The Effects on New Zealand Households of an Increase in The Petrol Excise Tax

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DISCLAIMER

Abstract

This paper reports estimates of the potential welfare effects of hypothetical increases in the petrol excise tax in New Zealand. Equivalent variations, for a range of household types and total expenditure levels, are obtained along with distributional measures. Household demand responses are modelled using the Linear Expenditure System, where parameters vary by total expenditure level and household type. The effects on inequality were founds to be negligible, but the marginal excess burdens typically ranged between 35 and 55 cents per dollar of additional revenue.

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1 Introduction

This paper examines the potential welfare and redistributive effects of a hypothetical increase in the petrol excise tax in New Zealand. Equivalent variations and excess burdens are obtained for a variety of household types at a range of total expenditure levels. Households are divided into a number of categories according to their composition. Also, overall summary measures of the distributional effects are reported using a money metric utility measure. Changes in indirect taxes give rise to changes in prices, assuming tax shifting to consumers, so the core of the modelling involves a method of examining the welfare effects of price changes. Household demand responses to price changes are modelled using the linear expenditure system (LES), with the modification that parameters are allowed to vary by total expenditure level and household characteristics.[1]

The data and household groups used are described in section 2. The more technical material on welfare measurement and the way in which household demands are modelled is placed in an Appendix. This includes the money metric utility measure and the computation of the required parameter values. Section 3 describes the relationship between tax rates and price changes. This is complicated in the present context by the fact that the goods and services tax (GST) is imposed on the excise-inclusive price, and the excise is a unit tax rather than an *ad valorem* tax. The approach is used in section 4 to examine the potential implications of a tax reform involving an increase in the petrol excise tax. Conclusions are in section 5.

2 The Data

This section describes the data used and the aggregation into household groups. Household expenditure data from the Household Economic Survey

[1] There are well-known potential problems associated with using an assumption of additivity, as discussed by Deaton (1974), although these are less severe when broad commodity groups are used.

(HES) for the years 1995, 1996, 1997, 1998 and 2001 were adjusted to 2001 prices using the consumer price index (CPI). Over this period there were very few changes in indirect taxes. The surveys were then pooled to form one large data base, for purposes of estimating the relationships between budget shares and total household expenditure for a range of household types.

Table 1 shows the household types used.[2] In each case households are further divided into smoking (S) and non-smoking (NS) households; a positive weekly expenditure on tobacco (group 17 in Table 2) was sufficient for the household to be designated as a smoking household. The division into smoking and non-smoking households, for examination of all commodity groups, was found to improve the goodness of fit of most of the budget share relationships substantially.[3] Table 1 also give the arithmetic mean total household expenditure for each household type.

3 Indirect Taxes and Price Changes

This section describes the 2001 indirect tax structure and the link between excise tax changes and proportional price changes, on the assumption that tax increases are fully passed to consumers. Two issues are involved. First, it is necessary to express all indirect taxes in terms of a tax-exclusive *ad valorem* tax rate. While this is straightforward for most commodity groups, for which only GST applies, the translation is more awkward where an excise tax is also imposed, since these are typically based on units of the commodity rather than values.

It is not possible, mainly because of estimation difficulties, to use all the separate and highly detailed HES commodity categories. Instead, these were consolidated into 22 groups. Table 2 shows the commodity groups used and the effective *ad valorem* tax-exclusive percentage rates, at 2001. The rates shown in Table 2 were taken from Young (2002). Where several HES categories were combined, the effective rates also required the computation of a weighted average of the individual components. Table 2 clearly indicates

[2]For the first two types, the age refers to that of the 'head' of the household.
[3]This is the relationship in equation (18) in the Appendix.

Table 1: Household Categories

No.	Household Type	Number of households		Mean total expenditure	
		S	N-S	S	N-S
1	65+ single	161	1282	267	274
2	65+ couple	224	1191	498	540
3	Single - no children	384	1098	406	437
4	Single - 1 child	148	239	400	403
5	Single - 2 children	148	181	428	438
6	Single - 3 children	59	75	468	475
7	Single - 4+ children	33	39	501	539
8	Couple - no children	966	2036	690	766
9	Couple - 1 child	381	643	668	763
10	Couple - 2 children	435	916	707	896
11	Couple - 3 children	207	458	805	844
12	Couple - 4+ children	98	195	673	822
13	3 adults - no children	319	456	975	992
14	3 adults - 1 child	122	157	898	1038
15	3 adults - 2+ children	117	34	826	920
16	4+ adults - no children	179	192	1311	1282
17	4+ adults - 1 child	65	60	1110	1129
18	4+ adults - 2+ children	47	47	1070	925

Table 2: Commodity Groups and Tax Rates

No.	Tax Rate	Commodity Group	HES Categories
1	12.5	Food	00-08
2	12.5	Food outside home	10
3	0	Rent	11
4	12.5	Pay to Local Authorities	13
5	12.5	House maintenance	15-17
6	12.5	Domestic fuel and power	18-30
7	12.5	Household equipment	31-32
8	12.5	Furnishings	33-36
9	12.5	Household services	37-38
10	12.5	Adult clothing	39-40,42-45,47-48
11	12.5	Children's clothing	41,46
12	12.5	Public transport in NZ	49
13	0	Overseas travel	50
14	7.05445	Vehicle purchase	51-53
15	71.776	Petrol etc	54-59
16	12.5	Vehicle supplies, parts etc	60-69
17	239.845	Cigarettes and tobacco	70-73
18	46.8191	Alcohol	74-85
19	12.5	Medical, cosmetic etc	86-88
20	12.5	Services	94-101
21	6.25	Recreational vehicles	58
22	12.5	Other expenditure	89-91,102

the high effective rates on petrol, cigarettes and tobacco and alcohol. These high rates are typically rationalised on merit good and externality grounds.[4]

