

APPENDIX A

HOUSEHOLD SURVEY QUESTIONNAIRE AND PROMPT CARDS

Survey conducted by the Dater Co-operative Ltd.

RESIDENTIAL DEMAND FOR WATER

		INTERVIEWER CODE	
Type of dwelling:			
☐ 1	☐ 2	☐ 3	☐ 4
house duplex one unit of 3 or more other (specify) _____			
1. How old is this building?			
☐ 1	☐ 2	☐ 3	
10 years or less	11-20 years	more than 20 years	
2. In which year did you start living here?			
☐ 1	☐ 2	☐ 3	☐ 4
☐ 5	☐ 6	☐ 7	
1982	1981	1980	1979
1978	1977	1976 or before	
3. Do you own or rent this house?			
☐ 1	☐ 2	☐ 3	
own	rent	other (specify) _____	
4. How many permanent residents have lived here (or are living here) for each of the following years? (i.e. people who have lived here (or are expected to live here) for at least 8 months of each year)			
This year (1982/83)			
Last year (1981/82)			
Year before last (1980/81)			
Next year (1983/84)??			
5. Do you have a rainwater tank or bore?			
No ☐ 0	Yes ☐	If yes, which is the most important use of rain/bore water to you?	
		drinking and food preparation	☐ 1
		personal washing	☐ 2
		gardening	☐ 3
		other (specify) _____	☐ 4
6. Which of the following facilities do you <u>now</u> have and how long have you been using them?			
	No	Yes	YEARS
(a) Dishwasher	☐	☐	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7+
(b) Garbage disposal unit	☐	☐	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7+
(c) Swimming pool	☐	☐	☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7+
SIZE? _____ x _____			

2

7. During summer, how much do you water your garden/lawn?

☐ 1☐ 2☐ 3☐ 4

never

lightly

a medium amount

heavily

8. Do you have any complaints about mains water quality or pressure?

No ☐Yes ☐

colour

flavour

additives

other (specify) _____

number of complaints ☐

9. As you know, the Water Board has introduced a new system of charges made up of a fixed charge based on the value of your land and a variable charge for the water you actually use. The fixed charge for your property this year is \$ _____. If you use the same quantity of water as you did last year (_____ k1) the variable charge will be \$ _____.

Bearing these new charges in mind, do you think that water is

☐ 1☐ 2☐ 3

cheap

reasonably priced

or expensive?

*1). The next 2 questions are about methods which could be used by households to reduce water usage.

(a) During the past four years you may have tried to reduce your water use in some way. If so, what methods of water saving have you been using?
(show card 1)

(b) If you were to reduce your water usage in the future, which methods in addition to those you already use, would you use?

INDOOR

Less time in shower

Bath sharing

Avoid running water into unplugged basins/sinks

Fix dripping taps/houses

Reduce water used in toilet flushing

Use a washing machine which uses less water

Use a suds saver

Re-use water

Restrict the use of washing machine/dishwasher

Wash dishes less frequently

Other (specify) _____

Number of methods
used in past ☐

Number of methods
for future ☐

10. Cont.

OUTDOOR

Handwater lawn/garden

Water less often

Limit the use of sprinklers

Use buckets/watering cans

Use trickle systems

Reduce lawn area e.g. put down paving

Put in native plants

Use woodchips/mulch

Wash car/boat on lawn or with a bucket

Collect rain water

Other (specify) -----

Number of methods
used in the past ☐Number of methods
for future ☐

- *11. In a period of serious water shortage, it might be necessary for the Water Board to impose measures to reduce mains water usage.

Following is a list of possible measures which could be taken. Please rate them according to whether you would find them easy or hard for your household, using the scale [card 2]

	Easy	Annoy- ing	Hard	Very hard	Unacceptable
(a) Restrict times for lawn and garden watering.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
(b) Restrict watering to hand-held hoses.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
(c) Ban complete emptying and refilling of swimming pools. [code as 0 if no pool]	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
(d) Increase water charges per kilolitre by 50%.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
(e) Increase water charges for usage above 500 kl.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
(f) Limit, to last years usage, the amount of water each household could use.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

12. If the Water Board was finding it difficult to supply the quantity of water demanded and only 2 alternatives were available, do you think it would be better to:

increase water prices and increase storage capacity ☐ 1
or to apply permanent water restrictions? ☐ 2

4

- *13. Please study the water use summary card carefully (card 3). Remember, under the new pricing structure you will pay a variable charge for the water you actually use and a fixed charge.

The fixed charge for your property this year is \$_____.

Last year you used _____ kilolitres.

Assuming that water restrictions do not apply, how much water do you think your household would like to buy per year, at each of the following prices?

30c per kilolitre (card 4) _____ kl
 60c per kilolitre (card 5) _____ kl
 90c per kilolitre (card 6) _____ kl
 \$1.20 per kilolitre (card 7) _____ kl

- *14. (a) Consider now the situation where your household has the right to _____ kilolitres of water, but you still have to pay 60c per kilolitre if you use any of this quota. If the Water Board wanted to supply new customers but had no spare water, how much of your household's quota would you be prepared to give up?

_____ kl

- (b) Having given up _____ kl, your remaining quota is _____ kl.

How much of this would you be prepared to give up if the Water Board offered you a rebate of 60c for every kilolitre given up? (card 8)

_____ kl

- (c) Now your quota is _____ kl.

How much more water would you give up if you were offered \$1.20 for every kilolitre given up? (card 9)

_____ kl

- (d) Now your quota is only _____ kl.

How much of this would you give up if you were offered \$3.00 for every kilolitre given up? (card 10)

_____ kl

5

*15. Are you prepared to answer a question on income level?

No ☐ 0 Yes - (card 11)

- (k) 0 - 3,999 ☐ 1
 (l) 4,000 - 7,999 ☐ 2
 (m) 8,000 - 11,999 ☐ 3
 (n) 12,000 - 15,999 ☐ 4
 (o) 16,000 - 19,999 ☐ 5
 (p) 20,000 - 23,999 ☐ 6
 (q) 24,000 - 27,999 ☐ 7
 (r) 28,000 or more ☐ 8

household head ☐

household total ☐

*16. Are you prepared to tell us the present or last occupation of the household head?

No ☐ 0 Yes - Professional etc. ☐ 1

Administrative etc. ☐ 2

Clerical ☐ 3

Sales ☐ 4

Farmers etc. ☐ 5

Miners etc. ☐ 6

Transport etc. ☐ 7

Tradesmen etc. ☐ 8

Service etc. ☐ 9

Code first box as:

0 Retired/pensioner/home duties

1 Unemployed

2 Now employed

*17. Are you prepared to tell us the age group of the household head?

No ☐ 0 Yes - (card 12)

(k) < 20 ☐ 1

(l) 20 - 29 ☐ 2

(m) 30 - 39 ☐ 3

(n) 40 - 49 ☐ 4

(o) 50 - 59 ☐ 5

(p) 60 or more ☐ 6

18. What is your main reason for helping us with this survey?

Concerned about new water charges ☐ 1

Concerned about water wastage ☐ 2

Like to co-operate with University research ☐ 3

Other (specify) _____ ☐ 4

1.

