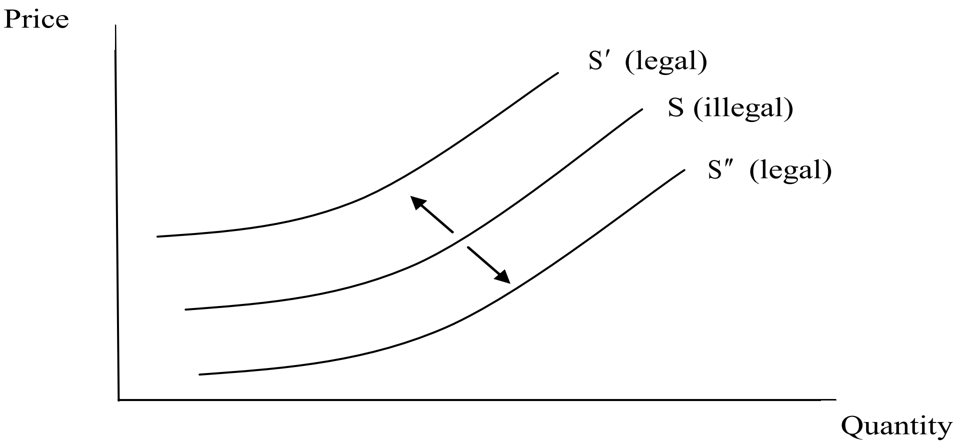
FIGURE 8.1

LEGALISING DRUGS

A. Drugs as Forbidden Fruit



B. Which Way Does the Supply Curve Shift?



C. Prices May Increase or Decrease

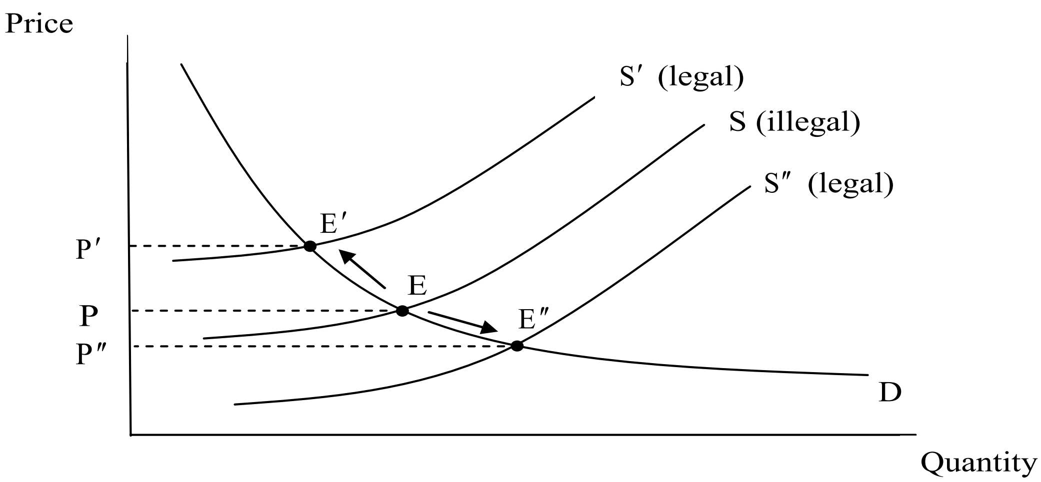


TABLE 8.1

EFFECTS OF LEGALISATION ON THE
CONSUMPTION OF MARIJUANA

(Standard errors in parentheses; percentage changes)

Type of user	Gender			Type of user	Gender		
	Male	Female	All		Male	Female	All
Daily	21.25 (14.80)	.00 (.00)	18.89 (13.70)	No longer	4.69 (4.67)	.00 (.00)	2.50 (2.48)
Weekly	8.15 (4.07)	11.18 (5.08)	9.32 (3.19)	All users	9.09 (2.28)	6.19 (1.78)	7.79 (1.49)
Monthly	6.79 (3.38)	9.12 (4.07)	8.06 (2.79)	Non-users	.19 (.18)	.38 (.24)	.30 (.15)
Occasional	10.88 (4.27)	3.89 (1.96)	7.29 (2.35)	All types	5.55 (1.42)	3.07 (.86)	4.27 (.82)

FIGURE 8.2
SHOCKS AND SUBSTITUTES

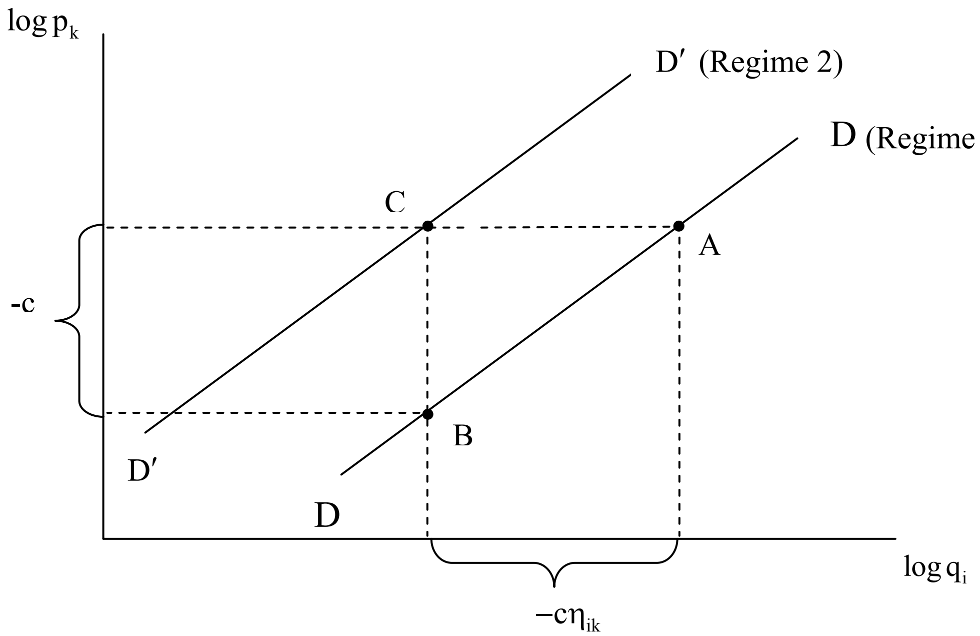


TABLE 8.2

EFFECTS OF LEGALISATION ON THE CONSUMPTION OF ALCOHOLIC BEVERAGES AND MARIJUANA

(Standard errors in parentheses; percentage changes)