It is required to calculate the tax-exclusive price and the effective *ad valorem* tax rate on petrol, given information about the consumer price (which is tax-inclusive) of petrol per litre, along with the excise per litre and the GST rate. This is partly complicated by the fact that the excise tax is a unit tax and GST is imposed on the excise. Hence an increase in the excise automatically increases the absolute amount of GST raised per litre of petrol.

Let P_0 and P_1 denote the tax-exclusive and tax-inclusive price of petrol per litre. The petrol excise per litre is E, and the GST (tax-exclusive *ad*

[4] For a case study of alcohol, see Barker (2002).

valorem) rate is g. The tax paid per litre, T, is given by:

$$\begin{aligned} T &= E + (P_0 + E)\, g \\ &= E\,(1+g) + P_0 g \end{aligned} \tag{1}$$

Hence the relationship between P_1 and P_0, assuming that the tax is passed to consumers, is:

$$P_1 = P_0 + E\,(1+g) + P_0 g \tag{2}$$

Hence:

$$P_0 = \frac{P_1}{1+g} - E \tag{3}$$

The effective *ad valorem* rate, t, is therefore given by T/P_0, or:

$$t = g + (1+g)\,\frac{E}{P_0} \tag{4}$$

For example, in 2001 the petrol excise was \$0.343 per litre, and the proportional GST rate was 0.125. Suppose the consumer price of petrol was \$1.08. Hence from (3) the tax-exclusive price was \$0.617. From (4) the effective *ad valorem* tax rate on petrol was 0.75. An increase in the excise by 5 cents per litre, to \$0.393, produces an effective tax rate of 0.842; an increase by 10 cents produces a rate of 0.933; and an increase of 15 cents gives an effective rate of 1.024.

Table 2 indicates that in estimating the budget share relationship for each household type, it was necessary to group the HES categories 54 to 59. This combines petrol with diesel, CNG and LPG. Hence the appropriate tax rate for this combination requires a weighted average of petrol and other fuel taxes. The basic (year 2001) rate used for this group is thus 0.71776, which is correspondingly lower than the effective rate of 0.75 on petrol. For an increase of 5 cents in the excise, the new effective rate for this commodity group becomes 0.787, and for an increase of 15 cents the effective rate becomes 0.952. The results reported below are obtained using these values.

Changes in effective rates must then be translated into proportionate price change. In general, suppose that the tax-exclusive *ad valorem* tax rate imposed on good i is denoted t_i, which is equivalent to a tax-inclusive rate of $t_i/(1+t_i)$. The revenue, R_i, from the indirect tax on the ith good is simply expenditure multiplied by the tax-inclusive rate. If t_i increases at the proportional rate $\dot{t}_i$, the resulting proportionate increase in the price of the ith good, $\dot{p}_i$, is given by:

$$\dot{p}_i = \dot{t}_i \left(\frac{t_i}{1+t_i} \right) \quad (5)$$

The price changes can then be fed into the expressions for the welfare changes given in the Appendix.[5]

4 Simulation Results

This section reports the main results of simulations of the potential effects of an increase in the petrol excise tax in New Zealand. Two cases are considered, of 5 and 15 cent increases. The relationship between the excise tax and the effective *ad valorem* tax rate is examined in the first subsection. This is followed by discussion of the numerical results.

4.1 Welfare Changes

The welfare change obtained for each household is the equivalent variation, EV. This is the difference between total expenditure, y, which remains unchanged by assumption, and the expenditure that would be needed to place the household at the new level of utility at the old (pre-change) prices. Since the pre-change prices are lower, and households are worse off as a result of the increase, the equivalent variation must be positive.

Tables 3 to 6 summarise the welfare changes resulting from the two hypothetical excise tax changes, for the various household types. The first two tables refer to households with positive expenditure on tobacco, while the second two tables are for non-smoking households. For each household type, the welfare changes are given for three different levels of total household expenditure per week. The respective average expenditure levels are shown in Table 1, in section 2 above.

[5] The Appendix also gives further details of the relationship between prices changes and the expressions required for computing equivalent variations.

The equivalent variation is given along with the ratio to total expenditure. The variation in EV/y with y gives an initial idea of whether the tax change is progressive or regressive: a progressive change is associated with an increase in EV/y with y. It can be seen that for many household types, the change is very slightly progressive. In some cases it appears to be slightly regressive, while in some case the change in EV/y is not monotonic.[6] The welfare losses are typically a small percentage of total expenditure, but are relatively higher for smoking households and for multi-adult households.