Water Saving Methods**INDOOR**

Less time in shower
Bath sharing
Avoid running water into unplugged basins/sinks
Fix dripping taps/hoses
Reduce the water used in toilet flushing
Use a washing machine which requires less water
Use a suds saver
Re-use water
Restrict use of washing machine/dishwasher
Wash dishes less frequently
Other (please tell interviewer if you use other methods)

OUTDOOR

Handwater lawn/garden
Water less often
Limit use of sprinklers
Use buckets/watering cans
Use trickle systems
Reduce lawn area e.g. put down paving
Put in native plants
Use woodchips/mulch
Wash car/boat on the lawn or with a bucket
Collect rain water
Other (please tell interviewer if you use other methods)

2.

Easy (1)

Annoying (2)

Hard (3)

Very hard (4)

Unacceptable (5)

3.

Water Use Summary

The following are average use rates (obtained from other studies) and are not necessarily an indication of water use patterns of particular people.

ACTIVITY	AVERAGE NUMBER OF LITRES USED PER PERSON PER DAY	AVERAGE NUMBER OF KILOLITRES USED PER PERSON PER YEAR	PERCENTAGE OF TOTAL WATER USED
DISHWASHING	17	6.2	8
CLOTHESWASHING	33	12	16
TOILET FLUSHING	37	13.5	18
SHOWERING	34	12.4	17
BATHING	20	7.3	10
DRINKING ETC.	8	2.9	4
CAR WASHING	4	1.5	2
LEAKAGES, GARDEN USES AND OTHER USES	53	19.2	25
TOTAL	206 LITRES	75 KILOLITRES	100%

*Please note that the above are usage figures per person. Average household usage can be calculated by multiplying by the number of permanent residents.

4.

<u>COST</u>	<u>AMOUNT PURCHASED</u>	<u>ANNUAL COST</u>	<u>COST PER WEEK</u>
<u>30¢ per kilolitre</u>	50 k1	\$15.00	29¢
	100 k1	\$30.00	58¢
	150 k1	\$45.00	87¢
	200 k1	\$60.00	\$1.15
	250 k1	\$75.00	\$1.44
	300 k1	\$90.00	\$1.73
	400 k1	\$120.00	\$2.31
	500 k1	\$150.00	\$2.88

5.

<u>COST</u>	<u>AMOUNT PURCHASED</u>	<u>ANNUAL COST</u>	<u>COST PER WEEK</u>
<u>60¢ per kilolitre</u>	50 kl	\$30.00	58¢
	100 kl	\$60.00	\$1.15
	150 kl	\$90.00	\$1.73
	200 kl	\$120.00	\$2.31
	250 kl	\$150.00	\$2.88
	300 kl	\$180.00	\$3.46
	400 kl	\$240.00	\$4.62
	500 kl	\$300.00	\$5.77

6.

<u>COST</u>	<u>AMOUNT PURCHASED</u>	<u>ANNUAL COST</u>	<u>COST PER WEEK</u>
<u>90¢ per kilolitre</u>	50 k1	\$45.00	87¢
	100 k1	\$90.00	\$1.73
	150 k1	\$135.00	\$2.60
	200 k1	\$180.00	\$3.46
	300 k1	\$270.00	\$5.19
	400 k1	\$360.00	\$6.92
	500 k1	\$450.00	\$8.65

7.

<u>COST</u>	<u>AMOUNT PURCHASED</u>	<u>ANNUAL COST</u>	<u>COST PER WEEK</u>
<u>\$1.20 per kilolitre</u>	50 k1	\$60.00	\$1.15
	100 k1	\$120.00	\$2.31
	150 k1	\$180.00	\$3.46
	200 k1	\$240.00	\$4.62
	250 k1	\$300.00	\$5.77
	300 k1	\$360.00	\$6.92
	400 k1	\$480.00	\$9.23
	500 k1	\$600.00	\$11.54

8.

<u>COMPENSATION</u>	<u>AMOUNT GIVEN UP</u>	<u>ANNUAL VALUE</u>	<u>VALUE PER WEEK</u>
<u>60¢ per kilolitre</u>	10 k1	\$6.00	12¢
	50 k1	\$30.00	58¢
	100 k1	\$60.00	\$1.15
	200 k1	\$120.00	\$2.31

9.

<u>COMPENSATION</u>	<u>AMOUNT GIVEN UP</u>	<u>ANNUAL VALUE</u>	<u>VALUE PER WEEK</u>
<u>\$1.20 per kilolitre</u>	10 k1	\$12.00	23¢
	50 k1	\$60.00	\$1.15
	100 k1	\$120.00	\$2.31
	200 k1	\$240.00	\$4.62

10.

<u>COMPENSATION</u>	<u>AMOUNT GIVEN UP</u>	<u>ANNUAL VALUE</u>	<u>VALUE PER WEEK</u>
<u>\$3.00 per kilolitre</u>	10 k1	\$30.00	58¢
	50 k1	\$150.00	\$2.88
	100 k1	\$300.00	\$5.77
	200 k1	\$600.00	\$11.54

11.

INCOME

	<u>PER ANNUM</u>	<u>PER WEEK</u>
(k)	0 - \$3,999	0 - \$77.00
(l)	\$4,000 - \$7,999	\$78.00 - \$154.00
(m)	\$8,000 - \$11,999	\$155.00 - \$231.00
(n)	\$12,000 - \$15,999	\$232.00 - \$308.00
(o)	\$16,000 - \$19,999	\$309.00 - \$385.00
(p)	\$20,000 - \$23,999	\$386.00 - \$462.00
(q)	\$24,000 - \$27,999	\$463.00 - \$538.00
(r)	\$28,000 or more	\$539.00 or more

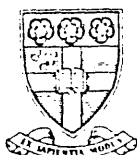
12.

AGE GROUP (household head)

- (k) 19 or less
- (l) 20 - 29
- (m) 30 - 39
- (n) 40 - 49
- (o) 50 - 59
- (p) 60 or more

APPENDIX B

HOUSEHOLD SURVEY MAIL ENCLOSURES



DEPARTMENT OF AGRICULTURAL ECONOMICS AND BUSINESS MANAGEMENT
THE UNIVERSITY OF NEW ENGLAND
ARMIDALE, N.S.W. 2351, AUSTRALIA

10th September, 1982

TELEPHONE (0671) 73 3333
TELEX 86050

Dear Sir/Madam,

You are probably aware that there is growing concern in the Newcastle community that water charges are unfair. You may also be aware that Australia faces long-term water problems which are quite independent of the current dry season. Decisions of water authorities about the management of water and about water charges are now more important than ever.

We are conducting independent University research designed to identify important aspects of the demand for water in residential areas. We hope that the information we gain will be useful for influencing water supply authorities in their setting of charges for water.