Good	Gender: Male	Female	All	Good	Gender: Male	Female	All
	A. Daily users				E. No longer a user		
Beer	-5.15 (5.15)	.00 (.00)	-4.58 (4.67)	Beer	-1.14 (1.40)	.00 (.00)	-.61 (.74)
Wine	-9.66 (9.83)	.00 (.00)	-8.59 (8.91)	Wine	-2.13 (2.65)	.00 (.00)	-1.14 (1.41)
Spirits	-19.32 (19.65)	.00 (.00)	-17.17 (17.81)	Spirits	-4.26 (5.29)	.00 (.00)	-2.27 (2.82)
Marijuana	21.25 (14.80)	.00 (.00)	18.89 (13.70)	Marijuana	4.69 (4.67)	.00 (.00)	2.50 (2.48)
	B. Weekly users				F. All users		
Beer	-1.98 (1.73)	-2.71 (2.30)	-2.26 (1.80)	Beer	-2.20 (1.68)	-1.50 (1.16)	-1.89 (1.40)
Wine	-3.71 (3.31)	-5.08 (4.42)	-4.24 (3.46)	Wine	-4.13 (3.23)	-2.81 (2.24)	-3.54 (2.71)
Spirits	-7.41 (6.62)	-10.16 (8.84)	-8.47 (6.92)	Spirits	-8.27 (6.47)	-5.63 (4.48)	-7.08 (5.42)
Marijuana	8.15 (4.07)	11.18 (5.08)	9.32 (3.19)	Marijuana	9.09 (2.28)	6.19 (1.78)	7.79 (1.49)
	C. Monthly users				G. Non-users		
Beer	-1.65 (1.44)	-2.21 (1.87)	-1.95 (1.56)	Beer	-.05 (.05)	-.09 (.09)	-.07 (.06)
Wine	-3.09 (2.76)	-4.15 (3.59)	-3.66 (3.00)	Wine	-.09 (.10)	-.17 (.17)	-.14 (.12)
Spirits	-6.17 (5.51)	-8.29 (7.18)	-7.33 (6.00)	Spirits	-.17 (.21)	-.35 (.34)	-.27 (.24)
Marijuana	6.79 (3.38)	9.12 (4.07)	8.06 (2.79)	Marijuana	.19 (.18)	.38 (.24)	.30 (.15)
	D. Occasional users				H. All types		
Beer	-2.64 (2.16)	-.94 (.83)	-1.77 (1.39)	Beer	-1.35 (1.03)	-.74 (.57)	-1.04 (.77)
Wine	-4.95 (4.15)	-1.77 (1.59)	-3.31 (2.68)	Wine	-2.52 (1.98)	-1.40 (1.11)	-1.94 (1.49)
Spirits	-9.89 (8.30)	-3.54 (3.17)	-6.63 (5.36)	Spirits	-5.05 (3.96)	-2.79 (2.21)	-3.88 (2.97)
Marijuana	10.88 (4.27)	3.89 (1.96)	7.29 (2.35)	Marijuana	5.55 (1.42)	3.07 (.86)	4.27 (.82)

TABLE 9.1

DATA FOR STOCHASTIC VICE

Variable/ parameter (1)	Mean (2)	Range (3)	Implied standard deviation (4)	Coefficient of variation (5)	Constraint (6)
Budget shares w_i					
1. Marijuana	.02	(.01, .03)	.005	.25	$0 < w_1 < 1$
2. Tobacco	.02	(.015, .025)	.0025	.125	$0 < w_2 < 1$
3. Alcohol	.04	(.03, .05)	.005	.125	$0 < w_3 < 1$
4. Other	.92	(.905, .935)	.0075	.008	$0 < w_4 < 1,\ w_4 = 1 - \sum_{i=1}^{3} w_i$
Sum	1.00				
Income flexibility					
5. ϕ	-.5	(-.75, -.25)	. 125	.25	$\phi < 0$
Correlation coefficient					
6. ρ	-.5	(-1.00,.00)	.25	.50	$-1 < \rho < 0$
Marginal shares θ_i					
7. Marijuana	.024	(.000, .048)	.012	.50	$\theta_1 > 0$
8. Tobacco	.008	(.004, .012)	.002	. 25	$\theta_2 > 0$
9. Alcohol	.04	(.02, .06)	.01	. 25	$\theta_3 > 0$
10. Other	.928	(.896, .96)	.016	.017	$\theta_4 > 0,\ \theta_4 = 1 - \sum_{i=1}^{3} \theta_i$
Sum	1.00				

Frisch price coefficient matrix ν

ν negative definite

$$\begin{bmatrix} \phi\theta_1 & \alpha & -\alpha & 0 \\ \alpha & \phi\theta_2 & -\alpha & 0 \\ -\alpha & -\alpha & \phi\theta_3 + 2\alpha & 0 \\ 0 & 0 & 0 & \phi\theta_4 \end{bmatrix}$$

$$\alpha = \rho\, |\phi|\, \sqrt{\theta_1\, \theta_2}$$

Notes: 1. The range for each variable given in column 3 is the approximate 95 percent confidence interval based on normality.

2. The parameter $\rho \approx -\nu^{12} \big/ \sqrt{\nu^{11}\, \nu^{22}}$ is a type of correlation coefficient for the relevant elements of ν^{-1}, so its value determines the degree of complementarity between marijuana and tobacco where complementarity refers to the interaction in the utility function. For details, see Clements et al. (2005).