The columns headed Δt give the increase in tax paid per week. The marginal excess burdens arising from the policy change can therefore be obtained by subtracting Δt from EV, for each household type and total expenditure level. The tables show that the marginal excess burden per dollar of extra tax revenue varies substantially among the household types and total expenditure levels. However, for most cases the variation lies between about 35 cents and 55 cents per dollar of additional revenue. It is widely recognised that excess burdens are approximately proportional to the square of the tax rate, and the present simulations involve non-marginal increases to an effective tax rate that is already very high, second only to that imposed on alcohol.

The excess burdens found here are substantially higher than those reported by Davies (2003). However, Davies computed an approximation (the consumers' surplus triangle) to the welfare change, based on an own-price elasticity for the aggregate market demand curve. Even where an approximation is used, the appropriate demand curve is not the market (Marshallian) curve but the Hicksian (or compensated) demand curve.[7] This excess burden is known to be an unreliable approximation.[8]

[6] The following subsection examines this issue in more detail.

[7] It seems that an income term was not included in the demand study from which Davies took his elasticity, so 'exact' measures cannot be computed by appropriate integration of the demand curve.

[8] For an introductory exposition of excess burden concepts, see Creedy (2003).

Table 3: Welfare Changes for Smoking Households: Types 1-9

		5 cents			15 cents		
HH Type	y	EV	EV/y	Δt	EV	EV/y	Δt
1	300	0.25	0.0008	0.16	0.81	0.0027	0.53
	600	0.65	0.0011	0.42	2.12	0.0035	1.35
	1000	1.45	0.0015	0.87	4.73	0.0047	2.77
2	300	0.46	0.0015	0.32	1.50	0.005	1.06
	600	0.9	0.0015	0.66	2.98	0.005	2.16
	1000	1.48	0.0015	1.05	4.90	0.0049	3.45
3	300	0.42	0.0014	0.29	1.39	0.0046	0.95
	600	0.90	0.0015	0.63	2.97	0.0049	2.06
	1000	1.58	0.0016	1.09	5.21	0.0052	3.55
4	300	0.41	0.0014	0.29	1.36	0.0045	0.95
	600	0.80	0.0013	0.6	2.64	0.0044	1.96
	1000	1.28	0.0013	0.9	4.23	0.0042	2.97
5	300	0.42	0.0014	0.29	1.37	0.0046	0.94
	600	0.89	0.0015	0.63	2.95	0.0049	2.06
	1000	1.63	0.0016	1.08	5.36	0.0054	3.5
6	300	0.28	0.0009	0.16	0.91	0.003	0.52
	600	0.69	0.0011	0.48	2.26	0.0038	1.55
	1000	1.29	0.0013	0.84	4.25	0.0042	2.74
7	300	-	-	-	-	-	-
	600	0.75	0.0013	0.43	2.42	0.004	1.33
	1000	1.83	0.0018	1.12	5.95	0.0059	3.56
8	300	0.61	0.002	0.43	2.00	0.0067	1.41
	600	1.08	0.0018	0.83	3.58	0.006	2.74
	1000	1.44	0.0014	1.18	4.81	0.0048	3.93
9	300	0.56	0.0019	0.41	1.86	0.0062	1.33
	600	1.07	0.0018	0.78	3.53	0.0059	2.57
	1000	1.71	0.0017	1.24	5.65	0.0056	4.08

Table 4: Welfare Changes for Smoking Households: Types 10-18

		5 cents			15 cents		
HH Type	y	EV	EV/y	Δt	EV	EV/y	Δt
10	300	0.57	0.0019	0.38	1.88	0.0063	1.23
	600	1.01	0.0017	0.78	3.37	0.0056	2.57
	1000	1.41	0.0014	1.13	4.71	0.0047	3.78
11	300	0.78	0.0026	0.56	2.58	0.0086	1.86
	600	1.13	0.0019	0.90	3.78	0.0063	3.00
	1000	1.44	0.0014	1.19	4.82	0.0048	3.97
12	300	0.56	0.0019	0.34	1.83	0.0061	1.08
	600	1.26	0.0021	0.94	4.17	0.0069	3.10
	1000	1.71	0.0017	1.42	5.74	0.0057	4.73
13	300	0.57	0.0019	0.34	1.84	0.0061	1.06
	600	1.25	0.0021	0.91	4.12	0.0069	3.00
	1000	1.81	0.0018	1.44	6.04	0.006	4.78
14	300	0.88	0.0029	0.68	2.94	0.0098	2.25
	600	1.28	0.0021	1.01	4.26	0.0071	3.35
	1000	1.68	0.0017	1.35	5.61	0.0056	4.48
15	300	-	-	-	-	-	-
	600	1.29	0.0022	0.83	4.22	0.007	2.66
	1000	2.11	0.0021	1.62	7.02	0.007	5.37
16	300	0.47	0.0016	0.46	1.53	0.0051	1.47
	600	1.60	0.0027	1.20	5.28	0.0088	3.95
	1000	2.22	0.0022	1.79	7.39	0.0074	5.95
17	300	0.81	0.0027	0.49	2.64	0.0088	1.56
	600	1.81	0.0030	1.32	5.96	0.0099	4.32
	1000	2.68	0.0027	2.09	8.92	0.0089	6.91
18	300	1.05	0.0035	0.83	3.5	0.0117	2.77
	600	1.51	0.0025	1.19	5.02	0.0084	3.93
	1000	2.09	0.0021	1.61	6.94	0.0069	5.32

