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THREE FACTS ABOUT MARIJUANA PRICES

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by

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Abstract

Australians are among the largest consumers of marijuana in the world, and estimates show that their expenditure on marijuana is about twice that on wine. In this paper we analyse the evolution of marijuana prices in Australia and show that they have declined in real terms by almost 40 percent over the last decade. This decline is far above that experienced by most agricultural products. Why has this occurred and what are the implications? The extensive adoption of hydroponic techniques in growing marijuana is likely to have enhanced productivity, with the benefits passed onto consumers in the form of lower prices. We find patterns in the prices that divide the country into three broad regions: (i) Sydney, where prices are highest; (ii) Melbourne and Canberra, which have somewhat lower prices; and (iii) everywhere else, where marijuana is cheapest. We also find that marijuana prices seem to be (positively) related to real estate prices. A further finding is that the price declines have stimulated marijuana consumption by about 15 percent, inhibited drinking (marijuana and alcohol being substitutes) and led to an increase in the real incomes of users in excess of \$1 billion p. a.

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1. Introduction

Productivity enhancement has been primarily responsible for the long-term decline in the prices of many agricultural products. Higher productivity, together with Engel's law, has led to average annual price declines of these goods of the order of 1-2 percent. In large measure, this is part of the return to successful research and development (R&D) activities financed by the public and private sectors. In this paper we demonstrate that a similar process seems to have operated with a product that receives no R&D support from the public sector, marijuana. But there is one important difference: Marijuana prices have declined much more rapidly than those of most other agricultural products -- by about 5 percent p. a. in real terms. This apparently exceptional behaviour of marijuana prices raises fundamental questions about what constitute "good" R&D practice. As marijuana is an illicit good, information about new production techniques would not seem to be as freely available as it is for other products, and the patenting of product-specific innovations would not be possible. In a similar vein, the publication of results would be problematic for research dealing with the production of an illicit good.¹ Finally, research offering the possibility of improved productivity of an illicit good would not be eligible to attract public subsidies.

Research on the behaviour of marijuana prices is also of interest due to the widespread use of the product. Surveys indicate that in some countries up to one third of the adult population have used marijuana and in Australia, one of world's biggest consumers, over 40 percent of people favour its decriminalisation (see Clements and Daryal, 1999, for details). Expenditure on marijuana by Australians has been estimated to be about twice that on wine (Clements and Daryal, 1999). To what extent has the decline in marijuana prices been responsible for the high level of consumption? By how much have real incomes of users increased as a result of lower prices? If marijuana consumption were legalised, should it be taxed to correct any negative externalities and to raise revenue?

¹ There are of course exceptions to this general rule, such as research on the use of hydroponic techniques for growing vegetables and horticultural products that could possibly be applied to growing marijuana. In this case, research on the legal and illicit products are good substitutes for each other.

In this paper we argue that there are three defining characteristics of the behaviour of marijuana prices, which we refer to as “three facts”:

- There seems to exist regional markets for marijuana, rather than one national market. Prices are substantially more expensive in the Sydney market, followed by Melbourne and Canberra, and then the rest of Australia. Interestingly, this pattern of marijuana prices seems to be correlated with housing prices.
- The real price of marijuana has fallen by almost 40 percent over the 1990s in Australia. As indicated above, this fall is much more than that of most agricultural products. We argue that the widespread adoption of hydroponic techniques of production is likely to have enhanced productivity; and the benefits of this boost to productivity have been passed onto users in the form of lower prices.
- Lower prices have stimulated consumption by about 15 percent. Over the 90s, on average the price of an ounce of marijuana declined by about \$100; as consumption is estimated to be about .8 oz per capita p. a., this price decline has led to an annual increase in users’ real income of about \$80 per capita, which roughly translates to more than \$1,000m p. a. in the aggregate.

The next section of the paper provides information regarding the data on marijuana prices. Section 3 deals with the identification of regional markets of marijuana. The substantial decline in prices is analysed in some depth in Section 4 and compared to the behaviour of the prices of other commodities, including internationally-traded agricultural goods and nontraded goods. Section 5 provides some estimates of the extent to which lower prices have encouraged marijuana usage and discouraged the consumption of a substitute product, alcohol. That section also contains an analysis of the impacts of the price decline on the real incomes of users. Section 6 contains some concluding comments.

2. The Data²

The data on Australian marijuana prices were generously supplied by Mark Hazell, of the Australian Bureau of Criminal Intelligence (ABCI). These prices were collected by law enforcement agencies in the various states 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”, as these products are the most popular. The data are described by ABCI (1996) who discuss some difficulties with them regarding different recording practices used by the various agencies and missing observations.

The prices are usually recorded in the form of ranges and the basic data are listed in Clements and Daryal (2001). The data are “consolidated” by: (i) Using the mid-point of each price range; (ii) converting all gram prices to ounces by multiplying by 28; and (iii) annualising the data by averaging the quarterly or semi-annual observations. Plotting the data revealed several outliers which probably reflect some of the above-mentioned recording problems. Observations are treated as outliers if they are either less than one-half of the mean for the corresponding state, or greater than twice the mean. These observations are omitted and replaced with the relevant means, based on the remaining observations. The data, after consolidation and editing, for each state and territory are given in Tables 1 and 2 for leaf and heads, purchased in the form of grams and ounces. Columns 2-5 of Table 3 give the corresponding Australian prices (defined as population-weighted means of the state prices), while column 6 gives a weighted mean of the four prices. This is a weighted geometric mean, with weights reflecting the relative importance of the products in consumption; see Clements (2002) for full details. In Figure 1 we plot the Australian average price and as can be seen, it exhibits a substantial decline over the 1990s, starting off at \$577 per ounce in 1990 and ending up nine years later in 1999 23 percent lower at \$442. More will be said about this decline later in Section 4.³

² This section draws heavily on Clements and Daryal (2001).

³ Note that the internal relative prices of the four types of marijuana have changed quite substantially over the period. On average, the relative price of leaf/gram increased by 4 percent p.a., head/gram decreased by 1 percent, leaf/ounce increased by 1 percent and head/ounce declined by 1 percent. For details, see Clements (2002).

TABLE 1
MARIJUANA PRICES: LEAF
(Dollars per ounce)

Year	NSW	VIC	QLD	WA	SA	NT	TAS	ACT	Weighted mean
<u>Purchased in the form of a gram</u>									
1990	770	735	700	802	700	700	910	630	747
1991	1,050	770	700	770	700	700	1,050	642	852
1992	1,060	700	630	700	560	700	700	630	798
1993	583	711	683	653	630	665	613	595	645
1994	998	698	648	700	630	665	443	753	779
1995	1,085	700	560	700	630	735	560	753	797
1996	1,400	793	665	753	630	788	508	700	949
1997	1,400	490	560	653	630	718	525	613	843
1998	1,097	735	630	467	653	683	467	723	798
1999	1,155	636	700	556	630	700	642	700	816
Mean	1,060	697	648	675	639	705	642	674	802
<u>Purchased in the form of an ounce</u>									
1990	438	513	225	210	388	275	313	413	390
1991	475	450	215	170	400	275	350	325	381
1992	362	363	188	340	225	300	188	350	313
1993	383	409	168	200	388	281	175	250	326
1994	419	394	181	288	325	244	170	400	341
1995	319	400	400	308	347	294	163	256	350
1996	325	383	350	283	350	263	200	408	339
1997	288	285	431	263	350	288	375	386	320
1998	333	363	375	250	350	300	375	450	344
1999	275	313	444	250	350	300	262	450	322
Mean	362	387	298	256	347	282	257	369	343

3. Fact 1: Marijuana is Expensive in New South Wales

Is the market for marijuana a nationally-organised activity, or is it merely a “cottage industry” that just satisfies local demand? To put it another way, is marijuana a (nationally) traded good, or is it nontraded? If there were a national market for marijuana, then after appropriate allowance for transport costs etc., prices

TABLE 2
MARIJUANA PRICES: HEADS
(Dollars per ounce)

Year	NSW	VIC	QLD	WA	SA	NT	TAS	ACT	Weighted mean
<u>Purchased in the form of a gram</u>									
1990	1,120	1,050	1,400	1,120	1,400	700	910	840	1,159
1991	1,120	1,120	1,400	962	1,400	700	1,120	840	1,168
1992	1,400	1,120	910	770	700	700	1,225	770	1,103
1993	863	665	858	840	1,173	700	927	747	834
1994	1,155	770	1,068	840	1,120	770	735	980	992
1995	1,190	793	843	749	1,138	793	1,155	1,033	974
1996	1,171	840	771	704	910	840	963	1,400	944
1997	1,400	858	630	700	840	863	700	793	977
1998	1,120	840	723	630	840	823	723	840	889
1999	1,224	630	589	560	840	840	630	1,006	841
Mean	1,176	869	919	788	1,036	773	909	925	988
<u>Purchased in the form of an ounce</u>									
1990	600	650	413	600	400	325	525	463	557
1991	600	550	425	502	200	325	450	375	504
1992	375	450	388	390	363	450	425	500	401
1993	500	348	363	431	450	363	344	383	419
1994	550	367	328	400	425	325	363	550	432
1995	538	400	320	354	438	358	350	438	430
1996	550	400	398	325	406	283	388	525	444
1997	550	400	538	300	400	358	383	442	466
1998	488	388	550	275	340	325	367	450	437
1999	513	400	300	250	400	300	325	479	403
Mean	526	435	402	383	382	341	392	461	449

should be more or less equalised across states and territories. This section investigates these issues.