FIGURE 9.1

SIMULATED SLUTSKY PRICE ELASTICITIES

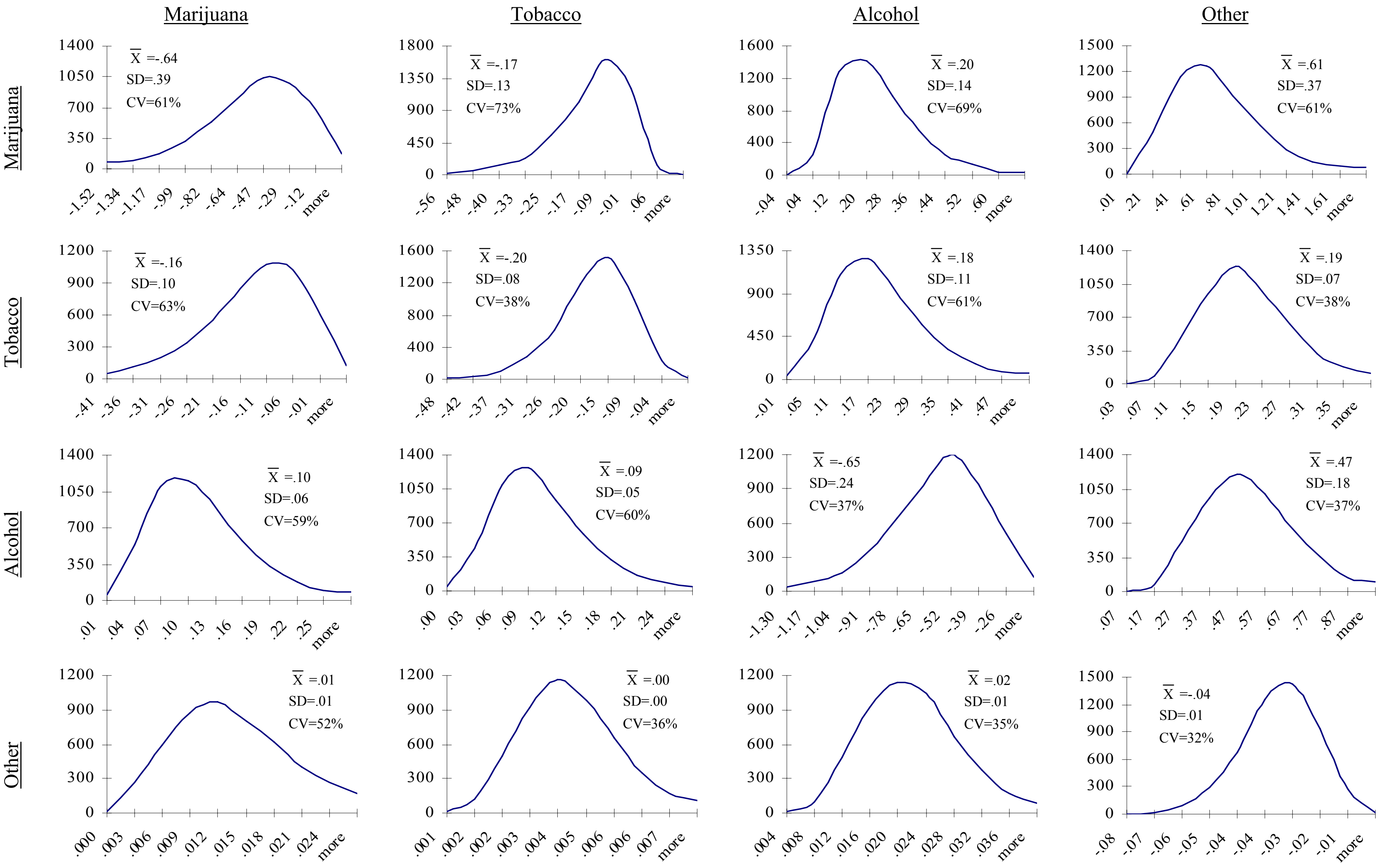
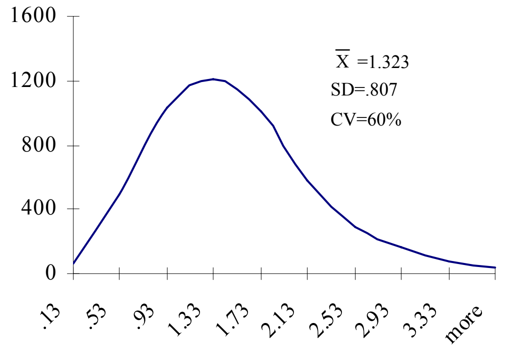
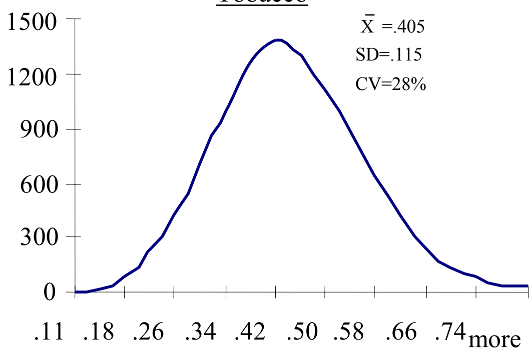


FIGURE 9.2
SIMULATED INCOME ELASTICITIES

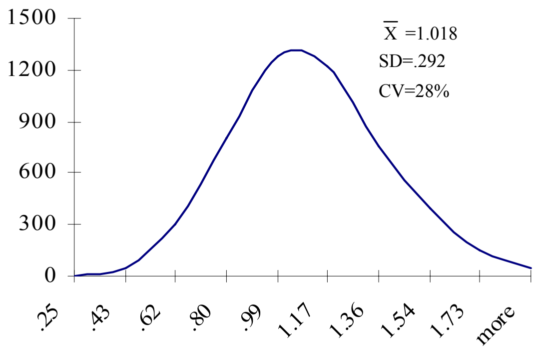
Marijuana



Tobacco



Alcohol



Other

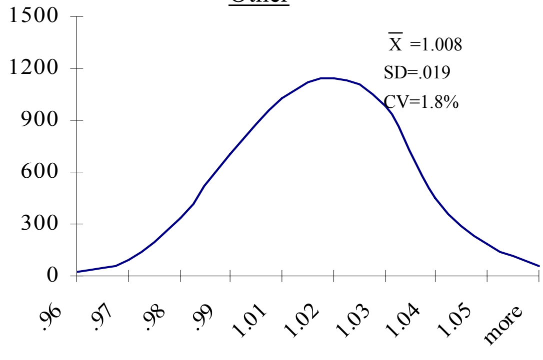


FIGURE 9.3

THE MARIJUANA DEMAND CURVE
(Mean over 5,000 trials)