Table 5: Welfare Changes for Non-smoking Households: Types 1-9

		5 cents			15 cents		
HH Type	y	EV	EV/y	Δt	EV	EV/y	Δt
1	300	0.26	0.0009	0.19	0.87	0.0029	0.64
	600	0.52	0.0009	0.38	1.73	0.0029	1.24
	1000	0.92	0.0009	0.63	3.02	0.003	2.05
2	300	0.45	0.0015	0.34	1.49	0.005	1.11
	600	0.83	0.0014	0.65	2.75	0.0046	2.14
	1000	1.11	0.0011	0.92	3.70	0.0037	3.06
3	300	0.50	0.0017	0.38	1.66	0.0055	1.26
	600	0.79	0.0013	0.64	2.64	0.0044	2.14
	1000	0.96	0.001	0.82	3.22	0.0032	2.77
4	300	0.46	0.0015	0.36	1.52	0.0051	1.19
	600	0.71	0.0012	0.56	2.37	0.0039	1.84
	1000	1.01	0.001	0.74	3.37	0.0034	2.46
5	300	0.40	0.0013	0.35	1.36	0.0045	1.17
	600	0.71	0.0012	0.48	2.33	0.0039	1.54
	1000	1.79	0.0018	0.93	5.8	0.0058	2.96
6	300	0.34	0.0011	0.26	1.12	0.0037	0.85
	600	0.66	0.0011	0.46	2.18	0.0036	1.48
	1000	1.37	0.0014	0.83	4.49	0.0045	2.68
7	300	0.53	0.0018	0.41	1.76	0.0059	1.35
	600	0.78	0.0013	0.7	2.64	0.0044	2.35
	1000	0.67	0.0007	0.6	2.25	0.0023	2.04
8	300	0.60	0.002	0.45	1.97	0.0066	1.48
	600	1.04	0.0017	0.82	3.45	0.0057	2.72
	1000	1.33	0.0013	1.12	4.46	0.0045	3.75
9	300	0.64	0.0021	0.5	2.13	0.0071	1.66
	600	0.99	0.0016	0.78	3.30	0.0055	2.6
	1000	1.33	0.0013	1.06	4.44	0.0044	3.53

Table 6: Welfare Changes for Non-smoking Households: Types 10-18

		5 cents			15 cents		
HH Type	y	EV	EV/y	Δt	EV	EV/y	Δt
10	300	0.68	0.0023	0.52	2.25	0.0075	1.72
	600	1.04	0.0017	0.83	3.47	0.0058	2.76
	1000	1.34	0.0013	1.11	4.48	0.0045	3.69
11	300	0.60	0.0020	0.47	2.00	0.0067	1.54
	600	1.01	0.0017	0.81	3.37	0.0056	2.68
	1000	1.26	0.0013	1.07	4.23	0.0042	3.59
12	300	0.56	0.0019	0.39	1.84	0.0061	1.28
	600	0.98	0.0016	0.77	3.25	0.0054	2.54
	1000	1.28	0.0013	1.05	4.29	0.0043	3.52
13	300	0.62	0.0021	0.43	2.04	0.0068	1.39
	600	1.28	0.0021	0.98	4.24	0.0071	3.22
	1000	1.75	0.0017	1.44	5.85	0.0058	4.80
14	300	0.87	0.0029	0.63	2.88	0.0096	2.08
	600	1.38	0.0023	1.09	4.6	0.0077	3.62
	1000	1.77	0.0018	1.48	5.95	0.0059	4.94
15	300	0.35	0.0012	0.17	1.12	0.0037	0.52
	600	1.05	0.0018	0.75	3.46	0.0058	2.46
	1000	1.62	0.0016	1.26	5.39	0.0054	4.16
16	300	0.42	0.0014	0.28	1.36	0.0045	0.86
	600	1.25	0.0021	0.90	4.12	0.0069	2.94
	1000	1.91	0.0019	1.48	6.35	0.0064	4.90
17	300	0.54	0.0018	0.33	1.76	0.0059	1.04
	600	1.29	0.0022	0.94	4.26	0.0071	3.07
	1000	1.97	0.002	1.51	6.56	0.0066	4.98
18	300	0.97	0.0032	0.75	3.22	0.0107	2.47
	600	1.46	0.0024	1.16	4.87	0.0081	3.86
	1000	1.93	0.0019	1.56	6.46	0.0065	5.18

4.2 Inequality Measures

In the previous subsection it was suggested that the variation in EV/y as y increases gives an indication of whether the tax change is progressive or regressive. However, this indication is incomplete because it does not reflect information about the distribution of changes, involving the numbers of households at the various total expenditure levels. Furthermore, it only allows comparisons between households in the same demographic group.

The redistributive effect of the tax change can be examined using the distribution of money metric utility, y_e, before and after the excise increase. A suitable money metric is defined as the value of total expenditure, y_e, which, at some reference set of prices, p_r, would give the same utility as the actual total expenditure.[9] For present purposes, the pre-change prices are used as the reference prices.