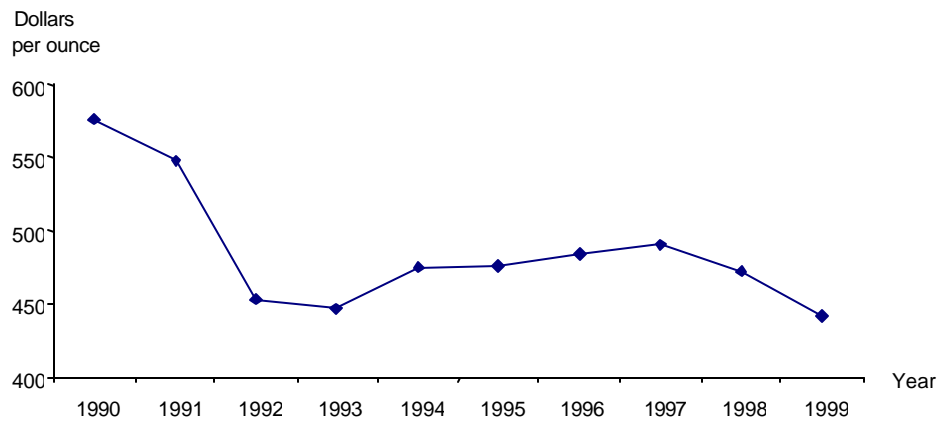
South Australia decriminalised marijuana in 1987 and recent media reports have focused on Adelaide as the centre of the marijuana industry. Radio National (1999) presented a Background Briefing entitled “Adelaide -- Cannabis Capital” and stated:

TABLE 3
MARIJUANA PRICES, AUSTRALIA
(Dollars per ounce)

Year	Purchased in the form of a				Total (Weighted mean)
	Gram		Ounce		
	Leaf	Heads	Leaf	Heads	
(1)	(2)	(3)	(4)	(5)	(6)
1990	747	1,159	390	557	577
1991	852	1,168	381	504	547
1992	798	1,103	313	401	454
1993	645	834	326	419	446
1994	779	992	341	432	475
1995	797	974	350	430	476
1996	949	944	339	444	484
1997	843	977	320	466	489
1998	798	889	344	437	473
1999	816	841	322	403	442
Mean	802	988	343	449	486

Note: The weighted mean, given in column 6, employs the following product weights: leaf/gram .06, leaf/ounce .24, head/gram .14 and head/ounce .56. For details, see Clements (2002).

FIGURE 1
MARIJUANA PRICE INDEX



“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, a front-page story in The Weekend Australian (Williams, 2002) refers to South Australian police saying that marijuana production involves

“...a sophisticated network...in which crops are grown hydroponically in suburban homes, pooled and shipped interstate in an industry worth \$60 million a year.”

The article goes on to describe the industry in the following terms:

“It is a complete web of organised crime, set up with equipment from a string of legal businesses that have flourished under the state’s liberal cannabis laws which, until recently, allowed 10 plants to be grown for ‘personal use’ with no penalty but a \$150 on-the-spot fine.

In 1990, Adelaide had three hydroponic stores. There were 52 in 2000 and 96 by last year, according to police.

Police say at least two bkie gangs run hydroponic chains, often supplying up to \$10,000 worth of equipment free in return for a cut of the crop.”

Finally, the Australian Bureau of Criminal Intelligence (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.

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...”

As the above considerations point to Adelaide being a major exporter of marijuana to other parts of Australia, this would seem to imply that the market is a national, not local, one. In turn, this would mean that marijuana prices would tend to be equalised across Australia if, as seems reasonable, transport and differences in other distribution costs were relatively minor. The validity of this hypothesis can be examined with our regional-level data and Panel I of Table 4 gives the results of regressing the prices on dummy variables for each state and territory. As NSW is used as the base, there are seven dummy variable coefficients for each of the four products. Only two of these $7 \times 4 = 28$ 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 significant, which says that marijuana prices are significantly lower in all other regions relative to NSW. Panel II of Table 4 transforms the estimated coefficients into percentage differences. As it is convenient to summarise the results for the prices of the four products in terms of one number, the last column in the table gives the weighted mean difference for each region, with the weights reflecting the relative importance of each type of marijuana in overall consumption. This column reveals that NT is the cheapest region with marijuana costing 32 percent less than that in NSW. Then comes WA (30 percent less), Tasmania (28 percent), Queensland (25 percent), SA (21 percent), Victoria (14 percent) and, finally, ACT (12 percent).

Taken as a whole, the results of Table 4 could be interpreted as saying that Australia can be divided into three “super regions”:

TABLE 4
ESTIMATES OF MARIJUANA PRICE EQUATIONS

$$\log p_{rt} = a + \sum_{u=2}^8 \beta_u z_{rtu} + e_{rt}$$

(t-values in parentheses)

Coefficient	Product								Total (wtd mean)
	Leaf				Heads				
	Gram		Ounce		Gram		Ounce		
<u>I. Coefficients</u>									
α NSW	6.938	(134.6)	5.876	(77.7)	7.060	(108.3)	6.259	(106.0)	-
β_u VIC	-39.80	(-5.46)	7.00	(.654)	-31.10	(-3.37)	-20.10	(-2.41)	-
QLD	-46.70	(-6.41)	-24.60	(-2.30)	-28.00	(-3.04)	-28.20	(-3.37)	-
WA	-43.40	(-5.95)	-34.90	(-3.26)	-40.90	(-4.44)	-34.50	(-4.13)	-
SA	-47.70	(-6.54)	-3.60	(-.336)	-14.40	(-1.56)	-33.50	(-4.01)	-
NT	-38.00	(-5.21)	-23.70	(-2.22)	-41.40	(-4.49)	-43.60	(-5.22)	-
TAS	-51.20	(-7.02)	-37.90	(-3.54)	-27.40	(-2.97)	-29.80	(-3.57)	-
ACT	-42.90	(-5.89)	1.40	(.131)	-24.80	(-2.69)	-13.40	(-1.60)	-
\bar{R}^2	.440		.284		.230		.281		
<u>II. Transformed coefficients</u>									
Price in NSW (\$/oz)	1030.7		356.4		1,164.4		522.7		603.1
Percentage difference from NSW price									
VIC	-32.83		7.25		-26.73		-18.21		-14.17
QLD	-37.31		-21.81		-24.42		-24.57		-24.65
WA	-35.21		-29.46		-33.57		-29.18		-30.22
SA	-37.94		-3.54		-13.41		-28.47		-20.95
NT	-31.61		-21.10		-33.90		-35.34		-31.50
TAS	-40.07		-31.55		-23.97		-25.77		-27.76
ACT	-34.88		1.41		-21.96		-12.54		-11.85

- Notes:
1. The variable p_{rt} is the price of the relevant type of marijuana in region r ($r=1, \dots, 8$) and year t ; and $z_{rtu} = 1$ if $u=r$, 0 otherwise.
 2. The estimated β_u coefficients in Panel I are to be divided by 100.
 3. In Panel II, the estimated price in NSW is computed as $\exp(\alpha)$; and the percentage difference of the price in state u from that in NSW is computed as $100 \times \{\exp(\beta_u) - 1\}$.
 4. The weights used in the last column are given in the note to Table 3.

1. NSW -- expensive marijuana.
2. Victoria and ACT -- moderately-priced marijuana.
3. The rest -- cheap marijuana.

While there is scope for debate regarding where the regional boundaries should be drawn, it is clear from the significance of the regional dummies in Table 4 that 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 30 percent? While such a transaction is certainly not risk free, is it plausible for the risk premium to be more than 30 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? One admittedly imperfect measure of the cost of living is the price of housing in the location. Table 5 analyses differences in housing prices in capital cities over the 1990s.⁴ The last column of the table, which gives the percentage differences relative to housing prices of Sydney, can be directly compared with the marijuana prices of the last column of Table 4. As can be seen, although the ranking of regions for marijuana prices is not exactly the same as that of the corresponding cities for housing prices, the two sets of prices are clearly positively correlated.

The comparison of prices for marijuana and housing is facilitated in Figure 2 which plots the two sets of prices relative to NSW/Sydney. The broken ray from the origin has a slope of 45⁰ and as the scales of both axes are inverted, the vertical distance between this line and any point measures the difference in the housing-marijuana relative price between the city/region in question and that in Sydney. This relative price is thus higher for Darwin,

⁴ These data were generously provided by David Wesney, Manager, Research and Statistics, REIA, Canberra. The data take the form of quarterly median sale prices of established houses and units (where the latter include flats, units and townhouses) for the period 1990-99. The quarterly data are then annualised by averaging.