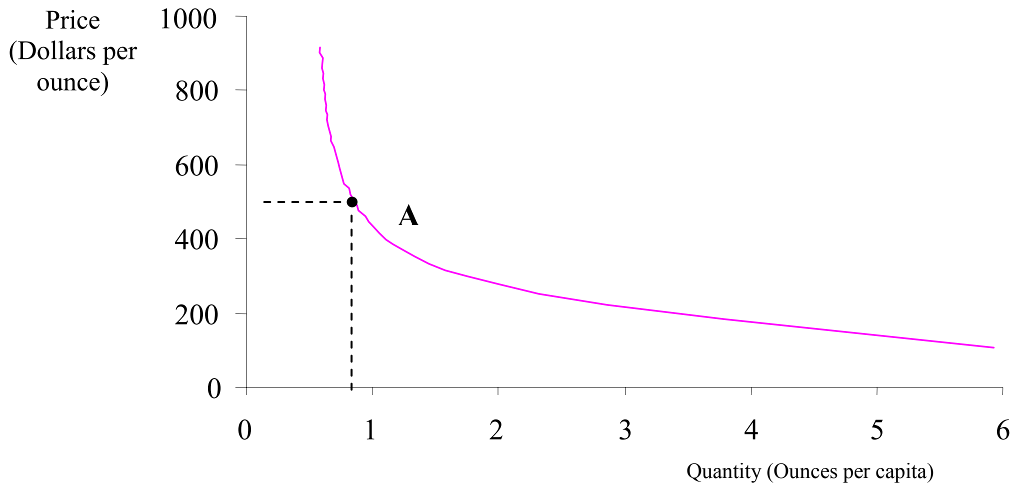


FIGURE 9.4

THE UNCERTAINTY OF THE DEMAND CURVE

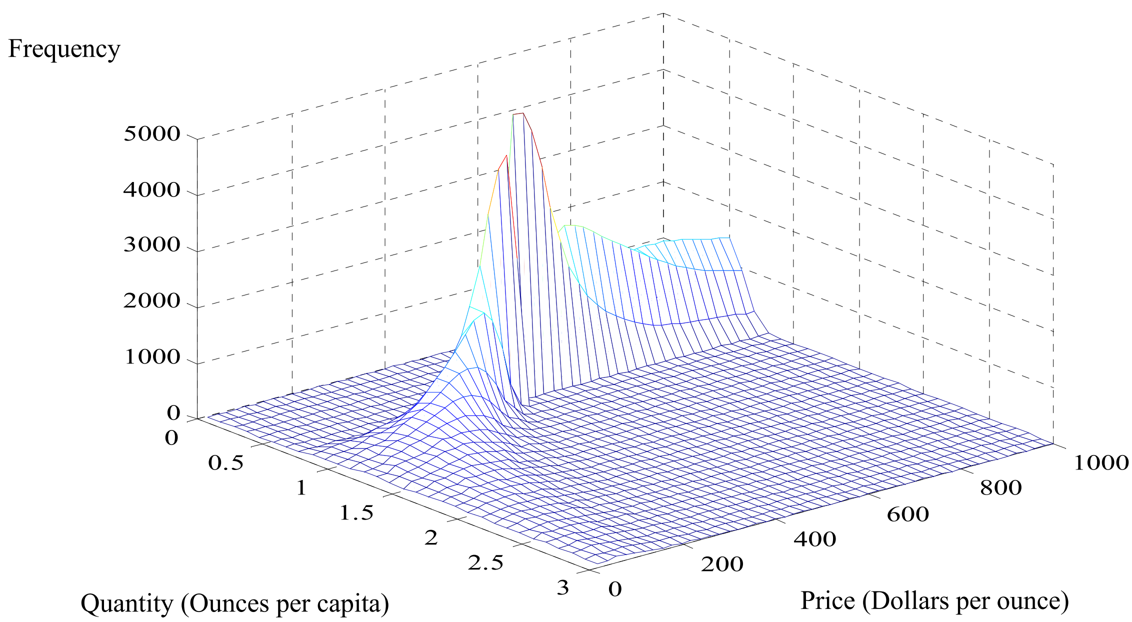
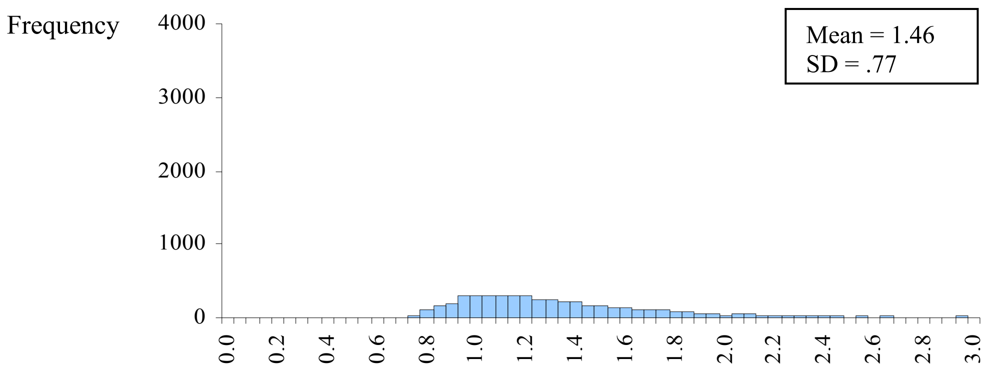


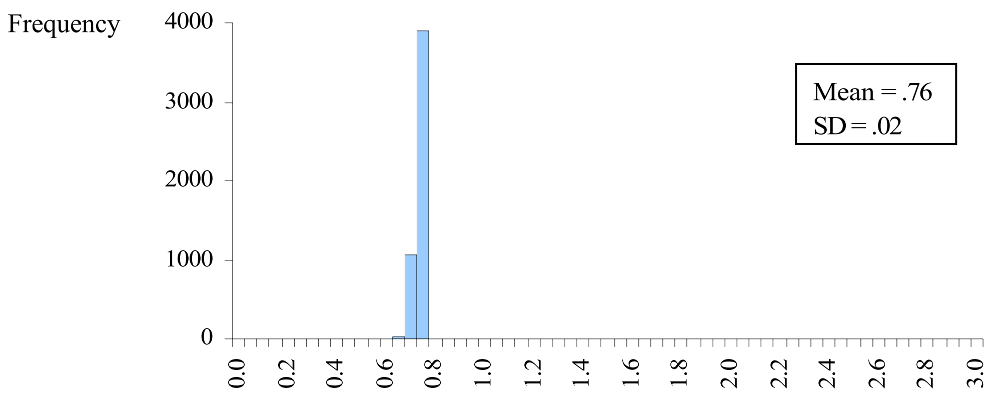
FIGURE 9.5

CONDITIONAL DISTRIBUTION OF MARIJUANA CONSUMPTION
(Ounces per capita)