The purpose of this letter is to seek your assistance with this research. Your household is one of 1600 which have been selected at random from a list of households in the Hunter Region. We would like to send an interviewer from the Datex Co-operative Limited to your home at a time of your choice, to conduct a twenty to thirty minute interview with the head of your household or his/her representative. As well, we would like your permission to collect from the Hunter District Water Board, your total water usage figures for the past three years. While this information will be vital to our research we could, if you wish, tell you how much you paid for water under the old pricing policy and how much you would pay for the same quantity of water under the new pricing regime. Our interviewer will have this information for you.

If you are prepared to help us in these ways, could you please complete the enclosed form and return it to us in the reply paid envelope as soon as possible. Also enclosed is some information on water use which we hope will be of interest to you.

You have our sincere assurance that all information obtained will be treated in an absolutely confidential way. Results of our research will not include your identity in any way and discussion will be in terms of group averages and similar statistics. A summary of our results will be provided to all participants in the survey.

We hope that you'll agree with us, that the more information about consumer preferences (with regard to water supply) that can be conveyed to water supply authorities, the better they should be able to serve community needs.

Yours sincerely,

Warren Musgrave,
Professor of Agricultural Economics
and Head of Department.

Encls.

The Cost of Water Supplied by The Hunter District Water Board

1. For customers connected to both water and sewerage
 - (a) A fixed charge:
 - 1.25¢ per dollar of 1977 unimproved land value for water
 - 1.25¢ per dollar of 1977 unimproved land value for sewerage
 - (for a block worth \$7,500 in 1977 this amounts to \$187.50 per year or \$3.60 per week)
 - (b) Plus a charge for water used:
 - 60¢ per kilolitre (40¢ for water, 20¢ for sewage)

2. For customers connected to water only
 - (a) A fixed charge:
 - 1.25¢ per dollar of 1977 unimproved land value
 - (for a block worth \$7,500 in 1977 this amounts to \$93.75 per year or \$1.80 per week)
 - (b) Plus a charge for water used:
 - 40¢ per kilolitre

3. In some areas there is also a charge for stormwater drainage but this is not a concern of our research, since such surface drainage is not connected to the water supply or sewerage systems.

Tenants

People who are renting the house in which they live were not responsible for water rates under the old pricing structure. However, under the new pricing policy, agreement on water charges will need to be reached between owner and tenant. For example, the owner may pay the fixed charge and the tenant may be responsible for the cost of water actually used.

Water Use Rates

The following information represents an approximation of average water usage for the tasks listed. Actual use rates by individuals or households may be substantially different from those below. However, they do represent a reasonable guide to the household.

Please note: one kilolitre equals one thousand (1000) litres.

Dishwashing (by hand)	18 litres per wash	(54 litres per day)
(by machine)	42 litres per wash	
	plus 14 litres for hand washed items	(84 litres per day)
Clothes washing (automatic and semi-automatic)	155 litres per wash	(4.3 kg or 10 pounds of clothes)
(non-automatic)	90 litres per wash	(4.3 kg of clothes)
Toilet flushing (public sewerage)	11 litres per flush	(44 litres per person per day)
(septic tank)	3.5 litres per flush	(14 litres per person per day)
Shower (approximately 5 minutes)	55 litres	
Bath	120 litres	
Drinking, cooking, house cleaning	8 litres per person per day	
Car wash (bucket)	70 litres per wash	
(running hose)	200 litres per wash	
Garbage disposal unit	30 litres per day	
Leakages and wastage	32 litres per person per day	

Water Use Summary

The following are average use rates (obtained from other studies) and are not necessarily an indication of water use patterns of particular people.

ACTIVITY	AVERAGE NUMBER OF LITRES USED PER PERSON PER DAY	AVERAGE NUMBER OF KILOLITRES USED PER PERSON PER YEAR	PERCENTAGE OF TOTAL WATER USED
DISHWASHING	17	6.2	8
CLOTHESWASHING	33	12	16
TOILET FLUSHING	37	13.5	18
SHOWERING	34	12.4	17
BATHING	20	7.3	10
DRINKING ETC.	8	2.9	4
CAR WASHING	4	1.5	2
LEAKAGES, GARDEN USES AND OTHER USES	53	19.2	25
TOTAL	206 LITRES	75 KILOLITRES	100%

*Please note that the above are usage figures per person. Average household usage can be calculated by multiplying by the number of permanent residents.

Water Saving Methods

INDOOR

Less time in shower
 Bath sharing
 Avoid running water into unplugged basins/sinks
 Fix dripping taps/hoses
 Reduce the water used in toilet flushing (e.g. place a brick in cistern)
 Install a dual flush cistern in toilet (small flush for liquids, large for solids)
 Use a washing machine which requires less water
 Use a suds saver
 Re-use water
 Restrict use of washing machine/dishwasher
 Wash dishes less frequently

OUTDOOR

Handwater lawn/garden
 Watering three times a week
 Watering twice a week
 Water lawn/garden at night only
 Limit use of sprinklers
 Use buckets/watering cans
 Use trickle systems
 Reduce lawn area
 Put down paving
 Put in native plants
 Use woodchips/mulch
 Wash car/boat on the lawn or with a bucket (e.g. use swimming pool or wash water for garden)
 Re-use water
 Collect rain water



DEPARTMENT OF AGRICULTURAL ECONOMICS AND BUSINESS MANAGEMENT

THE UNIVERSITY OF NEW ENGLAND

ARMIDALE, N.S.W. 2351, AUSTRALIA

TELEPHONE (067) 73 3333

TELEX 66050

RESEARCH PROJECT: AN EVALUATION OF THE DEMAND FOR WATER

I am willing to offer my help and co-operation for the above-mentioned research project and give permission to University research staff to obtain from Hunter District Water Board records, my household's water use over the last three years.

I realise that my assistance will involve one interview of twenty to thirty minutes at my home, at a time to be arranged.

I understand that all information about my household will be treated as confidential and will only be used for statistical analysis.

----- (signature)

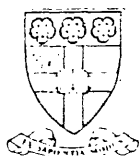
So that we can contact you to arrange a suitable interview time and date, could you please write down your telephone number.

If you do not have a telephone, could you please specify a general time of day during which you are likely to be at home and available for your interview.

Please return in the reply paid envelope provided, to:

Professor W.F. Musgrave,
Department of Agricultural Economics
and Business Management,
The University of New England,
Armidale, N.S.W. 2351

If you require further information please contact the Datex Co-operative Limited of Newcastle (phone 691851) or Professor Musgrave of Armidale (phone 067 732280).



DEPARTMENT OF AGRICULTURAL ECONOMICS AND BUSINESS MANAGEMENT

THE UNIVERSITY OF NEW ENGLAND

ARMIDALE, N.S.W. 2351, AUSTRALIA

IN REPLY PLEASE QUOTE

WFM:s1

TELEPHONE (067) 73 3333

TELEX 66050

11th October, 1982

Dear Sir/Madam,

Several weeks ago you may recall that I wrote to you about some research we are undertaking into the demand for water by households. In that letter I asked if you would be willing to participate in our survey of households in the Newcastle area.