An important feature of the inequality measures is that they refer to the inequality of individual (money metric) utilities, where each individual in a household is given that household's value of $z = y_e/h$, where h is the adult equivalent size. The inequality measure reported is the Atkinson measure, A, which is based on the additive welfare welfare function:

$$W = \frac{1}{\sum_{i=1}^{n} p_i} \sum_{i=1}^{N} p_i V(z_i) \tag{6}$$

where p_i is the number of individuals in the ith household ($i = 1, ..., n$) and $V(z)$ is increasing and concave.[10] Inequality is defined as the proportional difference between the equally-distributed-equivalent, $\widetilde{z}$, and the arithmetic mean, $\overline{z}$. Hence, $\widetilde{z}$ is the money measure per equivalent adult which, if received by every person, produces the same social welfare as the actual distribution, and:

$$A = 1 - \frac{\widetilde{z}}{\overline{z}} \tag{7}$$

[9] It is defined more precisely in the Appendix. Such a measure was used by Fortin and Truchan (1993) with the LES and an early brief discussion of this money metric, also using the LES, was provided by Roberts (1980).

[10] Hence for computing the inequality measure, the household distribution is treated as being weighted, with each household given a frequency corresponding to the total number of people in the household.

Although this may be used with any form of V, the most common form is:

$$V(z) = \frac{z^{1-\varepsilon}}{1-\varepsilon} \tag{8}$$

where $\varepsilon \neq 1$ is the degree of constant relative inequality aversion of the decision maker. For $\varepsilon = 1$, (8) becomes $V(z) = \log z$. Thus:

$$\widetilde{z} = \frac{1}{\sum_{i=1}^{n} p_i} \left\{ \sum_{i=1}^{n} p_i z^{1-\varepsilon} \right\}^{1/(1-\varepsilon)} \tag{9}$$

The coefficient $\varepsilon \neq 1$ is a measure of relative inequality aversion which, as the degree of concavity of $x^{1-\varepsilon}/(1-\varepsilon)$, reflects the judge's view of the 'wastefulness' of inequality. The value of ε is often linked to a judge's tolerance of the loss involved (using a 'leaky bucket') in making a transfer from a richer to a poorer individual.[11]

Equivalence scales are based on the following function:

$$h = (n_a + \theta n_c)^{\gamma} \tag{10}$$

where n_a and n_c respectively are the number of adults and children in the household. The parameter θ measures the 'size' of children relative to adults, and the term γ reflects economies of scale in consumption. On the use of this form, see Jenkins and Cowell (1994, p.894). The following results were obtained using values of $\theta = 0.3$ and $\gamma = 0.7$.

Table 7 lists the pre- and post-increase inequality measures for each household type, for the higher excise increase of 15 cents. for a relative inequality aversion coefficient of 1.2. This indicates a substantial degree of aversion. Within many of the demographic groups, the choice of adult equivalence scales do not affect the inequality comparison because those groups contain homogeneous households. But for categories 7, 13 and 15-18, the adult equivalent household size can vary.

[11] For individuals i and j,with $x_j > x_i$, then $\left.\frac{dx_i}{dx_j}\right|_W = -\left(\frac{x_j}{x_i}\right)^{\varepsilon}$. Hence, if j has twice the income of i, a value of $\varepsilon = 1$ means that the judge is prepared to take \$1 from j and transfer only 50 cents to i, losing the remaining 50 cents. For survey results on attitudes to inequality, producing values of ε substantially below 1, see Amiel *et al.* (1999).

The final row of the table provides an overall indication of the redistributive effect of the tax change; this shows a very small increase from 0.1622 to 0.1627. This overall change also reflects the relative numbers of households in the various demographic groups, as well as the distribution of total expenditure among households. When a lower degree of inequality aversion is used, the overall increase is trivial, being from 0.0297 to 0.0298.[12]

When the inequality of individual values of y_e/h is considered the overall effect is to increase inequality slightly. Furthermore, inequality increases slightly within most of the demographic groups, the exceptions being 1, 3, and 6-7 inclusive for the smoking households and groups 1 and 6 for the non-smoking households. However, these changes in inequality are negligible, typically involving either the third or fourth decimal place, and are most unlikely to be statistically significant.

5 Conclusions

This paper has examined the potential implications for New Zealand households of a hypothetical increase in the petrol excise tax. Two cases were considered of a 5 cents and 15 cents increase per litre. Changes in indirect taxes lead to changes in prices, so the core of the model is a method of examining the welfare effects of price changes. Household demand responses to price changes were modelled using the linear expenditure system, with the modification that parameters vary by total expenditure level and household characteristics. Pooled Household Economic Survey data were used to divide households into 18 demographic categories, and commodity groups were consolidated into 22 groups. In addition, households were distinguished according to whether their tobacco consumption was positive.

The welfare effects of the excise tax increase were found to vary considerably among demographic groups, reflecting the different variations in budget shares with total expenditure. Importantly the excess burdens also varied

[12] A wide range of inequality measures, included extended Gini measures for varying inequality aversion, was computed, and in all cases the changes were very small. The comparisons were also not affected by the choice of equivalence scale in this case, though the absolute size changes (except for single adult households, of course).