TABLE 5
ESTIMATES OF HOUSING PRICE EQUATIONS

$$\log p_{rt} = a + \sum_{u=2}^8 \beta_u z_{rtu} + e_{rtu}$$

(t-values in parentheses)

Coefficient	Type of housing		Total (Weighted mean)
	Houses	Units	
<u>I. Coefficients</u>			
α Sydney	5.33	(120.3)	5.11 (115.4)
β_u Melbourne	-26.94	(-4.30)	-30.80 (-4.92)
Brisbane	-47.24	(-7.54)	-38.95 (-6.22)
Perth	-55.03	(-8.78)	-65.50 (-10.46)
Adelaide	-60.63	(-9.68)	-61.85 (-9.87)
Darwin	-33.36	(-5.32)	-37.39 (-5.97)
Hobart	-70.02	(-11.18)	-72.48 (-11.57)
Canberra	-31.72	(-5.06)	-31.42 (-5.02)
\bar{R}^2	.683		.709
<u>II. Transformed coefficients</u>			
Price in Sydney (\$'000)	206.6		165.7
Percentage difference from Sydney price			
Melbourne	-23.62	-26.51	-24.34
Brisbane	-37.65	-32.26	-36.30
Perth	-42.32	-48.06	-43.76
Adelaide	-45.46	-46.12	-45.63
Darwin	-28.37	-31.20	-29.08
Hobart	-50.35	-51.56	-50.65
Canberra	-27.18	-26.96	-27.13

- Notes:
1. The variable p_{rt} is the price of the relevant type of housing in city r ($r = 1, \dots, 8$) and year t ; $z_{rtu} = 1$ if $u = r$, 0 otherwise.
 2. The estimated β_u coefficients in Panel I are to be divided by 100.
 3. In Panel II, the estimated price in Sydney is computed as $\exp(\alpha)$; and the percentage difference of the price in state u from that in Sydney is computed as $100 \times \{\exp(\beta_u) - 1\}$.
 4. The weights used in the last column are 0.75 for houses and 0.25 for units.

and lower for the rest. An equivalent way of interpreting the figure is to note that as along the 45⁰- line the two price changes are equal, all points on the line correspond to the elasticity of marijuana prices with respect to housing prices being equal to unity; and for the points above (below) the line the elasticity is greater than (less than) unity. Accordingly, in all cities other than Darwin this elasticity is less than unity. The solid line in Figure 2 is the least-squares regression line, constrained to pass through the origin.⁵ As can be seen, the slope of this line is positive, but substantially less than unity. The estimated elasticity is 0.61 and has a standard error of 0.07, so that the elasticity is significantly different from both unity and zero. 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. Interestingly and unexpectedly, the reverse is true for Adelaide: Among the seven non-Sydney cities, given its housing prices, marijuana would seem to be most overpriced in the “Marijuana Capital of Australia”! Of course, one could equally interpret this as just saying that housing is underpriced in the “City of Churches”.⁶ The final interesting feature of the figure is that the above three super regions defined with respect to the cost of marijuana – (i) NSW/Sydney, (ii) Victoria/Melbourne and ACT/Canberra, and (iii) the rest – also hold with respect to housing costs, as indicated by the shading in the figure.

The above discussion shows that marijuana prices are at least partially related to the cost of housing in the corresponding region. This can be interpreted as supporting the idea that the market for marijuana is not a national one, but a series of regional markets that are not too closely linked. Another interpretation is that a substantial part of the overall price of marijuana reflects local distribution activities, and housing prices are a (partial) index of these costs.⁷

⁵ As prices are all expressed in terms of percentage differences from NSW/Sydney, any fixed effects have been differenced out.

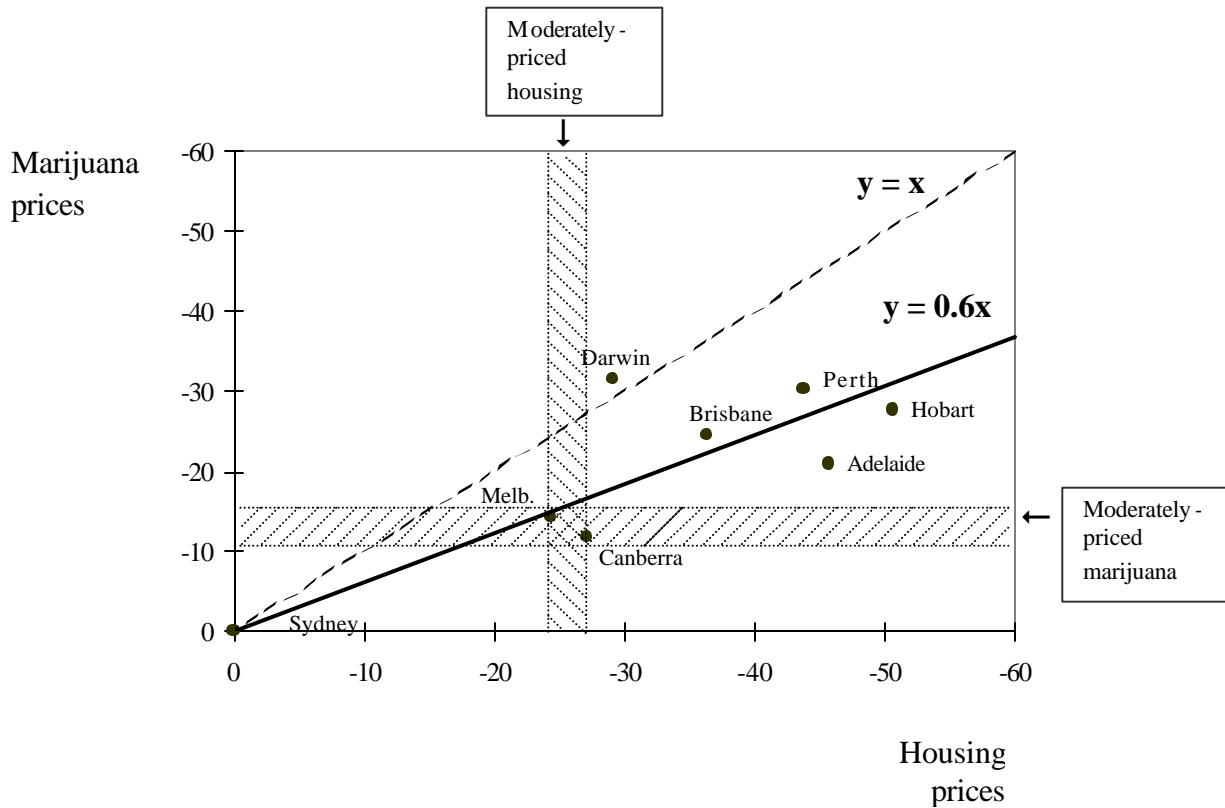
⁶ The slope of a ray from the origin to any of the seven cities in Figure 2 is the elasticity of marijuana prices with respect to housing prices for the city in question. Visually, it can be seen that this elasticity is lower for Canberra than Adelaide. But as this elasticity is the percentage change in marijuana prices for a unit percentage change in housing prices, it should not be confused with using the regression line to identify anomalies in the pricing of marijuana. The vertical distance between any observation and the regression line represents the extent of mispricing.

⁷ In Clements (2002) quarterly and semi-annual data are used to explore further the issue of regional price differences. While there are some differences in detail between the two sets of results, the overall conclusion remains that, on average, NSW is the most expensive region for marijuana in the country.

FIGURE 2

MARIJUANA AND HOUSING PRICES

(Percentage differences from Sydney; inverted scales)



4. Fact 2: Marijuana has Become Substantially Cheaper⁸

Table 6 shows that over the 1990s marijuana prices have fallen by about 23 percent in nominal terms (column 2), and 35 percent relative to the CPI (column 5). The last entries in columns 10 and 11 of this table reveal that on average over the decade, marijuana prices in terms of consumer prices fell by 4.9 percent p.a. and by 5.7 percent p.a. in terms of alcohol prices. Figure 3 plots the paths of real marijuana prices in the form of both levels and log-changes.

⁸ The first part of this section is based on Clements and Daryal (2001), except that here we use population-weighted marijuana prices.