As yet we have not heard that you are willing to participate in the survey. This may, of course, be because you find yourself unable to participate. I am writing to you now in the hope that you can participate but for some reason have not been able to respond to our earlier approach. If you are able to help us would you please complete the enclosed form and return it in the reply-paid envelope provided?

The research project was initiated, not because of particular problems in Newcastle, but because of general pressures on water supplies which we believe are emerging throughout Australia. The results of our study are intended to help water managers in tackling these emerging problems. Since starting the project the particular problems of Newcastle, with which you are no doubt familiar, emerged. Both the Hunter District Water Board and the Hunter District Water Board Consumer's Committee see our study as being important in tackling the water problem of Newcastle and they are strongly supporting the project. Your support of the project would also be most helpful. I should be most grateful if you could assist by participating in a brief interview at your home at a time which is convenient to you.

I look forward to hearing from you.

Yours sincerely,



Warren Musgrave,
Professor of Agricultural Economics
and Head of Department.

Encl.

APPENDIX C

STATISTICAL METHODS AND TEST STATISTICS

This appendix is devoted to a review of the statistical methods and test statistics used in the present study. The appendix is divided into five sections. In the first, the least-squares regression model is presented and some of the statistical problems which are likely to arise in empirical demand analysis are discussed. The test statistics reported in Chapter 4 are also outlined. In the second section, the Box-Cox regression framework is described. In the third, tests of the statistical significance of estimated elasticities are outlined and in the fourth, tests of the statistical significance of the difference between two means are outlined. In the final section, details of a procedure for testing for homogeneity of degree zero are presented.

C.1 The Least-squares Model

Least-squares regression is a technique which produces best (minimum variance) linear unbiased estimates of parameters. The general form of a single regression equation may be written in matrix notation as follows:

$$Y = XB + u$$

where $Y = (n \times 1)$ column vector containing the values of the dependent variable at each observation y_i ;
 $X = (n \times k)$ matrix of explanatory variables (x_{ij} represents the i^{th} observation on the j^{th} variable);
 $B = (k \times 1)$ column vector of parameters, B_j ; and
 $u = (n \times 1)$ column vector of disturbances u_i .

The estimation procedure involves minimising the sum of squares of the residuals (estimated disturbances), defined as:

$$\begin{aligned} e_i &= y_i - X_i \hat{B} \\ &= y_i - \hat{y}_i \quad (i = 1, 2, \dots, n) \end{aligned}$$

where $X_i =$ row vector of explanatory variables;
 $\hat{B} =$ column vector of estimated coefficients; and
 $\hat{y}_i =$ predicted value of y_i .

The sum of squares of the residuals is defined as:

$$\begin{aligned} \text{RSS} &= \sum_{i=1}^n e_i^2 \\ &= \sum_{i=1}^n (y_i - X_i \hat{B})^2 \end{aligned}$$

This is minimised by setting to zero the first-order derivatives with respect to $\hat{B}$, yielding the estimating equation:

$$\hat{B} = (X'X)^{-1} X'Y.$$

There are four major assumptions upon which least-squares regression analysis is based:

- (a) the expected (or mean) value of the disturbances is zero;
- (b) disturbances are uncorrelated;
- (c) disturbance variance is constant (that is, homoscedastic); and
- (d) the matrix of explanatory variables is fixed and has a rank of k , equal to the number of explanatory variables.

C.1.1 Heteroscedasticity

Heteroscedasticity violates the assumption that variances of the stochastic disturbance term are finite and constant over the sample. Heteroscedasticity causes estimates to be inefficient in the sense that they are no longer minimum-variance estimators. Estimates are also biased so that t tests and F tests are invalid.

Essentially, traditional testing for heteroscedasticity involves the dividing of large samples into several sub-samples, based on the level of a relevant explanatory variable, and calculation of the variances of each sub-sample. If the variances of each sub-sample differ markedly, then heteroscedasticity is evident. The Goldfeld-Quandt test (Goldfeld and Quandt 1965) is based on such a procedure.

The test used in this study was the Breusch-Pagan test (Breusch and Pagan 1979) which does not require the ordering of data, although it is a powerful test for heteroscedasticity (Judge et al. 1980, p.146). In this test it is assumed that:

$$s_i^2 = f(z_i'a)$$

where s_i^2 = variance of the residuals;

f = a function independent of the observation, i ;

a = a vector of unknown parameters; and

z_i = a vector of non-stochastic variables which may be identical to, or a function of, the regression variables.

Under the null hypothesis of homoscedasticity and the assumption that the residuals are distributed normally, the Breusch-Pagan test requires that half of the regression sum of squares from

$$e_i^2/s^2 = z_i'a + v_i$$

is distributed as χ^2 with $(K-1)$ degrees of freedom, where e_i are the residuals from the preferred regression model and

$$s^2 = \sum_{i=1}^N e_i^2/N.$$

Overcoming the problem of heteroscedasticity involves the scaling or weighting of observations by the use of generalised least-squares estimation. The weighting procedure makes use of estimates of s_i , which are not constant. In matrix notation, the homoscedastic model is specified as:

$$\hat{B} = (X'X)^{-1}X'Y.$$

However, the heteroscedastic model makes use of:

$$P = \begin{vmatrix} 1/s_1 & 0 & 0 \\ 0 & 1/s_2 & 0 \\ & & \ddots \\ 0 & 0 & 1/s_i \end{vmatrix} ;$$

$$Y^* = PY; \text{ and}$$

$$X^* = XP.$$

$$\begin{aligned} \text{Therefore, } \hat{B} &= (X^{*'}X^*)^{-1}X^{*'}Y^* \\ &= (X'P'PX)^{-1}X'P'PY \\ &= (X'Q^{-1}X)^{-1}X'Q^{-1}Y \end{aligned}$$

$$\text{where } P'P = Q^{-1} = \begin{vmatrix} 1/s_1^2 & 0 & 0 \\ 0 & 1/s_2^2 & 0 \\ & & \ddots \\ 0 & 0 & 1/s_i^2 \end{vmatrix} ; \text{ and}$$

$$\text{Cov}(\hat{B}) = (X'Q^{-1}X)^{-1}X.$$

Unfortunately the true error variances are unknown in empirical studies. Therefore, estimates must be made. These estimates are obtained from hypothesised relationships between the variance of the residuals and particular explanatory variables. In cross-sectional analysis of consumption, it is likely that the income variable will be related to residual variances (Intriligator 1978, p.156). The Breusch-Pagan test is suitable for detecting this type of heteroscedasticity. If the relationship is of a simple linear type, then the matrix, P , will contain non-zero diagonal elements $1/x_i$.

C.1.2 Autocorrelation

One of the assumptions underlying least-squares regression analysis is that the disturbances are uncorrelated. This implies that successive disturbances are drawn independently of previous values. Therefore, it is necessary to test estimated models to ascertain whether or not this

assumption is violated. That is, one must test for the presence of autocorrelation, the condition of correlated disturbances, since such a condition results in a loss in the efficiency of parameter estimation and under-estimated sampling variances (Johnston 1963, p.179).