A. Marijuana price = $200



B. Marijuana price = $500



C. Marijuana price = $800

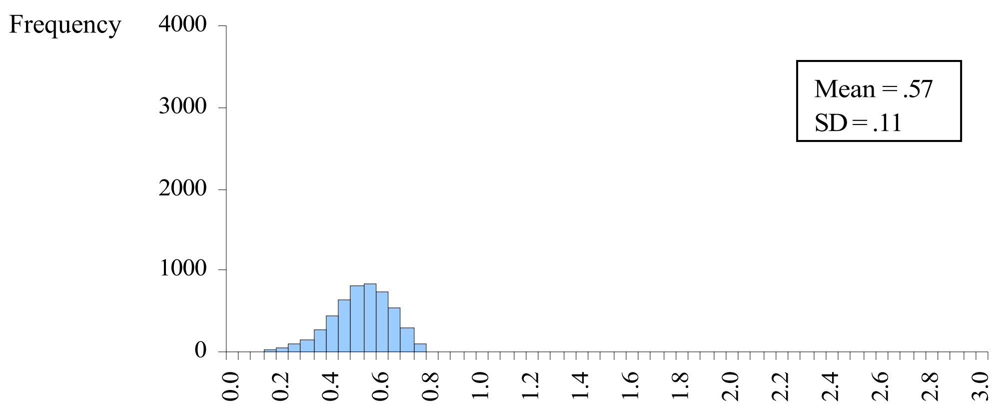


TABLE 9.2

TAXATION AND CONSUMPTION OF VICE

Variable (1)	Marijuana (2)	Tobacco (3)	Alcohol (4)	Total (5)
1. Consumption expenditure (Dollars per capita)	372	597	879	1,848
2. Tax rate (Percent of consumer price)	0	54.3	41.0	-
3. Tax revenue (Dollars per capita)	0	324	360	684

Notes:
1. Consumption expenditure refers to the year 1998 and is from Clements et al. (2005).
2. The tax rate for tobacco is derived from excise and customs revenue published in the Australian Institute of Health and Welfare Statistics on Drug Use in Australia 2002, Tables 2.5 and 2.6, as well as consumption data from the Australian Bureau of Statistics Cat. No. 5206.0
3. The tax rate for alcohol is derived from Selvanathan and Selvanathan (2005a) as follows. In their Table 11.12 (page 319), the Selvanathans report for Australia the following taxes (as percentages of consumer prices): Beer 43 percent, wine 23 percent and spirits 55 percent. The corresponding conditional budget shares ($\times 100$) for 1998, from Clements et al. (2005), are 55, 23 and 22 (in the same order). Thus a budget-share weighted average tax rate for alcohol as a whole is $.55 \times 43 + .23 \times 23 + .22 \times 55 = 41$ percent, as reported in row 2 of column 4 above.
4. Tax revenue is the product of the corresponding tax rate and consumption expenditure.
5. Population, used to convert to per capita, refers to those aged 14 years and over.

TABLE 9.3

REVENUE FROM TAXING MARIJUANA

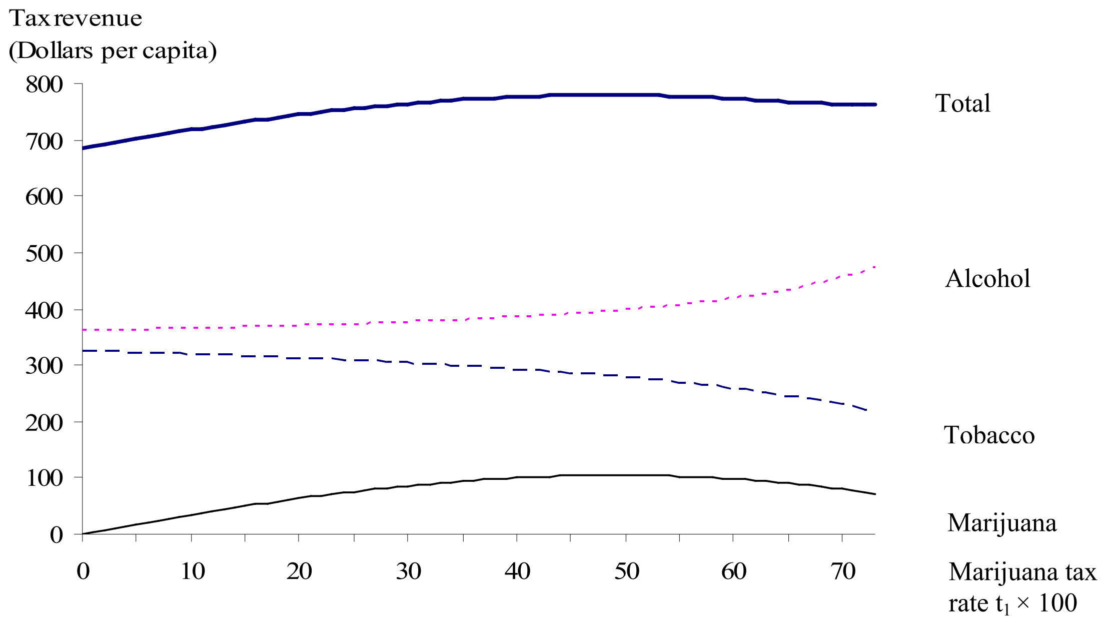
Marijuana tax rate $t_1 \times 100$	Tax revenue (dollars per capita)			
	Marijuana	Tobacco	Alcohol	Total vice
(1)	(2)	(3)	(4)	(5)
0	0 -	324 -	360 -	684 -
10	35 (1)	318 (4)	364 (2)	717 (3)
20	64 (6)	311 (8)	369 (5)	744 (8)
30	86 (13)	303 (13)	376 (9)	764 (15)
40	100 (23)	292 (19)	385 (15)	776 (25)
50	105 (34)	277 (27)	397 (23)	779 (36)
60	98 (46)	257 (37)	418 (37)	773 (46)
70	79 (54)	228 (50)	455 (65)	763 (52)

Note: The elements in the table are the means over the 5,000 trials and the corresponding standard deviations are in parentheses.