TABLE 6

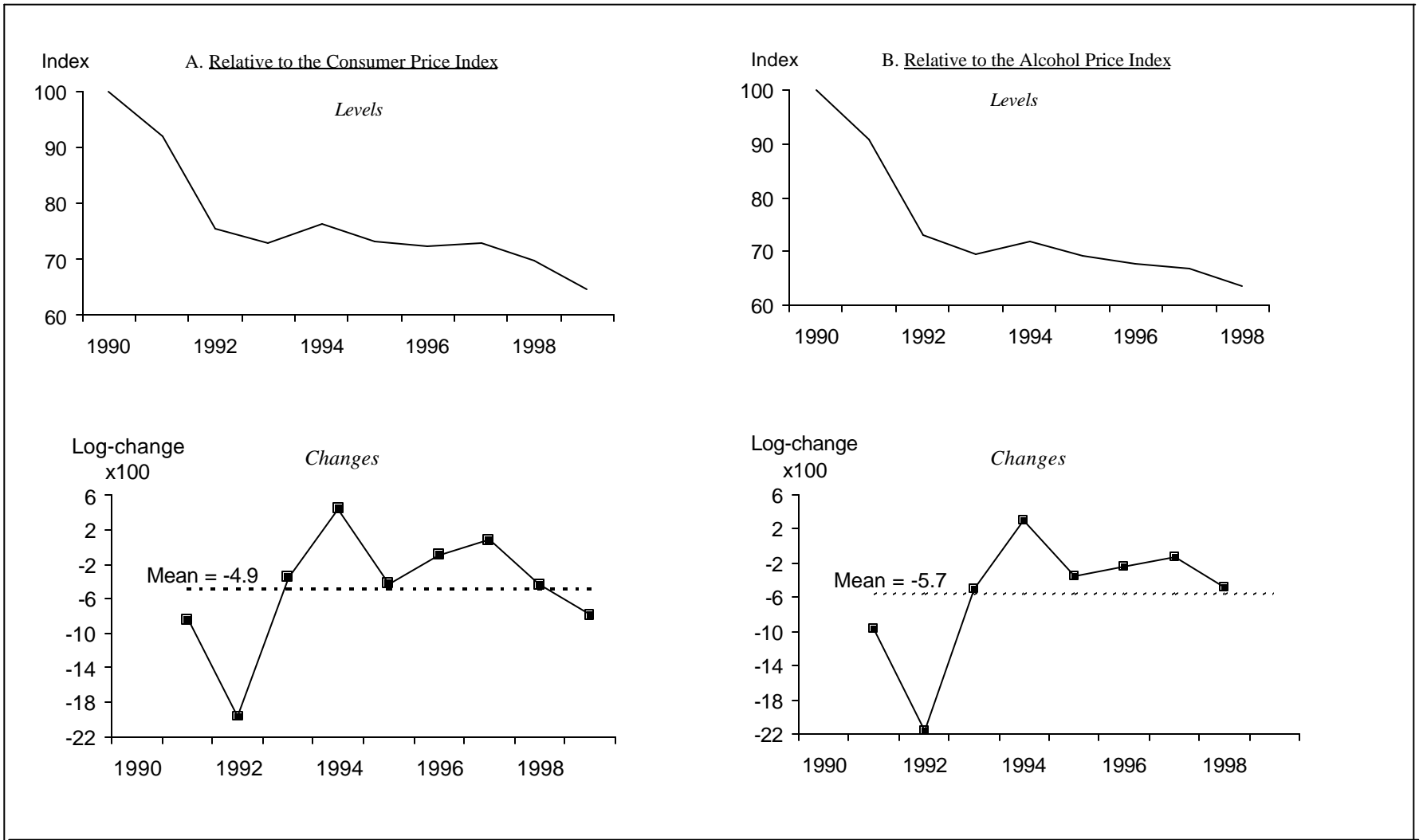
MARIJUANA, CONSUMER AND ALCOHOL PRICE INDEXES

Year	Levels					Log-changes ($\times 100$)				
	Nominal Prices			Relative Prices		Nominal Prices			Relative Prices	
	MPI	CPI	API	$\frac{\text{MPI}}{\text{CPI}}$	$\frac{\text{MPI}}{\text{API}}$	MPI	CPI	API	$\frac{\text{MPI}}{\text{CPI}}$	$\frac{\text{MPI}}{\text{API}}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1990	100.0	100.0	100.0	100.0	100.0					
1991	94.9	103.2	104.5	91.9	90.8	-5.26	3.17	4.40	-8.43	-9.66
1992	78.7	104.2	107.5	75.5	73.2	-18.71	.98	2.86	-19.70	-21.58
1993	77.3	106.1	111.1	72.8	69.6	-1.75	1.80	3.28	-3.56	-5.04
1994	82.4	108.1	114.8	76.2	71.8	6.35	1.88	3.26	4.47	3.09
1995	82.6	113.2	119.3	73.0	69.2	.25	4.53	3.85	-4.28	-3.60
1996	83.9	116.1	124.2	72.3	67.6	1.64	2.58	4.03	-.94	-2.39
1997	84.9	116.4	127.3	72.9	66.7	1.09	.25	2.43	.84	-1.34
1998	81.9	117.4	128.9	69.8	63.6	-3.51	.85	1.25	-4.36	-4.76
1999	76.6	118.7	-	64.5	-	-6.77	1.13	-	-7.87	-
Mean	-	-	-	-	-	-2.96	1.91	3.17	-4.87	-5.66

Note: MPI = marijuana price index; CPI = Consumer Price Index; and API = alcohol price index.

Sources: The MPI is from column 6 of Table 3 with 1990 = 100; the CPI is from the DX database, rebased such that 1990 = 100; and the API is a levels version of a Divisia index of the prices of beer, wine and spirits, from Clements and Daryal (1999).

FIGURE 3
RELATIVE PRICES OF MARIJUANA



Why did prices fall by so much? One reason is that the growing of marijuana has been subject to productivity enhancement by the adoption of hydroponic techniques⁹, which lead to a higher-quality product containing higher THC levels.¹⁰ For example, hydroponically-grown marijuana from northern Tasmania has been analysed as containing 16 percent of THC, while that grown outdoors in the south of the state contained 12.8 percent (Australian Bureau of Criminal Intelligence, 1996). Hydroponically-grown plants use no soil. The hydroponic system manages the plants' growth by creating an artificial climate that controls exposure to light, heat and nutrients in order to produce a better product and faster growth. Plants are grown in containers filled with a sterile growing medium -- such as gravel, sand or vermiculite -- and the nutrients, which plants normally absorb from soil, are supplied to the roots through a water-nutrient mixture. For further details of these techniques see, e.g., Asher and Edwards (1981) and Ashley's Sister (1997). The ease of concealment, and near ideal growing conditions which produce good-quality plants, are the main reasons for the shift to hydroponic systems. According to the Australian Bureau of Criminal Intelligence (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.”

The newspaper article in Box 1 reports rapid growth in the number of stores supplying hydroponic activities in the late 1990s in WA and the situation is probably not too different in other states. 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. Some indication of the nature of clientele served by these hydroponic suppliers is given by the advertisement

⁹ The word *hydroponic* means “water working”.

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.

BOX 1

TECHNICAL PROGRESS IN PLANT PRODUCTION

Suppliers Cash In – But Mum’s the Word

WA’s hydroponic store owners and suppliers estimate up to 15 percent of their business could come from marijuana growers.

But most surveyed by The West Australian said the industry had been tarnished unfairly by its association with the drug trade and denied they were making a fortune from people chancing their hand at marijuana.

The number of hydroponic stores in WA has doubled in the last two years to nearly 40 shops and there is a modest but expanding industry of about 25 large-scale commercial growers producing everything from cherry tomatoes to orchids.

Store owners and suppliers guessed that anywhere between 5 and 15 percent of sales were for growing marijuana but said there was an unwritten rule that it was never mentioned.

Shaun Reid, who runs The Highlife Company, said: “No one will say that they are doing it because it is an indictable offence. Theoretically, no one grows (hydroponic) marijuana. We get told that they are growing daffodils but you can sometimes assume otherwise.”

Mr Reid, who estimated about 10 percent of customers would use the equipment for marijuana growing, said many growers were older smokers scared of dealing with the criminal element.

North Perth’s Home Grow Shop manager Lise Bysterveld said that if a customer dropped hints that they were going to use the equipment for marijuana growing, she would try to distance herself from them. “I would say that I do not want to know that,” she said.

The industry had enormous potential for commercial vegetable, flower and herb producers, she said.

Canning Vale commercial supplier Aquaponics owner Robert Vanaurich said hydroponics accounted for more than half of the cherry tomatoes grown in WA, up from almost nil 10 years ago.

Source: The West Australian, February 6, 1999, p. 9.

in Figure 4, reproduced from X-Press Magazine, which declares itself to be “Australia’s biggest free weekly magazine”. Judging by the nature of the other advertisements (drums, guitars), this publication seems to be directed at younger people who are unlikely to have an interest in traditional gardening.

How do marijuana prices compare with those of other commodities? In an influential article, Grilli and Yang (1988) analyse the prices of 24 commodities which are traded internationally. We convert these to relative prices (using the US CPI) and then compute the average annual log-changes over the period 1914-86; for further details, see Clements (2002). Figure 5 gives the price changes for the 24 commodities plus marijuana. The striking feature of this graph is that marijuana prices have fallen the most by far. The only commodity to come 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.) There is a substantial drop off in the price declines after rubber -- 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 .9 percent p.a. Note also the minerals (aluminum, 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. Additionally, in earlier parts of the twentieth century, the area devoted to agriculture was still rising in some countries, and this would have contributed to the downward pressure on commodity prices.