The test used for the detection of autocorrelation in the present study was that of Durbin and Watson (1951). This test is detailed in many econometric texts, including Johnston (1960), Judge et al. (1980), Theil (1971) and Pindyck and Rubinfeld (1981). The test statistic, d , is defined as:

$$d = \frac{\sum_{i=2}^N (e_i - e_{i-1})^2}{\sum_{i=1}^N e_i^2}$$

where e_i = residual (estimated disturbance) at observation i .

This statistic lies between zero and four, with a value of approximately two indicating the absence of first-order autocorrelation (Pindyck and Rubinfeld 1981, p.159).

In cases where a lagged dependent variable is included in the regressor set, however, the Durbin-Watson statistic cannot be used. In such cases the 'h' statistic (Durbin 1970) should be utilised (Pindyck and Rubinfeld 1981, p.194). This is defined as:

$$h = (1 - d/2) (N / 1 - N[s_b^2])^{0.5}$$

where d = Durbin-Watson statistic;
 N = number of observations; and
 s_b^2 = variance of the estimated coefficient of the lagged dependent variable.

The h statistic is approximately normally distributed with unit variance. Therefore, with reasonably large samples, as in the present study, h statistics which fall between -2 and 2 indicate that first-order autocorrelation is not apparent. The h statistics have been reported in Chapter 4 because the use of a variable describing the previous year's water use in the preferred model formulation is analogous to using a lagged dependent variable.

C.1.3 Normality of the Residuals

Least-squares regression analysis is not dependent upon disturbances being drawn from a normal distribution. However, normally distributed disturbances are necessary for the appearance of unbiased results from tests of significance (Judge et al. 1980, p.300; Jarque and Bera 1980, p.255).

Since the t and F tests rest on the assumption that the stochastic disturbances are normally distributed, such tests can be valid only when that assumption holds. A test for normality in the residuals will, therefore, be a guide to the relevance of the assumption for the particular set of data being examined. If the assumption of normality is violated, then it may be necessary to transform the data or to apply a type of analysis other than least-squares regression.

A widespread test for normality is the chi-square 'goodness-of-fit' test. The Shapiro-Wilk statistic is also used widely in empirical economic studies. In addition, coefficients of skewness and kurtosis and the Jarque-Bera chi-square test (Jarque and Bera 1980) provide valuable guidance as to the normality or otherwise of the disturbances.

The chi-square test involves the grouping of the residuals into classes so that a frequency distribution is formed and the mean and standard deviation calculated. Given the mean and standard deviation, a normal distribution is fitted and expected frequencies (f_1') in each class are obtained. The test criterion is (Snedecor and Cochran 1967, pp.84-5):

$$\chi^2_{c.a.l.c} = \sum_{i=1}^k (f_i - f_i')^2 / f_i' \sim \chi^2_{k-1-r}$$

where k = number of classes;
 f_i = observed frequencies; and
 r = number of parameters estimated.

The Shapiro-Wilk statistic (Shapiro and Wilk 1965) which involves the use of best linear unbiased with scalar covariance matrix (BLUS) residuals, also enables one to test for normality in the disturbances.¹ It is defined as:

$$W = \left(\sum_{i=1}^h a_{in} [\tilde{e}_{(n-i+1)} - \tilde{e}_{(i)}] \right)^2 / \sum_{i=1}^n (\tilde{e}_{(i)} - \tilde{\bar{e}})^2$$

where n = number of observations minus the number
of parameters in the regression equation;
 $\tilde{e}_{(1)} \leq \tilde{e}_{(2)} \leq \dots \leq \tilde{e}_{(n)}$ = ordered BLUS residuals;
 $\tilde{\bar{e}} = \sum_{i=1}^n \tilde{e}_{(i)} / n$;
 $h = n/2$ or $(n-1)/2$ according to whether n is even
or odd; and
 a_{in} = coefficients tabulated by Shapiro and
Wilk (1965).

The test for normality uses the null hypothesis that the disturbances are normally distributed, with the critical region given by low W values. Significant points are tabulated in Shapiro and Wilk (1965).

The Jarque-Bera asymptotic LM normality test statistic was outlined

¹A detailed treatment of BLUS residuals is given by Judge et al. (1980) and by Theil (1972). The mathematical details of their derivation are beyond the scope of this study but it is appropriate to note their characteristics: a set of BLUS residuals is a linear function of the dependent variable; is unbiased; is homoscedastic; and is not autocorrelated (Judge et al. 1980, p.120).

by Bera and Jarque (1981). The author in the present study was able to use this statistic because it was included in the output of the programme, SHAZAM, which was used to obtain the results reported in Chapter 4. It is inappropriate to present the full details of the test in the present study, although it is pertinent to point out that the test statistic is asymptotically distributed as chi square.

Finally, consider normality in terms of the skewness and kurtosis of the distribution. A measure of the amount of skewness in a sample is given by the value of the third moment about the mean. The coefficient of skewness is calculated as:

$$g_1 = m_3 / (m_2^{3/2})$$

where $m_3 = \sum (e_i - \bar{e})^3 / n$; and

$$m_2 = \sum (e_i - \bar{e})^2 / n.$$

If the sample is drawn from a normal population, g_1 is approximately normally distributed with a mean of zero and a standard deviation of $(6/n)^{0.5}$. Therefore, if $|g_1|$ exceeds approximately $2.(6/n)^{0.5}$, normality is rejected at the .05 probability level (Snedecor and Cochran 1967, p.86).

The coefficient of kurtosis may be calculated as:

$$g_2 = (m_4 / m_2^2) - 3$$

where $m_4 = \sum (e_i - \bar{e})^4 / n$.

If the result is positive, the distribution is peaked compared to the normal distribution and if it is negative, the distribution is relatively flat topped (Snedecor and Cochran 1967, p.87).

In relation to test statistics derived from regressions which yield non-normal residuals, it has long been 'common belief' that if the residuals do not diverge widely from a normal distribution, that is, provided the residuals form an essentially bell-shaped histogram, then t and F test statistics are likely to be robust. Such a 'rule-of-thumb'

follows from the work of such researchers as Pearson (1931) and Box and Watson (1962).

C.1.4 Multicollinearity

The rank condition, that the rank of X (the matrix of regressor variables) equals k , ensures that no column is a linear combination of another. If one column is a linear combination of another and, therefore, the rank condition is violated, there exists perfect multicollinearity. If such is the case the required inverse matrix does not exist.

A much more frequent problem, and one which is more difficult to detect and rectify, is where one column of the X matrix is almost a linear combination of another. If the value of the determinant of $X'X$ is almost zero, then $(X'X)^{-1}$ will tend to have large diagonal elements, thus resulting in large standard errors of estimated coefficients. In addition, the R^2 may be high, as may be the calculated F statistic. Such results show that the explanatory variables, as a set, may be correct but the separate effects of each are indistinguishable. As well, the omission of variables may have severe effects on the explanatory power of the model.

Essentially, the problem is one of experimental design and data deficiency, leading to a lack of sufficient information and ambiguity of statistical results. This occurs in economic analyses because of the frequent existence of relationships among the set of explanatory variables. For example, in demand studies, wealth and income appear frequently in regression equations. However, these variables are likely to be related in a strongly positive way in cross-sectional studies. Such collinearity results in the problems outlined above.