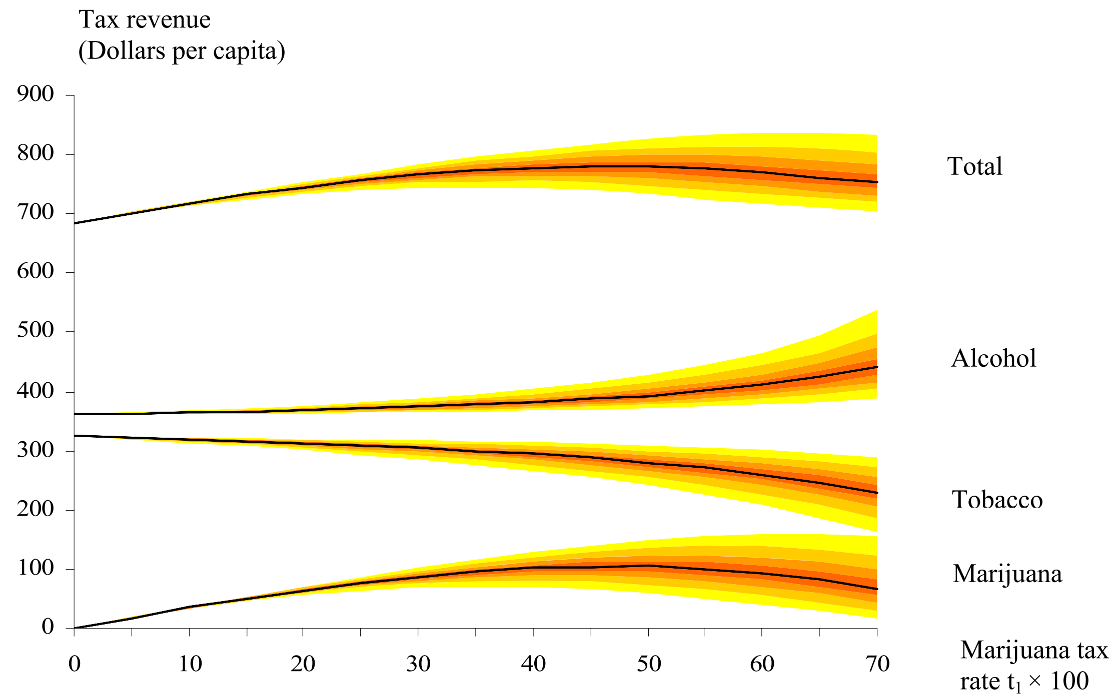
Figure 9.6

THE MARIJUANA LAFFER CURVE

A. Taxation Revenues



B. The Uncertainty of Taxation Revenues

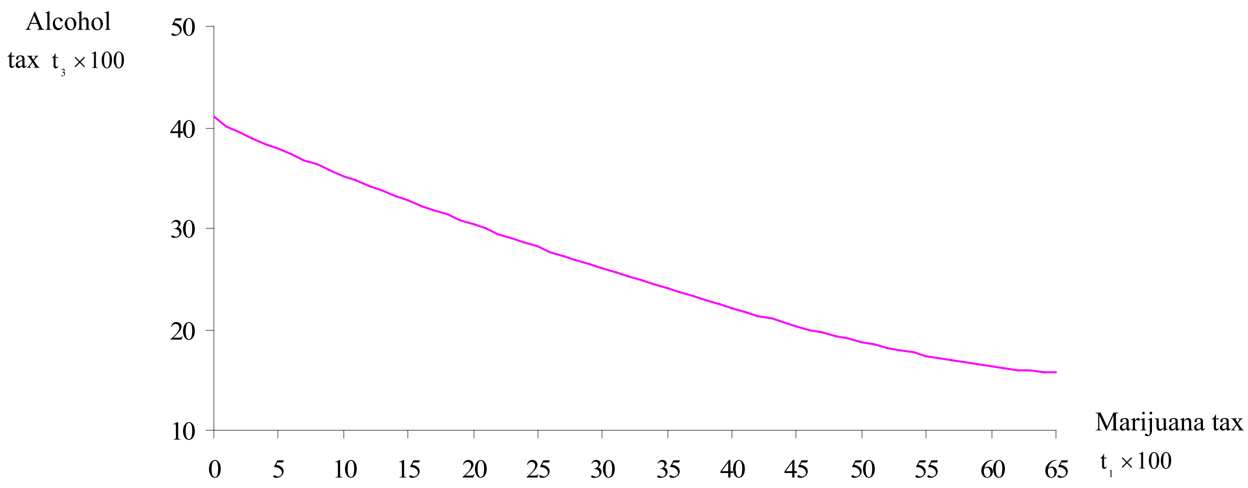


Note: Panel A plots the means over the 5,000 trials. In Panel B, the boundaries of the fan chart are the 10, 20, …, 90 percentiles of the distribution of tax revenues from the simulation, so that the solid lines are the medians, instead of the means as in Panel A.

FIGURE 9.7

THE ALCOHOL-MARIJUANA TAX TRADEOFF
(Means over 5,000 trials)