What about the prices of other goods which are not traded commodities? Figure 6 presents a selection of relative prices from The Economist (2000/01). Again, these are average annual log-changes, but this time 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 technical 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).

FIGURE 4
ADVERTISEMENT FOR
HYDROPONIC EQUIPMENT

FOR SALE

DRUM KIT - 7 Pce Pearl, Paiste 2002 Cymbals & stands included. \$1800 ono Contact Dean 9341 6147 & mob 0416 208 919

GIBSON GUITAR - LES PAUL CUSTOM - Brand new never been used. \$3200 ono. Ph 9414 6618

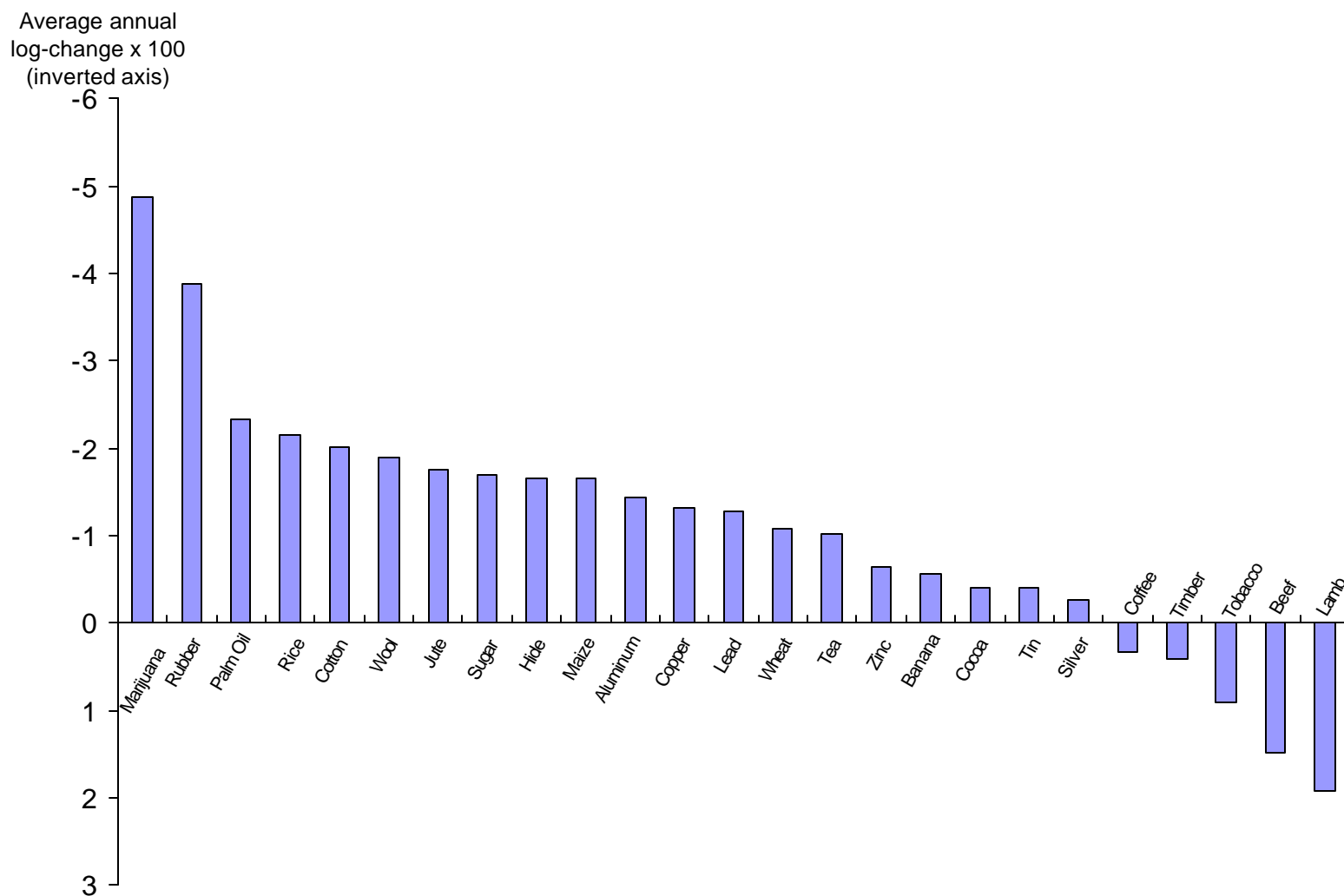
HYDRO, HYDRO, HYDRO - HPS Kits 400W \$170 600W \$240 MH100W \$330 400W HPS Bulbs \$45 Perlite & Clay \$20 bag X Rated Hormones \$35 CANNA COCO in stock! CANNA 5L A & B \$60 pH & EC meters \$75 Don't miss out! Home Grow Shop 362 Charles St N. Perth 9443 2703

Source: X-Press Magazine, 24 February, 2000. Issue No. 680, p.72.

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. 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 (x 100) of -4.24 p.a. As the real price of marijuana has an annual average log-change (x 100) of -4.87 (see column 10 of Table 6), 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 $\log(1-k) / -.0063$. It thus takes about 35 years for the price of marijuana relative to light to fall by 20 percent, which shows that this relative price is fairly constant. One interpretation is that the production of both goods has been subject to similar degrees of productivity improvement.

FIGURE 5

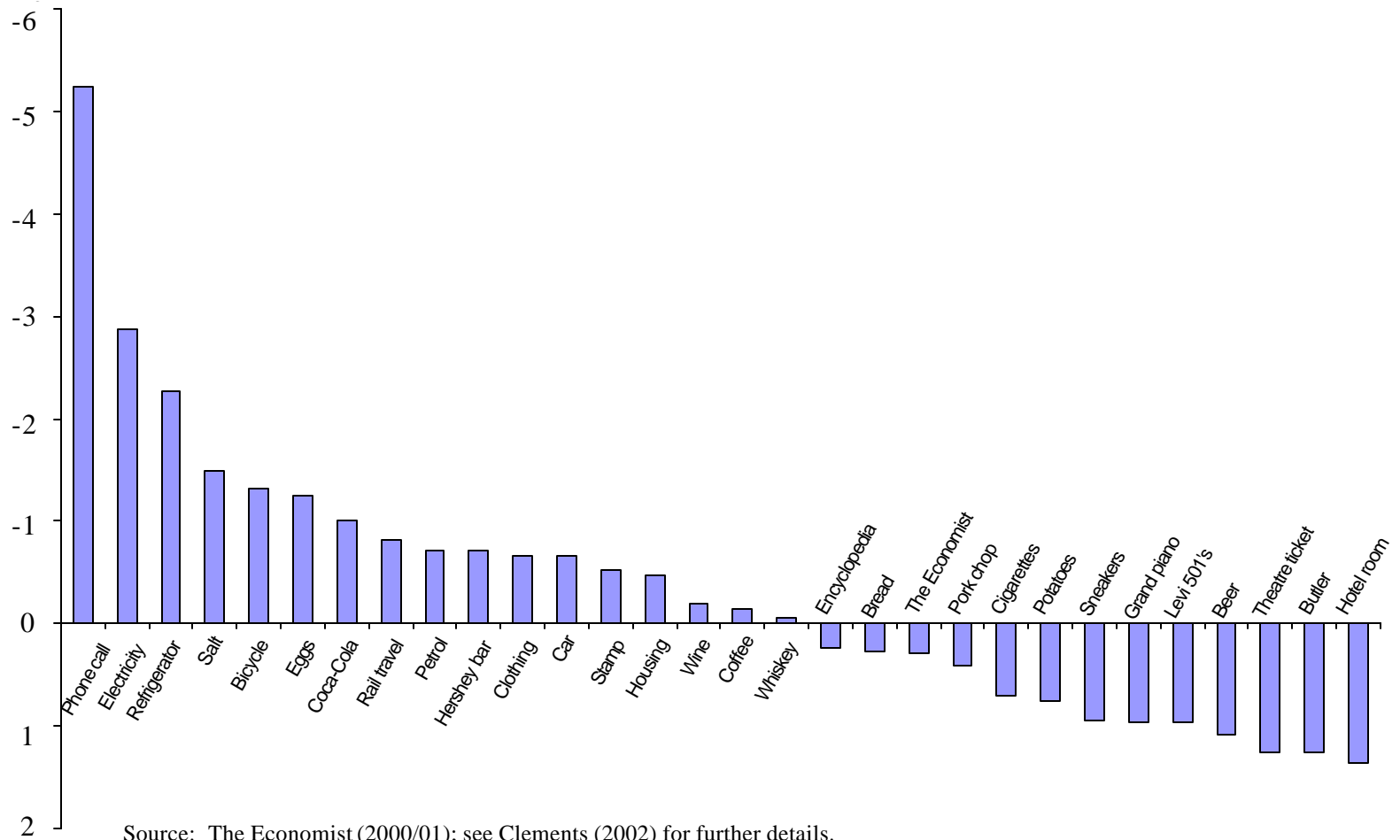
MARIJUANA AND COMMODITY RELATIVE PRICE CHANGES



Source: Marijuana prices, Table 6; commodity prices, Grilli and Yang (1988). See Clements (2002) for further details of the commodity prices.