Detection of multicollinearity is generally afforded by the use of 'rules-of-thumb', although these rules are largely ineffective (Judge et al. 1980, p.458). One guide is the relative size of simple correlations among regressors. If the correlation coefficient is greater than 0.8 and/or greater than the R^2 for the equation, then multicollinearity may

be a problem. Another guide to be used is that obtained from regressing the dependent variable on sub-groups of explanatory variables and detecting by how much R^2 values differ. If the difference is small when a variable is omitted, then multicollinearity, or model mis-specification, may be a problem.

The relative sizes of F , R^2 and t statistics also offer guidance as to the presence of multicollinearity. It is suggested that an indication of the problem is given when F and R^2 statistics are high but t -values are low. A fifth method of detection relates to the relative size of the determinant of the $X'X$ matrix, although Judge et al. (1980, p.461) dismiss this method as largely irrelevant to applied workers. A sixth technique, although not amenable to the separation of inter-relationships among independent variables, is to regress each of the independent variables upon all other explanatory variables. If the R^2 is high for these auxiliary regressions, near-linear dependence between regressors is indicated. Following from this technique, is that using the 'variance inflation factor' which makes use of the diagonal elements of the $(X'X)^{-1}$ matrix for the auxiliary regressions, but which is the subject of the criticism that it is of little use to applied researchers (Judge et al. 1980, p.462).

Solution of the problem of multicollinearity can be difficult, although several alternative paths are canvassed in the literature. The most obvious solution is to obtain additional data with which the explanatory power of each variable can be distinguished. Another is to apply linear constraints upon the parameters, or combinations of parameters, based on theoretical considerations, or to give some coefficients particular values, derived from other empirical studies. Careful exclusion of offending variables may also be of value, although ad hoc selection of variables should be avoided.

C.1.5 The Coefficient of Multiple Determination

The coefficient of multiple determination (R^2) measures the proportion of total variance which is explained by the regression. That is:

$$R^2 = 1 - \sum e_i^2 / \sum y_i^2 \quad (0 < R^2 < 1)$$

where $\sum y_i^2$ = sum of squares of deviations from the mean
of the dependent variable; and
 $\sum e_i^2$ = residual sum of squares.

This is a measure of the explanatory power of the regression. Comparison of equations using R^2 is valid when the same data are used for the estimation of each, the same dependent variable appears in each and the same number of explanatory variables appears in each. Since the addition of explanatory variables will always increase the value of R^2 , it is invalid to compare equations with differing numbers of explanatory variables, unless the adjusted coefficient of variation ($\bar{R}^2$) is used. This statistic takes account of the change in the number of degrees of freedom which results from altering the number of variables in the regressor set:

$$\bar{R}^2 = R^2 - (k-1)(1-R^2)/(n-k)$$

where k = number of elements in the vector of regression
coefficients; and
 n = number of observations on each variable.

An $\bar{R}^2$ of above 0.5 is considered to be reasonable for cross-sectional data (Intriligator 1978, p.127).

Unfortunately, these coefficients of multiple determination are not comparable across models unless the same dependent variable is used in each model. Therefore, it is necessary to transform the $\bar{R}^2$ so that comparisons across models are possible. This was done in the present

study. The procedure adopted to adjust the $\bar{R}^2$ for the heteroscedastic and Box-Cox models may be illustrated with respect to equation 4.5, using the following stepwise procedure:

(i) regress the dependent variable on the independent variables:

$$(Y/H) = (X/H)\hat{B}$$

where H = the vector of 'heteroscedasticity correction factors' as reported in Chapter 4;

(ii) save the vector of predicted values of Y (that is, $\hat{Y}$); and

(iii) multiply the vector of predicted values of Y by the vector of heteroscedasticity correction factors and regress the result on the vector of actual observations on Y :

$$\hat{Y}H = Y\tilde{B}.$$

The R^2 calculated for this regression is that reported in Chapter 4. It provides a comparable measure of the explanatory power of each regression.

C.2 Box-Cox Regression

Regression analysis is usually justified by assuming that residuals are uncorrelated and drawn from a normal distribution with constant variance (Box and Cox 1964). However, for some statistical models these assumptions may be violated and it is sometimes possible to transform the dependent and/or independent variable(s) so that the residuals are normally distributed and homoscedastic.

The Box-Cox transformation involves searching for a value of λ which transforms the dependent variable such that:

$$Y_i(\lambda) = X_i'\hat{B} + e_i$$

where λ = the transformation constant;

$$Y_i(\lambda) = (Y_i^\lambda - 1)/\lambda;$$

Y_i = observation, i , on the dependent variable;

X_i = observation, i , on the vector of explanatory variables;

$\hat{B}$ = vector of estimated regression coefficients; and

e_i = residual, i .

This transformation has been used as a device for generalising the functional form of econometric models and may be applied to the independent variables as well as the dependent variable, either separately or in combination. At the limit, as lambda approaches zero, the logarithmic transformation is approximated, while, as lambda approaches unity, the variables remain untransformed (Judge et al. 1980, p.309-10). Lambda, in the above equation, can be estimated, directly or indirectly, using the maximum likelihood technique which utilises the log of the likelihood function:

$$L = \text{const} - (N \ln s^2)/2 - (Y^\lambda - XB)^\lambda (Y^\lambda - XB)^\lambda / 2s^2 \\ + (\lambda - 1) \sum_{i=1}^N \ln y_i$$

where $Y = (y_1, y_2, \dots, y_N)'$;

$X' = (x_1, x_2, \dots, x_N)$; and

s^2 = estimated variance.

To estimate the appropriate values for lambda and other parameters, this likelihood function can be maximised directly by simultaneously setting all first-order partial derivatives equal to zero (and checking the second order condition). Alternatively, the concentrated likelihood function

$$L(\lambda) = -N \ln s^2(\lambda)/2$$

can be used to choose the set of estimates for which $s^2(\lambda)$ is a minimum, where $s^2(\lambda)$ is the estimated variance, conditional on λ . This involves using a search procedure to establish the appropriate value for λ (Judge et al. 1980, p.310).

C.3 Testing the Significance of Elasticities

Elasticities of demand were defined in Chapter 2 as:

$$E_i = (\partial Y / \partial X_i) \cdot (X_i / Y) = \hat{B}_i (X_i / \bar{X}\hat{B}).$$

In order to test the significance of an elasticity estimate, it is necessary to determine its estimated variance. This is achieved by making use of the product and quotient rules for variance calculation (Mood, Graybill and Boes 1974, p. 180-1) and the information available from the regression analysis.