Table 7: Inequality Measures for Excise Increase of 15 Cents

No.	Household Type	Inequality Measure			
		Smoking		Non-Smoking	
		Pre-	Post-	Pre-	Post-
1	65+ single	.1553	.1551	.1692	.1692
2	65+ couple	.1012	.1012	.1728	.1731
3	Single - no children	.1804	.1802	.1928	.1933
4	Single - 1 child	.0876	.0876	.1310	.1314
5	Single - 2 children	.1027	.1026	.1318	.1318
6	Single - 3 children	.1140	.1137	.1270	.1269
7	Single - 4+ children	.0696	.0690	.1126	.1131
8	Couple - no children	.1285	.1290	.1670	.1677
9	Couple - 1 child	.1236	.1238	.1657	.1664
10	Couple - 2 children	.1072	.1076	.1749	.1757
11	Couple - 3 children	.1656	.1666	.1463	.1470
12	Couple - 4+ children	.1207	.1210	.1381	.1386
13	3 adults - no children	.1354	.1360	.1387	.1394
14	3 adults - 1 child	.1284	.1291	.1387	.1396
15	3 adults - 2+ children	.1173	.1174	.1409	.1412
16	4+ adults - no children	.1114	.1121	.1121	.1125
17	4+ adults - 1 child	.1120	.1127	.2092	.2095
18	4+ adults - 2+ children	.1683	.1689	.1738	.1748
	All Individuals	Pre: 0.1622		Post: 0.1627	

substantially, though most cases ranged between about 35 and 55 cents per dollar of extra revenue. Public expenditure financed from such a tax increase would therefore need to establish significant external benefits.

Inequality comparisons, based on money metric utility per adult equivalent, were also made based on the distribution of individual values. The majority of household types, along with the overall comparison, showed very small - indeed negligible - increases in inequality. The results suggest that the most important consideration from such a selective tax increase arises from the marginal excess burdens generated.

Appendix: Welfare Changes, Demand Elasticities and Parameters

This appendix describes the computation of the welfare measures and the method used to compute the required parameters for each demographic group and total expenditure level. Only the main results are stated, as their derivations are available elsewhere.[13] The basis of the approach is the use of the linear expenditure system to model households' behaviour. The demands are assumed to vary in a partial equilibrium, rather than a general equilibrium, context. The total expenditure (though not its composition) of each household is assumed to remain fixed when prices of goods and services change. Thus, possible changes in production (associated with the changing structure of demands) and factor prices, along with the distribution of income, are ignored.[14]

The direct utility function for the linear expenditure system is:

$$U = \prod_{i=1}^{n} (x_i - \gamma_i)^{\beta_i} \tag{11}$$

with $0 \leq \beta_i \leq 1$, and $\sum_{i=1}^{n} \beta_i = 1$. Here, x_i and γ_i are respectively the total and the committed consumption of good i. If p_i is the price of good i, and y is total household expenditure, the budget constraint is $\sum_{i=1}^{n} p_i x_i = y$. In the present context, the parameters of the utility function differ according to both household type and total expenditure, as discussed further below. The next two subsections define equivalent variations and money metric utility, which are used in distributional analyses.

Equivalent Variations

The equivalent variation, EV, is defined in terms of the expenditure function as $EV = E(p_1, U_1) - E(p_0, U_1)$, where $E(p, U)$ is the minimum expenditure required to reach utility level U at prices p. Defining the terms A and B

[13] For example, see Powell (1974), Allen (1975), Creedy (1998a,b).

[14] Such general equilibrium effects are more important, the larger is the tax change envisaged.

respectively as $\sum_{i=1}^{n} p_i \gamma_i$ and $\prod_{i=1}^{n} (p_i/\beta_i)^{\beta_i}$, the indirect utility function, $V(p, y)$, is:

$$V = (y - A) / B \tag{12}$$

The expenditure function is found by inverting (12) and substituting E for y to get:

$$E(p, U) = A + BU \tag{13}$$

Suppose that the vector of prices changes from p_0 to p_1. Substituting for E using (13) and assuming that total expenditure remains constant at y, gives:

$$EV = y - (A_0 + B_0 U_1) \tag{14}$$

Substituting for U_1, using equation (12), into (14) gives:

$$EV = y - A_0 \left[1 + \frac{B_0}{B_1} \left(\frac{y}{A_0} - \frac{A_1}{A_0} \right) \right] \tag{15}$$

The term A_1/A_0 is a Laspeyres type of price index, using γ_is as weights. The term B_1/B_0 simplifies to $\prod_{i=1}^{n} (p_{1i}/p_{0i})^{\beta_i}$, which is a weighted geometric mean of price relatives.[15] A convenient feature of the present approach is that the expression for the equivalent variation requires only the percentage changes in prices to be specified.

Money Metric Utility

For distributional analyses of tax reforms, it is necessary to have a money metric measure of each household's utility. A suitable money metric is defined as the value of total expenditure, y_e, which, at some reference set of prices, p_r, would give the same utility as the actual total expenditure.[16] A feature of this metric is that it ensures that alternative situations are evaluated using a common set of reference prices. It is, importantly, invariant with respect to monotonic transformations of utility. Using the expenditure function gives:

$$y_e = E(p_r, V(p, y)) \tag{16}$$

[15] The corresponding result for the compensating variation follows by substituting into $CV = E(p_1, U_0) - E(p_0, U_0)$.