FIGURE 6
30 MORE RELATIVE PRICE CHANGES

Average annual
log change $\times 100$
(inverted axis)



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

Another well-known example of the impact of productivity improvement on prices is the case of personal computers. In a recent paper, Berndt and Rappoport (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 (PC’s) 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 PC’s 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 Rappoport 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 grown, and those that involve electronics such as computing, power generation and telecommunications.

The conclusion of this section is that marijuana prices have decreased substantially more than many other commodities. One reason is productivity enhancement in the cultivation of marijuana due to the extensive use of hydroponic techniques. The magnitude of the price fall could also reflect in part the effects of an easing of the enforcement of prohibition laws. It has been argued, however, that prohibition could have the perverse effect of lowering, not increasing, prices because illicit activities can evade many taxes and government regulations, and do not engage in costly advertising campaigns. Miron (1998) argues:

“The most direct effects of prohibition are on the supply and demand for drugs. Prohibition tends to raise supply costs because suppliers face legal punishments for manufacturing, distributing and selling drugs. More or less equivalently, black market suppliers incur the costs of bribing law enforcement authorities and elected officials so as to avoid these legal punishments. Prohibition tends to decrease costs, however, because black

market suppliers of drugs face low marginal costs of evading government regulations and taxes, including environmental regulation, employment discrimination laws, child labour laws, antitrust laws, occupational health and safety regulation, income taxes, social security taxes and excise taxes. Similarly, suppliers of drugs produced in other countries face low marginal costs of evading tariffs and other import restrictions. And prohibition can help maintain a market equilibrium in which suppliers do not advertise, which then permits lower prices (Motta, 1997).

Prohibition tends to reduce the demand for drugs by creating legal penalties for possession of drugs, greater uncertainty about product quality, and decreased availability at any given monetary price; it might also decrease demand because consumers exhibit 'respect for the law'. Prohibition tends to increase the demand for drugs, however, to the extent it creates a forbidden fruit effect.

Beyond its direct effects on supply and demand, prohibition might also encourage increased market power or cartelisation in the drug industry ... Suppliers in a prohibited industry necessarily hide their activities from law-enforcement officials, so they face low marginal costs of evading antitrust laws. These suppliers also face low marginal costs of using violence to settle commercial disputes, which encourages collusion by permitting severe punishments. To the extent that prohibition does encourage cartelisation, this will yield real profits rather than just quasi-rents offsetting law-evasion costs, and it will tend to reduce supply and increase price.

On *a priori* grounds, therefore, prohibition has ambiguous effects on the price and quantity of drugs; both the magnitude and direction of these effects must be determined empirically."

Miron (1999a) studies the impact of prohibition on alcohol consumption in the US 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" which some consumers might find attractive (Miron, 1999a). To shed further light on the impact of prohibition on prices, Miron (1999b) also compares the markup from farmgate to retail of cocaine with that of several legal products. He finds that while the markup for cocaine is high, it is of the same order of magnitude of that of chocolate, coffee, tea and barley/beer. While there are other factors determining markups, this evidence is suggestive that illegality *per se* may not raise drug prices as much as some people might think. On the basis of this and other evidence, Miron (1999b) concludes that "the current black market price of cocaine

is at most 2-3 times higher than it would be in a legal market, not 10-20 times higher as suggested in previous work”. Consistent with this line of thinking is research which shows that increased enforcement of drug laws does not seem to result in higher prices (DiNardo, 1993, Weatherburn and Lind, 1997, Yuan and Caulkins, 1998).

If the above arguments about prices and prohibition/enforcement are accepted, then we are left with productivity enhancement as the remaining explanation for the decrease in marijuana prices. Productivity should probably be interpreted broadly to include both the use of better physical production techniques, such as hydroponics, as well as the enhanced ability of marijuana producers to evade taxes and regulations that would otherwise add to their costs. A variation on this theme is that as it is the price of marijuana in terms of all other (legal) goods that has declined so much, increasing taxes and regulations that producers of other goods may have been subject to could also account for part of the reduction in the relative price of marijuana (Miron, 1999b).

5. Fact 3: Lower Prices have Boosted Marijuana Consumption and Reduced Drinking

The section contains some explorations of the possible impact of the lower marijuana prices on marijuana usage, as well as their role on the consumption of an important substitute product, alcohol.

Table 7 contains information on consumption and prices in Australia of three alcoholic beverages, beer, wine and spirits, as well as that for marijuana. The consumption of marijuana is from Clements and Daryal (1999) who estimated it on the basis of the various National Drug Strategy Household Surveys, together with some additional assumptions that linked intensity of use to frequency of use. Although all care was taken in preparing these estimates, it must be emphasised that they are likely to be subject to a substantial margin of error. Table 8 reveals that per capita consumption of beer and wine declined at an average annual rate of 1.9 and .5 percent, respectively, while that of spirits and marijuana rose by .8 and 2.0 percent, respectively. The nominal prices of the alcoholic beverages rose by 3-4 percent p.a. on average, while that of marijuana fell by 2.5 percent.

TABLE 7
 QUANTITIES CONSUMED AND PRICES OF
 ALCOHOLIC BEVERAGES AND MARIJUANA

Year	Beer	Wine	Spirits	Marijuana
<u>Quantities</u>				
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
<u>Prices</u>				
1988	2.819	6.190	30.578	-
1989	2.928	6.607	33.315	-
1990	3.116	6.801	36.601	577
1991	3.271	6.883	39.064	547
1992	3.361	7.056	40.532	454
1993	3.478	7.271	41.847	446
1994	3.583	7.597	43.044	475
1995	3.724	7.983	44.254	476
1996	3.891	8.306	45.687	484
1997	3.981	8.559	46.714	489
1998	4.020	8.755	47.088	473
Mean	3.470	7.455	40.793	491

- 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.

- Sources: 1. The marijuana prices are from column 6 of Table 3.
 2. All other data are from Clements and Daryal (1999).

TABLE 8
LOG-CHANGES IN QUANTITIES CONSUMED AND PRICES
OF ALCOHOLIC BEVERAGES AND MARIJUANA

Year	Beer	Wine	Spirits	Marijuana
	<u>Quantities</u>			
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
	<u>Prices</u>			
1989	3.83	6.51	8.57	-
1990	6.20	2.90	9.41	-
1991	4.86	1.19	6.51	-5.26
1992	2.72	2.49	3.69	-18.71
1993	3.41	3.00	3.19	-1.75
1994	3.00	4.38	2.82	6.35
1995	3.85	4.95	2.77	.25
1996	4.40	3.97	3.19	1.64
1997	2.27	3.00	2.22	1.09
1998	.98	2.27	.80	-3.51
Mean	3.55	3.47	4.32	-2.48

Note: All entries are to be divided by 100.

Table 9 gives a 4×4 matrix of own- and cross-price elasticities, from Clements and Daryal (1999) who estimated them from a version of the Rotterdam demand model under three assumptions. First, that the consumption of alcohol and marijuana as a group are separable in the utility function from all other goods. Second, that the four goods in question are preference independent so that they exhibit no utility interactions. Third, the income elasticities of the four goods are fixed at values consistent with prior studies. While these assumptions are restrictive, they are

TABLE 9
COMPENSATED PRICE ELASTICITIES OF DEMAND

Good	Beer	Wine	Spirits	Marijuana
Beer	-.17	.03	.06	.08
Wine	.09	-.36	.13	.15
Spirits	.17	.13	-.60	.30
Marijuana	.10	.08	.15	-.33

Source: Clements and Daryal (1999).

necessary to analyse the available data which are limited in both quantity and quality. The entries on the main diagonal of Table 9 indicate that the own-price elasticities are $-.2$ (beer), $-.4$ (wine), $-.6$ (spirits) and $-.3$ (marijuana). The last column of the table gives the cross-price elasticities involving the price of marijuana; these are beer/marijuana $.1$, wine/marijuana $.2$ and spirits/marijuana $.3$. Note that the positive sign of each of these cross-elasticities implies that marijuana is a substitute for each alcoholic beverage. While this is plausible, it should be noted that complementarity is ruled out by the preference independence assumption.