The relevant formula is as follows:

$$\begin{aligned} \hat{\text{Var}}(E_i) = & (\bar{X}_i / \bar{X}\hat{B})^2 \hat{\text{Var}}(\hat{B}) \\ & + [(\hat{B}_i \bar{X}_i) / (\bar{X}\hat{B})^2]^2 \hat{\text{Var}}(\bar{X}\hat{B}) \\ & - 2\hat{B}_i [\bar{X}_i^2 / (\bar{X}\hat{B})^3] \hat{\text{Cov}}(\hat{B}_i, \bar{X}\hat{B}) \end{aligned}$$

where

- E_i = elasticity of demand with respect to the i^{th} variable;
- $\bar{X}_i$ = mean value of the i^{th} variable;
- $\bar{X}$ = vector of mean values of variables;
- $\hat{B}$ = vector of estimated coefficients;
- $\hat{\text{Var}}(\bar{X}\hat{B}) = \bar{X}' \hat{\text{Var}}(\hat{B}) \bar{X}$;
- $\hat{\text{Cov}}(\hat{B}_i, \bar{X}\hat{B}) = \bar{X} C_i$; and
- C_i = i^{th} column of the covariance matrix of estimated coefficients.

C.3.1 The variance of the price elasticity of demand

The components of the above formula relevant to the calculation of the variance of estimation of the price elasticity of demand (E_p) in the present study are as follows:

$$\bar{XB} = \begin{bmatrix} 0.0085 \\ 8.21 \\ 231.70 \\ 2.99 \\ 0.72 \\ 15.36 \\ 0.12 \end{bmatrix} \begin{bmatrix} 26.66 \\ 0.16 \\ 0.83 \\ 4.67 \\ -51.74 \\ 0.11 \\ -9.26 \end{bmatrix} ;$$

$$\text{Var}(\hat{B}_1) = 25;$$

$$\hat{B}_1 = -51.74;$$

$$\bar{X}_1 = 0.72;$$

$$\text{Var}(\bar{XB}) =$$

$$\begin{bmatrix} 0.0085 \\ 8.21 \\ 231.70 \\ 2.99 \\ 0.72 \\ 15.36 \\ 0.12 \end{bmatrix} \begin{bmatrix} -0.2 \times 10^{-2} & -0.2 \times 10^{-1} & -3.3 & -15.7 & -0.3 \times 10^{-5} & 0.7 & 37.7 \\ 0.3 \times 10^{-6} & -1.3 \times 10^{-6} & 1.3 \times 10^{-4} & -1.3 \times 10^{-4} & -0.3 \times 10^{-7} & -0.6 \times 10^{-3} & -0.2 \times 10^{-2} \\ -1.3 \times 10^{-6} & 2.5 \times 10^{-4} & -0.8 \times 10^{-2} & 0.7 \times 10^{-2} & -0.3 \times 10^{-7} & -0.2 \times 10^{-2} & -1.6 \times 10^{-2} \\ 1.3 \times 10^{-4} & -0.8 \times 10^{-2} & 2.3 & -3.8 \times 10^{-1} & -1.3 \times 10^{-4} & 0.2 & -3.3 \\ -1.3 \times 10^{-4} & 0.7 \times 10^{-2} & -3.8 \times 10^{-1} & 25.0 & -0.8 \times 10^{-5} & -0.7 & -15.7 \\ -0.3 \times 10^{-7} & -0.2 \times 10^{-6} & -1.3 \times 10^{-4} & -0.6 \times 10^{-5} & -0.5 \times 10^{-7} & 0.4 \times 10^{-4} & -0.3 \times 10^{-5} \\ -0.6 \times 10^{-3} & -0.2 \times 10^{-2} & 0.2 & -0.7 & 0.4 \times 10^{-4} & 27.5 & 0.7 \end{bmatrix} \begin{bmatrix} 0.0085 \\ 8.21 \\ 231.70 \\ 2.99 \\ 0.72 \\ 15.36 \\ 0.12 \end{bmatrix} ; \text{ and}$$

$$\text{Cov}(\hat{B}_1, \bar{XB}) = \begin{bmatrix} 0.0085 \\ 8.21 \\ 231.70 \\ 2.99 \\ 0.72 \\ 15.36 \\ 0.12 \end{bmatrix} \begin{bmatrix} -15.67 \\ -1.3 \times 10^{-4} \\ 0.007 \\ -0.36 \\ 25.01 \\ -0.8 \times 10^{-5} \\ 0.65 \end{bmatrix} .$$

Therefore, $\text{Var}(E_p) = 0.0024$; and

$$[\widehat{\text{Var}}(E_p)]^{0.5} = S_{E_p} = 0.049.$$

C.3.2 The significance of the price elasticity of demand

The testing of hypothesis (a) from Chapter 1 requires the execution of two hypothesis tests. First, the null hypothesis that price elasticity of demand (E_p) is equal to or less than -1 should be examined against the alternative hypothesis that E_p is greater than -1. Second, the null hypothesis that E_p is greater than or equal to zero should be examined against the alternative hypothesis that E_p is less than zero. In the present study t tests are appropriate, assuming that E_p is drawn from a normal distribution, and these were performed as follows.

$$(a) \quad H_0 : E_p \leq -1$$

$$H_1 : E_p > -1$$

$$t = (-0.181 + 1)/0.049 = 16.71$$

Therefore, in view of the tabulated critical t values of 1.96 for a two-tailed test and 1.65 for a one-tailed test (at the 0.05 level of probability), the null hypothesis is rejected and it is concluded that E_p is greater than -1 (that is, $|E_p|$ is smaller than 1).

$$(b) \quad H_0 : E_p \geq 0$$

$$H_1 : E_p < 0$$

$$t = (-0.181 - 0)/0.049 = 3.69$$

Therefore, the null hypothesis is rejected and it is concluded that E_p is less than zero.

C.3.3 The variance of the income elasticity of demand

With the exception of two components, the calculation of the variance of estimation of the income elasticity of demand (E_i) is as for establishing the variance of estimation of E_p . The exceptions are as follows:

$$\bar{X}_1 = 15.363; \text{ and}$$

$$\text{Var}(\hat{B}_1) = 0.022.$$

Therefore, using the formula presented above,

$$\text{Var}(E_{\bullet}) = 1.85 \times 10^{-4}; \text{ and}$$

$$[\text{Var}(E_{\bullet})]^{0.5} = S_{E_{\bullet}} = 0.0136.$$

C.3.4 The significance of the income elasticity of demand

The tests which applied to testing the significance of the estimate of E_p are equally applicable to testing the significance of the estimate of $E_{\bullet}$. These were performed as follows.

$$(a) \quad H_0 : E_{\bullet} \geq 1$$

$$H_1 : E_{\bullet} < 1$$

$$t = (0.073 - 1)/0.0136 = 68.19$$

Therefore, the null hypothesis is rejected and it is concluded that $E_{\bullet}$ is less than 1.

$$(b) \quad H_0 : E_{\bullet} \leq 0$$

$$H_1 : E_{\bullet} > 0$$

$$t = (0.073 - 0)/0.0136 = 5.37$$

Therefore, the null hypothesis is rejected and it is concluded that $E_{\bullet}$ is greater than zero.

C.3.5 Conclusion

As a result of consideration of the above hypothesis tests it is concluded that, in the Lower Hunter Valley, for the period of the study and based on the chosen sample, the price elasticity of annual residential demand for water lies between 0 and -1 and the income elasticity lies between 0 and 1. Hence, hypothesis (a) of Chapter 1 is

accepted.