[16] In terms of the indirect utility function, y_e is defined by $V(p_r, y_e) = V(p, y)$. This metric was called 'equivalent income' by King (1983), but this term can lead to confusion when used in conjunction with adult equivalent scales.

For the linear expenditure system, this is found to be:

$$y_e = \sum_{i=1}^{n} p_{ri}\gamma_i + \left\{ \prod_{i=1}^{n} \left(\frac{p_{ri}}{p_i} \right)^{\beta_i} \right\} \left\{ y - \sum_{i=1}^{n} p_i \gamma_i \right\} \quad (17)$$

The effect on welfare can be measured in terms of a change in y_e from y_{e0} to y_{e1}, where, as before, the indices 0 and 1 refer to pre- and post-change values respectively. If pre-change prices are used as reference prices, so that $p_{ri} = p_{0i}$ for all i, y_{e1} is simply the value of actual total expenditure after the change less the value of the equivalent variation; that is, $y_{e1} = y_1 - EV$. Hence the proportionate change, $(y_1 - y_{e1})/y_1$, is conveniently the ratio of EV to y_1.

Total Expenditure Elasticities

Given cross-sectional budget data, the total expenditure elasticities, for different household types, can be obtained by first estimating the relationship, for each commodity group, between the budget shares and total household expenditure. If $w_i = p_i x_i / \sum_{i=1}^{n} p_i x_i = p_i x_i / y$ is the budget share of the ith good, a flexible specification that has been found to provide a good fit is (omitting subscripts):[17]

$$w = \delta_1 + \delta_2 \log y + \frac{\delta_3}{y} \quad (18)$$

This form has the convenient property that, if parameters are estimated using ordinary least squares, the adding-up condition, $\sum_{i=1}^{n} w_i = 1$, holds for predicted shares, at all total expenditure levels, y. With the level of disaggregation used, it was necessary to carry out a total of 792 $(22 \times 2 \times 18)$ budget share regressions. Hence these cannot be reported here.

At any given level of y, the expenditure elasticity is given by:

$$e = 1 + \frac{dw}{dy}\frac{y}{w} \quad (19)$$

[17] For further discussion of this form, see Deaton and Muellbauer (1980). One small difficulty with the use of (18) is that ordinary least squares estimators do not guarantee that predicted budget shares are always non-negative. In the few cases where this arises - for very low y, the $w$are replaced by zero, and others are adjusted to ensure additivity.

which can be expressed as:

$$e = 1 + \frac{(y/\delta_3)\,\delta_2 - 1}{(y/\delta_3)\,(\delta_1 + \delta_2 \log y) + 1} \tag{20}$$

so that $e = 0$ for $y = 0$, and converges to 1 as $y \to \infty$ (though of course it may exceed unity over certain ranges of y).

Demand Elasticities

For the linear expenditure system, the total expenditure elasticities are:

$$e_i = \frac{\beta_i}{w_i} \tag{21}$$

Hence, given values of e_i, calculated using (20), the corresponding value of β_i can easily be obtained using (21), as $\beta_i = e_i w_i$.

Cross-sectional budget data do not provide direct information about price responses. However, the own-price elasticities, e_{ii}, and cross-price elasticities, e_{ij}, are obtained using a general property of directly additive utility functions. It was shown by Frisch (1959) that:

$$e_{ij} = -e_i w_j \left(1 + \frac{e_j}{\xi}\right) \tag{22}$$

$$e_{ii} = e_i \left\{\frac{1}{\xi} - w_i \left(1 + \frac{e_i}{\xi}\right)\right\} \tag{23}$$

In these expressions, ξ denotes the elasticity of the marginal utility of total expenditure with respect to total expenditure; this is called the Frisch parameter.

The computation of welfare changes does not actually require each value of γ_i, but the value of $p_i\gamma_i$, the committed expenditure on good i. Given own-price elasticities of demand for each good at each income level, obtained using (23), the committed expenditures can be obtained by making use of the property of the linear expenditure system that:

$$e_{ii} = \frac{\gamma_i\,(1 - \beta_i)}{x_i} - 1 \tag{24}$$

Hence:

$$p_i \gamma_i = \frac{w_i y \left(1 + e_{ii}\right)}{1 - \beta_i} \tag{25}$$

A difficulty is that household budget data cannot provide direct estimates of the Frisch parameter. It is therefore necessary to make use of extraneous information. The results reported above were obtained using a fixed Frisch parameter of -1.9.[18]

Experiments with varying Frisch parameters, allowing the absolute Frisch to fall as total expenditure rises, showed that the results were not sensitive. Hence only the constant case is reported here. Frisch (1959, p.189) himself argued that the parameter would vary with income and some empirical support for this conjecture was found by Lluch *et al.* (1977). Sensitivity analyses were carried out using a flexible specification which extends the logarithmic form used by Lluch *et al.* (1977):

$$\log\left(-\xi\right) = \phi - \alpha \log\left(y + \theta\right) \tag{26}$$

For the LES, it can be shown that $-\xi = y/y^*$, that is the ratio of total expenditure to supernumerary expenditure. A falling absolute Frisch parameter with y means that total committed expenditure rises in absolute and proportional terms as y increases. However, own-price elasticities may rise or fall with y depending on variations in w_i and e_i as well as ξ.