We now use the cross-price elasticities to simulate consumption under the counter-factual assumption that marijuana prices did not fall as much as they did. As alcohol and marijuana are substitutes, this will have the effect of stimulating consumption of three beverages and causing marijuana usage to grow by less. Let q_{it} be the per capita consumption of good i ($i = 1, 2, 3, 4$, for beer, wine, spirits and marijuana) in year t and let $Dq_{it} = \log q_{it} - \log q_{i,t-1}$ be the corresponding log-change from year $t-1$ to t . Then, if $\eta_{ij} = \partial(\log q_i) / \partial(\log p_j)$ is the elasticity of consumption of good i with respect to the price of good j , as an approximation it follows that $Dq_{it} = \eta_{ij} \times Dp_{jt}$, where Dp_{jt} is the log-change in the j^{th} price. In the simulation, let all determinants of consumption be unchanged except the price of marijuana, which is specified to take the value $D\hat{p}_4$. The associated simulated value of the change in consumption of good i is then $\eta_{i4} D\hat{p}_4$. This change in consumption holds everything else constant. The impact on consumption of the

observed changes in all factors, including the price of marijuana, is incorporated in the observed log-change, Dq_{it} . We shall allow these factors to vary as in fact they did, but we need to take out the impact of the observed changes in marijuana prices. To avoid the appearance of being overly precise, suppose that in each year marijuana prices change by a constant amount, by the mean log-change of -2.5 percent, which we denote by α . If marijuana prices were constant and the other determinants took their observed values, then the change in the consumption of good i would be $Dq_{it} - \eta_{i4} \alpha$. Adding back the effect due to the simulated price change $D\hat{p}_4$, the simulated change in consumption of good i is

$$(5.1) \quad D\hat{q}_{it} = Dq_{it} + \eta_{i4} (D\hat{p}_4 - \alpha).$$

To evaluate equation (5.1), we use $\alpha = -2.48 \times 10^{-2}$, the mean log-change of marijuana prices. The first term on the right-hand side of (5.1), Dq_{it} , is the observed quantity log-change for good i , which is given in Table 8. The price elasticity η_{i4} is the i^{th} element of the last column of Table 9. The final element in equation (5.1) involves $D\hat{p}_4$, the simulated log-change in marijuana prices, for which we use two values. First, we hold nominal prices constant, so that $D\hat{p}_4 = 0$. Second, we assume that marijuana prices increase at the same rate as those of the alcoholic beverages, so that the price of marijuana in terms of alcohol is now held constant. Clements and Daryal (1999) compute a Divisia index of the alcoholic beverage prices, and for the period 1989-98 the mean is 3.68 percent p.a. Thus, we also set $D\hat{p}_4 = 3.68 \times 10^{-2}$.

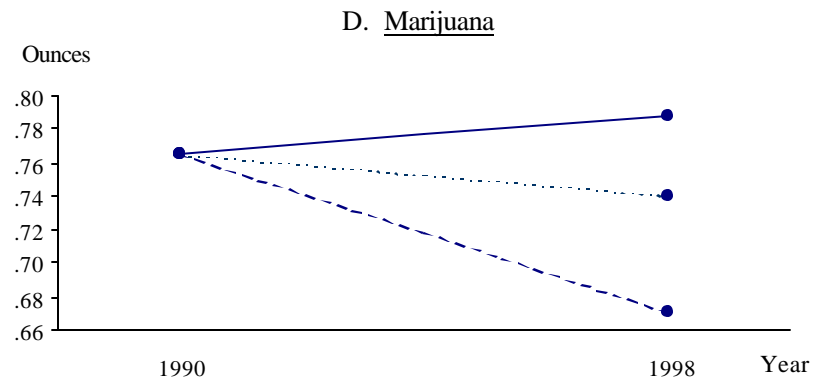
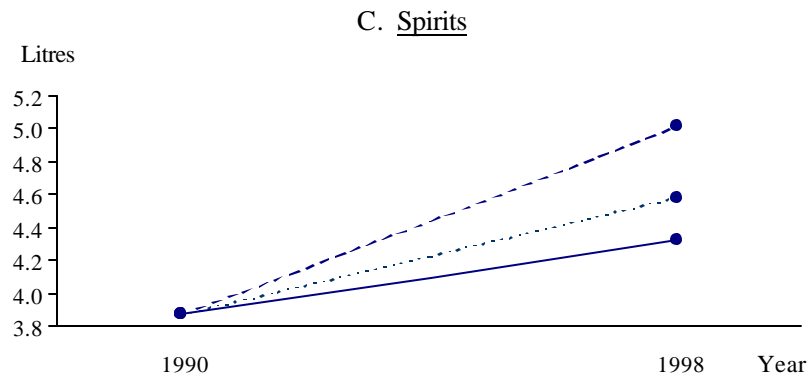
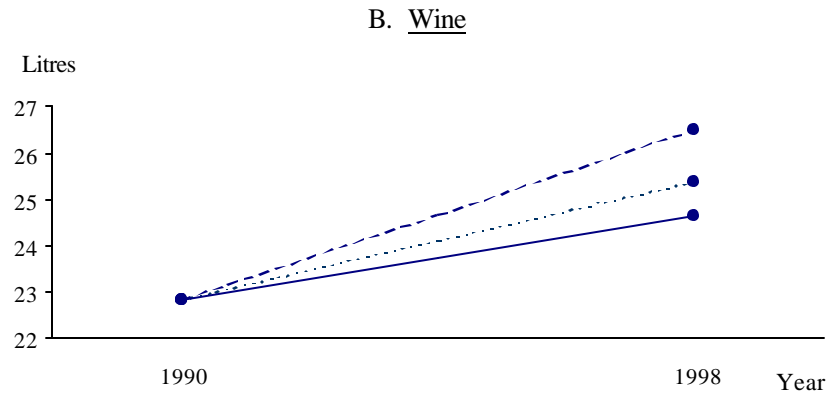
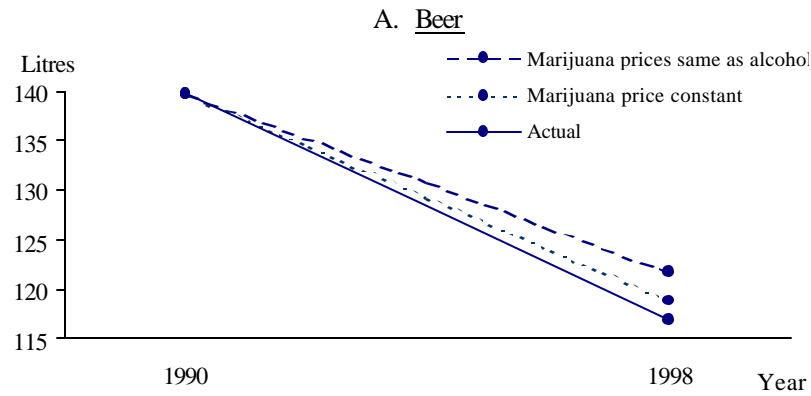
The results of the simulations are contained in Table 10. To facilitate the comparison, Figure 7 plots for each good actual consumption in the first and last years (1990 and 1998), together with the two simulated values. As actual marijuana prices fell over the period, the effect of holding them constant in the simulation is to cause consumption to grow less rapidly. In fact, rather than marijuana consumption growing from .77 oz in 1990 to .79 in 1998 (see column 5 of Table 10), when prices are held constant, consumption now falls from .77 oz to .74 (column 9). Over this period, the average annual log-change in the price of marijuana is -2.48×10^{-2} . As over the period 1990-98 there are 8 transitions from year $t-1$ to t , holding the price constant in the simulation amounts to its log-change being $8 \times 2.48 \times 10^{-2} \approx .198$, so that relative to actual the price increases by about 20 percent. With an own-price elasticity of $-.33$, this means that the log-change in consumption of marijuana would be $-.33 \times 8 \times 2.48 \times 10^{-2} \approx -.065$,

TABLE 10
ACTUAL AND SIMULATED QUANTITIES CONSUMED

Year	Simulated with marijuana prices											
	Actual				Constant				Growing at same rate as alcohol prices			
	Beer	Wine	Spirits	Marijuana	Beer	Wine	Spirits	Marijuana	Beer	Wine	Spirits	Marijuana
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1990	139.9	22.85	3.870	.7652	139.9	22.85	3.870	.7652	139.9	22.85	3.870	.7652
1991	134.9	23.01	3.614	.8278	135.2	23.10	3.641	.8210	135.6	23.22	3.681	.8111
1992	127.8	23.23	3.595	.7695	128.3	23.41	3.648	.7569	129.0	23.67	3.729	.7388
1993	123.8	23.14	3.982	.7090	124.6	23.40	4.071	.6918	125.7	23.79	4.208	.6670
1994	122.1	23.19	4.168	.7120	123.0	23.54	4.293	.6890	124.5	24.07	4.487	.6564
1995	120.2	22.96	4.130	.6913	121.4	23.40	4.286	.6653	123.2	24.06	4.529	.6261
1996	118.7	23.29	4.106	.7442	120.1	23.83	4.293	.7104	122.2	24.63	4.587	.6605
1997	117.6	24.18	4.158	.7575	119.2	24.82	4.380	.7171	121.7	25.80	4.732	.6587
1998	116.9	24.63	4.318	.7875	118.8	25.38	4.583	.7395	121.6	26.52	5.006	.6710
Mean	124.7	23.39	3.993	.7516	125.6	23.75	4.118	.7285	127.0	24.29	4.314	.6950

Note: See Table 7 for the units of measurement.