A. The Tradeoff



B. The Slope of the Tradeoff

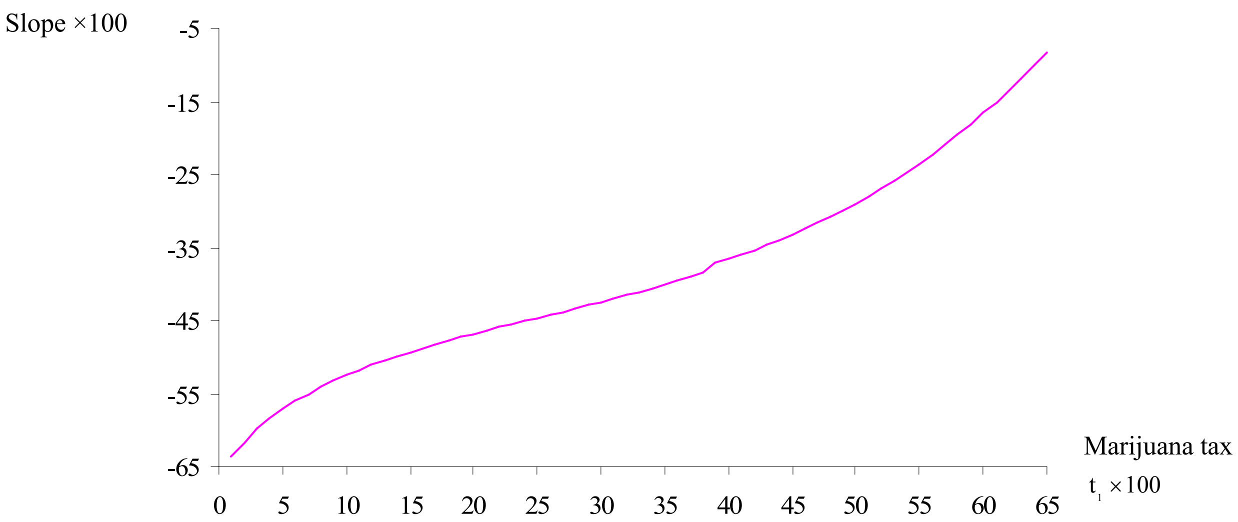
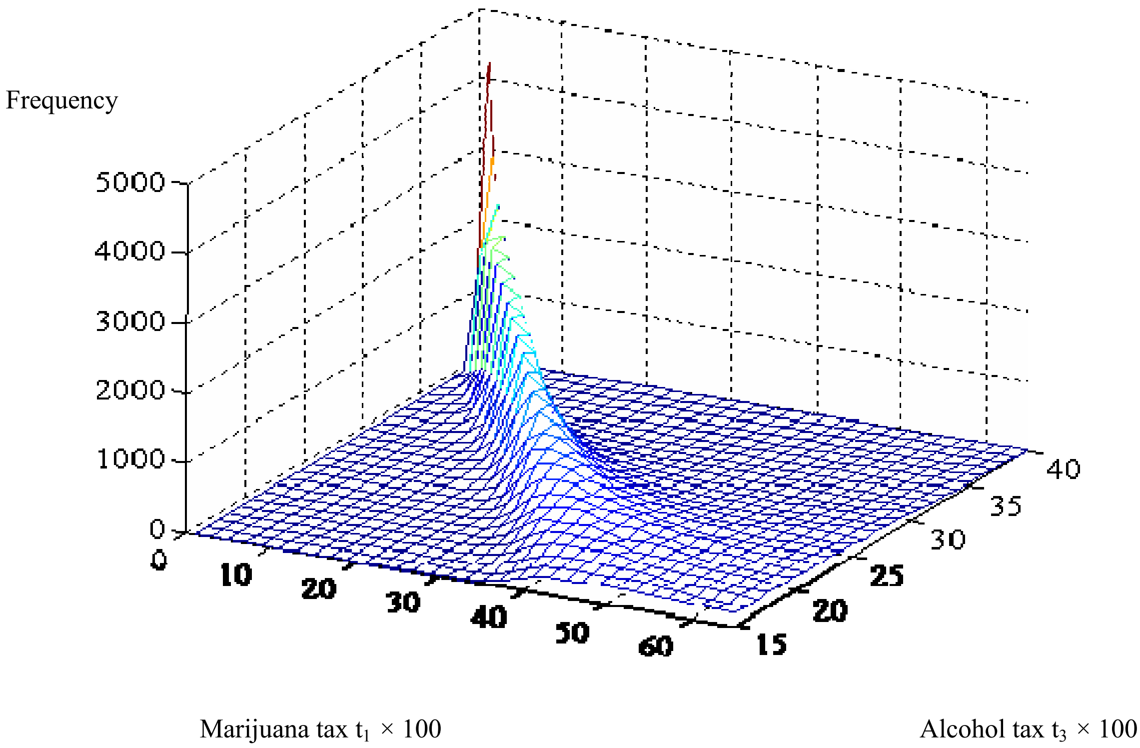


FIGURE 9.8

THE UNCERTAINTY OF THE TRADEOFF

A. The Tradeoff



B. The Slope of the Tradeoff

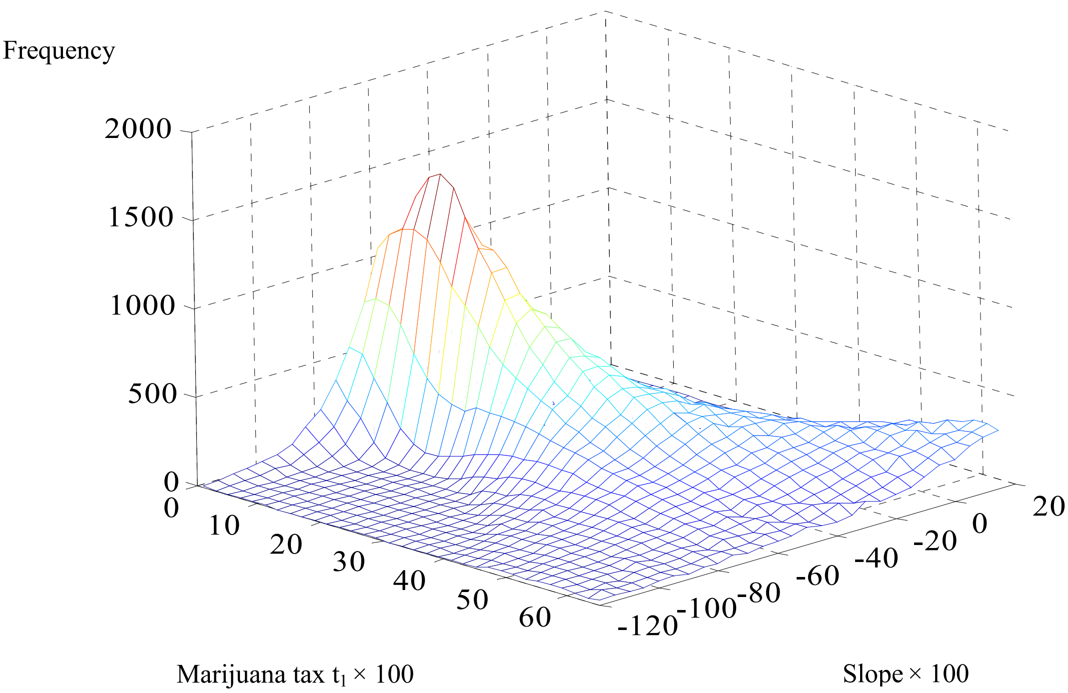
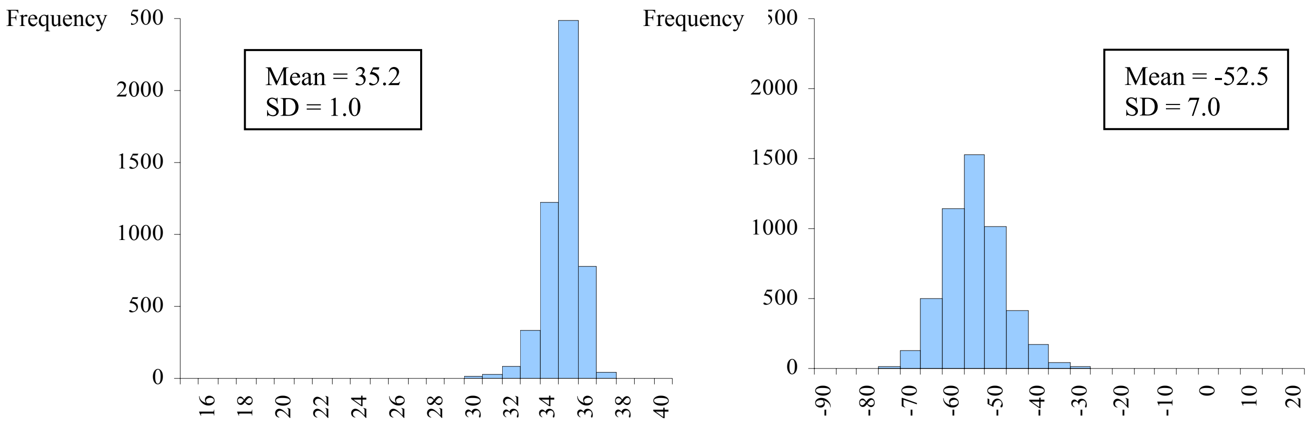