Price Changes

In general the demand functions can be expressed as $x_i = x_i\left(p_1, ..., p_n \left| y\right.\right)$. Holding y constant and differentiating the demand for good i with respect to the prices gives:

$$\dot{x}_i = \sum_{j=1}^{n} e_{ij} \dot{p}_j \tag{27}$$

where the dots again indicate proportionate changes and e_{ij} is the elasticity of demand for i with respect to a change in the price of good j. The proportional

[18] For a review of earlier estimates of the Frisch parameter, see Brown and Deaton (1973). Tulpule and Powell (1978) used a value of $\xi = -1.82$ when calculating elasticities at average income for Australia, based on work of Williams (1978), and this value was adopted by Dixon *et al.* (1982) in calibrating a general equilibrium model.

change in the budget share, $\dot{w}_i$, is:

$$\dot{w}_i = \dot{p}_i + \sum_{j=1}^{n} e_{ij}\dot{p}_j \tag{28}$$

which, as total expenditure is fixed, is equivalent to the proportional change in expenditure on good i.

A convenient feature of the present approach is that the expression for the equivalent variation requires only the percentage changes in prices to be specified. The relevant terms can be expressed in terms of the $\dot{p}$s. Since $p_{1i} = p_{0i}\left(1 + \dot{p}_i\right)$, and defining $s_i = p_{0i}\gamma_i / \sum_i p_{0i}\gamma_i$, it can be shown that $A_1/A_0 = 1 + \sum_i s_i\dot{p}_i$ and $B_1/B_0 = \prod_i \left(1 + \dot{p}_i\right)^{\beta_i}$. Suppose that all prices change by the same proportion. If all prices change in the same proportion, $\dot{p}_i = \dot{p}$ for all i, and $B_1/B_0 = A_1/A_0 = 1 + \dot{p}$.

References

[1] Amiel, Y., Creedy, J. and Hurn, S. (1999) Measuring attitudes towards inequality. *Scandinavian Journal of Economics*, 101, pp. 83-96.

[2] Allen, R. G. D. (1975) *Index Numbers in Theory and Practice.* London: Macmillan.

[3] Atkinson, A. B. (1970) On the measurement of inequality. *Journal of Economic Theory,* 2, pp. 244-263.

[4] Barker, F. (2002) Consumption externalities and the role of government: the case of alcohol. *New Zealand Treasury Working Paper*, no. 02/25.

[5] Brown, J. A. C. and Deaton, A. S. (1973) Models of Consumer Behaviour. In *Surveys of Applied Economics*, I, pp. 177-268. London: Macmillan.

[6] Creedy, J. (2003) The excess burden of taxation and why it (approximately) quadruples when the tax rate doubles. *New Zealand Treasury Working Paper,* no. .

[7] Creedy, J. (1998a) Measuring the welfare effects of price changes: a convenient parametric approach. *Australian Economic Papers*, 37, pp. 137-151.

[8] Creedy, J. (1998b) *Measuring Welfare Changes and Tax Burdens.* Cheltenham: Edward Elgar.

[9] Davies, P. (2003) Efficiency implications of a petrol tax in the Auckland region: report to Auckland regional transport funding steering group. *New Zealand Institute of Economic Research Report* (September).

[10] Deaton, A. S. (1974) A Reconsideration of the Empirical Implications of Additive Preferences. *Economic Journal,* 84, pp. 338-348.

[11] Deaton, A. S. and Muellbauer, J. (1980) *Economics and Consumer Behaviour.* Cambridge: Cambridge University Press.

[12] Dixon, P., Parmenter, B. R., Sutton, J. and Vincent, D. P. (1982) *ORANI: A Multisectoral Model of the Australian Economy.* Amsterdam: North Holland Publishing Company.

[13] Fortin, B. and Truchon, M. (1993) On Reforming the Welfare System: Workfare Meets the Negative Income Tax. *Journal of Public Economics,* 51, pp. 119-151.

[14] Frisch, R. (1959) A Complete Scheme for Computing All Direct and Cross Demand Elasticities in a Model With Many Sectors. *Econometrica*, 27, pp. 177-196.

[15] King, M. A. (1983) Welfare Analysis of Tax Reforms Using Household Data. *Journal of Public Economics*, 21, pp. 183-214.

[16] Lluch, C., Powell, A. A. and Williams, R. A. (1977) *Patterns in Household Demand and Saving.* Oxford: Oxford University Press for the World Bank.

[17] Powell, A. A. (1974) *Empirical Analytics of Demand Systems.* Lexington, Massachusetts: Lexington Books.

[18] Roberts, K. (1980) Price-Independent Welfare Prescriptions. *Journal of Public Economics*, 18, pp. 277-297.

[19] Tulpule, A. and Powell, A. A. (1978) *Estimates of Household Demand Elasticities for the Orani Model.* IMPACT Project Preliminary Working Paper, OP-22.

[20] Williams, R. A. (1978) The Use of Disaggregated Cross-Section Data in Explaining Shifts in Australian Consumer Demand Patterns Over Time. *Impact Project Research Paper*, SP-13.

[21] Young, L. (2002) *Ad valorem* indirect tax rates in New Zealand. New Zealand Treasury Internal Paper (#435217).