FIGURE 7
ACTUAL AND SIMULATED CONSUMPTION OF FOUR GOODS



or about -6.5 percent. As simulated and actual consumption in 1998 are $.7395$ (column 9 of Table 10) and $.7875$ (column 5) respectively, the log-change is $\log .7395 - \log .7875 \approx -.063$, or about -6.3 percent, which is close enough to confirm the calculation in the previous sentence. Columns 6-8 of Table 10 show that when marijuana prices are held constant, the consumption of each of the three alcoholic beverages is higher than actual, which is due to alcohol and marijuana being substitutes.

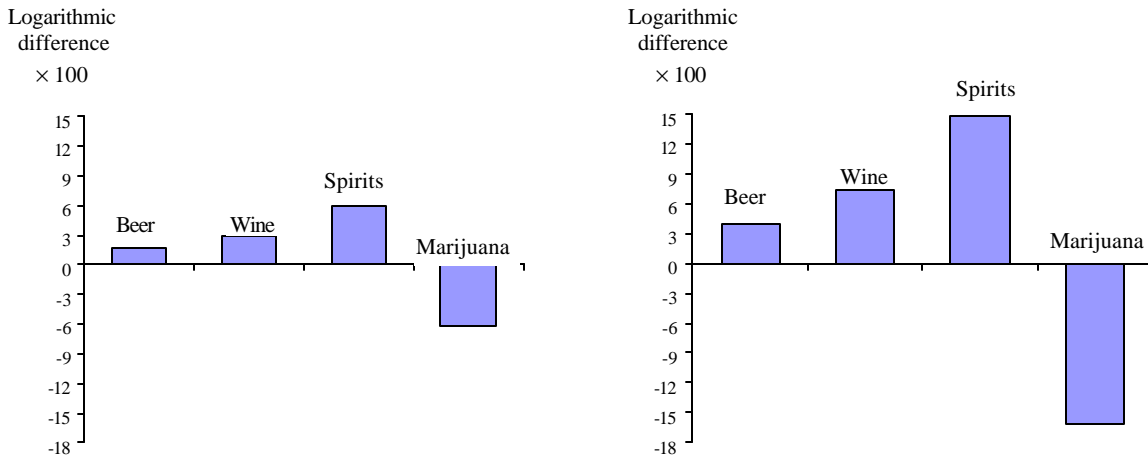
Panel A of Figure 8 compares consumption in 1998 of the four products when marijuana prices are held constant with actual consumption. As can be seen, marijuana usage is about 6 percent lower than actual, as discussed above, while consumption of each alcoholic beverage is higher. Beer consumption is higher by almost 2 percent, wine about 3 percent and spirits about 6 percent. This ranking of the effects on consumption -- beer, then wine and then spirits -- follows from the values of the cross elasticities involving the price of marijuana. From the last column of Table 9, these are $.1$, $.2$ and $.3$ for beer/marijuana, wine/marijuana and spirits/marijuana, respectively. The results of the simulation when marijuana prices grow at the same rate as alcohol prices are given in the last four columns of Table 10, the broken lines in Figure 7 and in Panel B of Figure 8. Qualitatively, the results are the same as before -- marijuana usage falls and drinking rises. But the magnitude of the effects are much larger as now the price of marijuana increases by much more: In the previous simulation, the log-change in the price over the period 1990 to 1998 was $8 \times 2.48 \times 10^{-2} \approx 20$ percent, whereas now it is $8 \times (2.48 + 3.68) \times 10^{-2} \approx 49$ percent. As in the two simulations, these price changes are multiplied by the same elasticities, it follows that for each product the quantity change in the second simulation is $49 / 20 \approx 2 \frac{1}{2}$ times that of the first.

What can be said about the welfare effects of the changes in the price of marijuana? This is a difficult question for several reasons. First, if we were to use consumer surplus to evaluate the impact of the lower price, as the height of the demand curve is interpreted as the marginal valuation of an additional gram of marijuana consumed, no account would be taken of externalities. But are these externalities positive or negative for marijuana? In some cases, marijuana may affect users in such a manner that they can interact “better” with other members of society, so that additional consumption confers a positive externality. But

FIGURE 8
CHANGE IN CONSUMPTION IN 1998
(Simulated relative to actual)

A. Marijuana prices constant

B. Marijuana prices same as alcohol



in other cases, marijuana usage would surely lead to negative externalities, such as road accidents etc. that harm innocent parties. There could also be health costs associated with high marijuana consumption, but whether or not these constitute an externality depends on the institutional arrangements for funding health care. It is not easy to judge where the net balance would lie between positive and negative externalities. A further complication relates to the interaction in consumption between marijuana usage and drinking. As consumption of alcoholic beverages and marijuana are likely to be substitutes, a fall in the price of the latter leads to less drinking. If there are externalities associated with drinking (again, are these positive or negative on balance?), a complete analysis of the welfare effects of the fall in marijuana prices would require that the reduced external costs/benefits of drinking also be accounted for. A final problem relates to the quality of marijuana. The increasing use of hydroponic techniques has in all probability enhanced the quality of the product such as increasing THC levels. Accordingly, quality-constant prices are likely to have declined by even more than our prices. Unfortunately, we have no information on quality to make the appropriate adjustments.

Due to the above problems, we confine our welfare comparisons to the change in real income of users of marijuana brought about by the price decline. The real income

change is just the price decline times consumption, $-\Delta p \times q_t$, and the question of just what consumption to use (q_t = base period, current period, geometric mean, etc.) is the subject matter of much of index-number theory. As shown in Table 11, using Laspeyres' (base-period consumption), Paasche (current-period) and the Fisher ideal (geometric mean) approaches, the price fall induces a rise in real income of about \$80 per capita p. a. As in 1998 there were about 15 million people (14 years and over) in Australia, in the aggregate real income increases by more than \$1,200m p. a. as a result of the lower price of marijuana. This real income increase need to be carefully interpreted as its distribution is far from uniform. As a small number of heavy users account for a large share of total marijuana consumption (Clements and Daryal, 1999), it is clear that these heavy users receive most of the gains, while others receive little or no benefit from the lower prices.

6. Concluding Comments

This paper has identified a substantial decline in the relative price of marijuana, discussed the possible causes and analysed some of the implications. Rather than reiterating the findings, we comment briefly on some of their broader implications:

- By their very nature, illicit goods and services are excluded from official statistics. If the prices of other illicit activities have fallen as much as that of marijuana, the CPI will be overstated, and real incomes and productivity measures will be understated.
- Further studies of illicit sectors of the economy could be rewarding in understanding how incentives operate to encourage the adoption of new technology. This may provide some guidance regarding appropriate policies to boost productivity in legal activities, and in the identification of impediments to the introduction of technological improvements.
- Our estimates show that the lower price of marijuana has substantially reduced consumption of a substitute product, alcohol. Producers of beer, wine and spirits may thus be tempted to argue that on the basis of considerations of competitive neutrality, marijuana production should be legalised and subject to the same hefty taxes as they are.

TABLE 11
MARIJUANA AND REAL INCOME

Year	Price (\$ per oz)	Quantity (Oz per capita)	Change in real income (\$ per capita)		
			Laspeyres' (t = 1990)	Paasche (t = 1998)	Fisher (t = $\sqrt{1990 \times 1998}$)
1990	577	.7652			
1998	473	.7875			
$\Delta p, \Delta q$	-104	.0223			
$-\Delta p \times q_t$			79.5	81.9	80.7

- Suppose marijuana were legalised and its production taxed. In view of the apparent ease with which marijuana can now be grown with hydroponic techniques and because demand is almost surely price inelastic, it would be consumers who would bear the bulk of the incidence of the tax, not growers. In such a case, maybe the incentives to innovate would remain more or less unchanged in a legalised regime.
- Economic historians have long studied the impacts of innovation and how the benefits are distributed between shareholders, workers and consumers. A leading example of this work relates to textile production in the industrial revolution in Britain for which it has been estimated that about half of the benefits from falling prices went overseas in the form of a worsening of Britain's terms of trade (Crafts, 2001, IMF, 2001, Chap. 3). During the recent IT boom, it would also seem that the bulk of the benefits took the form of lower prices, rather than higher profits and wages (IMF, 2001, Chap. 3). In related research, Baumol (2002) estimates that on average only 20 percent of the benefits of innovation are captured by the innovators themselves. Although no data exist on the profitability of marijuana production, or on wages paid, the substantial decline in prices would seem to point to the distributional effects of innovation within the marijuana industry as being not too different to those experienced by other sectors at other times.

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