FIGURE 9.9

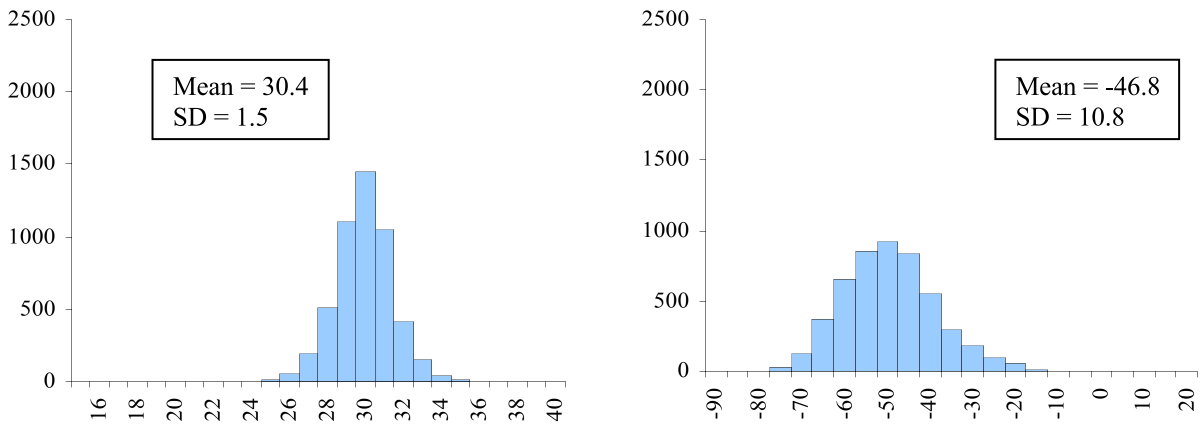
CONDITIONAL DISTRIBUTION OF ALCOHOL TAX AND SLOPE OF TRADEOFF

Alcohol tax rate × 100 | Slope of tradeoff × 100

A. Marijuana tax rate × 100 = 10%



B. Marijuana tax rate × 100 = 20%



C. Marijuana tax rate × 100 = 30%

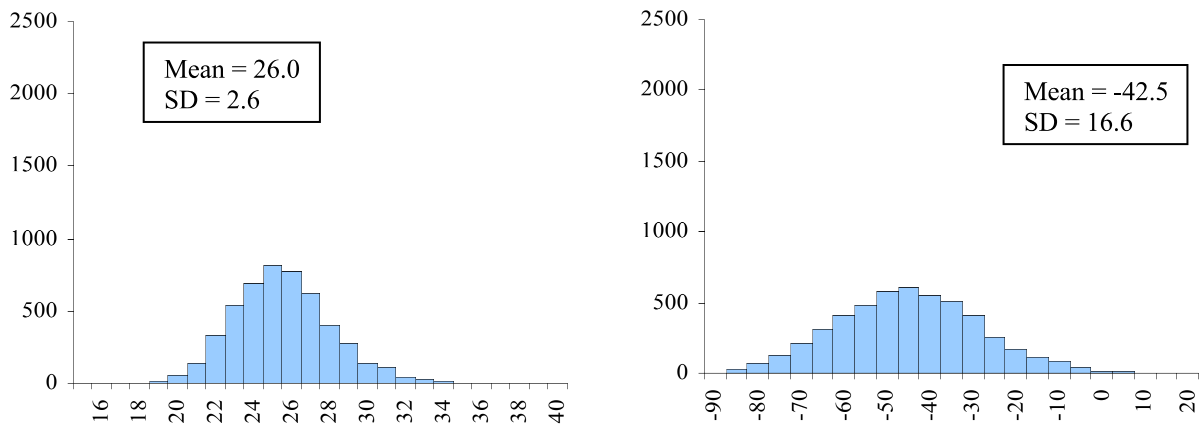


TABLE 10.1

HOW DIFFERENT IS MARIJUANA?

Economic dimension of marijuana	Comparison with other products	
	Similarity	Difference
1. Pricing		
1.1 Quantity discounts	Similar to other products	
1.2 Regional differences	Similar to housing	More than income
1.3 Changes over time		More than many other primary products
2. Price sensitivity of consumption	Similar to other products	
3. Taxation		Currently tax free, but has substantial revenue-raising potential
4. Externalities	Similar to alcohol? Tobacco?	
5. Legal status	Other illicit drugs	