C.4 Tests of Significant Difference Between Means

The results of six t tests of the difference between means of particular variables, for the survey sample and the population, have been reported in Chapter 5. These tests follow Snedecor and Cochran (1968, Ch.4) and are reported below.

C.4.1 Water use in 1981/82: respondents vs non-respondents

$$\begin{aligned} t &= (X_r - X_n) / (s_r^2/n_r + s_n^2/n_n)^{0.5} \\ &= (231.7 - 210.99) / [(130.6)^2/415 + (145.87)^2/1185]^{0.5} \\ &= 2.7 \end{aligned}$$

C.4.2 UCV: respondents vs non-respondents

$$\begin{aligned} t &= (8205.1 - 7301.3) / [(3831.5)^2/415 + (3459.9)^2/1185]^{0.5} \\ &= 4.238 \end{aligned}$$

C.4.3 Water use in 1981/82: respondents vs population

$$\begin{aligned} t &= (X_r - X_p) / (s_r^2/n_r)^{0.5} \\ &= (223.7 - 214.3) / [(130.16)^2/415]^{0.5} \\ &= 2.723 \end{aligned}$$

C.4.4 Water use in 1981/82: non-respondents vs population

$$\begin{aligned} t &= (216.45 - 210.99) / [(145.87)^2/1185]^{0.5} \\ &= 1.289 \end{aligned}$$

C.4.5 Water use by all interviewed households: USE82 vs WTPUSE

$$t = (245.2 - 235.2) / [(145.87)^2/1185]^{0.5}$$

$$= 1.289$$

C.4.6 Water use by final usable sub-sample; USE82 vs WTPUSE

$$t = (231.7 - 229.6) / [(130.2)^2/415 + (122.7)^2/415]^{0.5}$$

$$= 0.239$$

C.4.7 Conclusion

On consideration of the above tests of significant difference between means and in view of the tabulated critical t value of 1.96 for a two-tailed test (at the 0.05 level of probability), it is concluded that:

- (a) there is a significant difference between respondents and non-respondents regarding mean water use in 1981/82 and mean UCV;
- (b) there is a significant difference between respondents and the population regarding mean water use in 1981/82; and
- (c) there is no significant difference between the non-respondents and the population regarding mean water use in 1981/82.

C.5 Homogeneity of Degree Zero

As indicated in Chapter 5, utility theory implicitly assumes that demand functions are homogenous of degree zero in prices and income. This assumption is tested readily by means of an F test.

The preferred model in the present study is given by equation 4.5:

$$\text{WTPUSE} = B_0 + B_1\text{UCV} + B_2\text{USE82} + B_3\text{RES83} \\ + B_4P_w + B_5\text{HEADINC} + B_6D_s .$$

Estimation of this (unconstrained) equation yielded a residual sum of squares (RSS) of 37.665.

The homogeneity condition implies the null hypothesis:

$$P_w B_4 = -(\overline{UCV} B_1 + \overline{HEADINC} B_3).$$

This leads to the constrained equation:

$$\begin{aligned} WTPUSE = & B_0 + B_1 UCV + B_2 USE82 + B_3 RES83 \\ & - \left(\frac{\overline{UCV}}{P_w} B_1 + \frac{\overline{HEADINC}}{P_w} B_3 \right) P_w + B_3 HEADINC + B_4 D_4. \end{aligned}$$

or

$$\begin{aligned} WTPUSE = & B_0 + B_1 \left(UCV - \frac{\overline{UCV}}{P_w} P_w \right) + B_2 USE82 + B_3 RES83 \\ & + B_3 \left(HEADINC - \frac{\overline{HEADINC}}{P_w} P_w \right) + B_4 D_4. \end{aligned}$$

which, when estimated in the present study, yielded an RSS of 39.094.

After estimating the RSS for both the unconstrained equation [RSS(H₁)] and the constrained equation [RSS(H₀)], the following F test (Pindyck and Rubinfeld 1981, p. 118) was undertaken:

$$F = \frac{[RSS(H_0) - RSS(H_1)]/M}{RSS(H_1)/(N-K-1)}$$

where M = number of constraints;

N = number of observations; and

K = number of parameters.

For the present study:

$$\begin{aligned} F &= (39.094 - 37.665) / (37.665/408) \\ &= 15.48 \end{aligned}$$

which compares with $F_{1,408}^{0.05} \sim 3.86$ and $F_{1,408}^{0.01} \sim 6.7$. Hence, the null hypothesis is rejected and homogeneity of degree zero in price, income and wealth is not applicable to the preferred model (equation 4.5).

The data used in the estimation of the preferred model (equation 4.5) are presented in Table D.1. Each row of data corresponds to a particular household. Column headings correspond to the variables specified in equation 4.5 and are defined as follows:

WTPUSE = intended water use at a particular price, elicited from consumers using question 13 of the survey questionnaire;

UCV = unimproved capital value of the dwelling in thousands of dollars;

USE82 = actual water use in 1981/82, as measured by HDWB water meters;

RES83 = number of residents per household in 1982/83;

P_w = water price in dollars per kilolitre;

HEADINC = income of household head in thousands of dollars per annum; and

D_s = dummy variable taking the value one for households with septic tanks.

The mean value and standard deviation of each of these variables appear in Table D.2.

Table D.1

Data Used in Estimation of the Preferred Model

WTPUSE	UCV	USE82	RES83	P.	HEADINC	D.
447	6000	447.5	5	.30	14000	0
500	6500	510.4	4	.60	26000	0
300	5000	338.4	4	.90	3200	0
150	6000	166.7	2	1.20	10000	1
372	5000	372.8	5	.30	18000	0
150	6000	191.6	2	.60	10000	0
150	6750	95.4	1	.90	32000	0
200	7000	264.5	4	1.20	26000	0
200	4500	193.5	2	.30	6000	0
150	3000	123.0	4	.60	22000	0
146	4000	162.6	2	1.20	6000	0
100	3300	107.8	2	.30	10000	1
344	5750	343.6	5	.60	18000	0
250	5500	329.6	4	.90	10000	0
80	6000	74.7	2	.30	18000	0
220	6500	241.8	4	.60	32000	0
150	5500	253.3	4	.90	10000	0
350	5750	420.0	4	1.20	26000	0
400	6250	359.3	6	.30	22000	0
205	1750	205.0	4	.60	22000	0
250	6000	318.3	2	.90	14000	0
211	6250	211.4	3	1.20	32000	0
338	6000	238.1	4	.30	14000	0
201	6000	200.8	2	.60	6000	0
200	6500	294.0	4	.90	18000	0
208	6000	207.6	2	.30	6000	0
197	6000	197.0	5	.60	14000	0
76	6000	76.7	2	.90	3200	0
200	6000	171.4	5	.30	22000	0
218	6000	202.5	2	.60	32000	0
400	7000	415.6	4	.90	32000	0
35	7500	39.0	1	1.20	3200	0
250	6500	193.1	2	.30	10000	0
150	6750	133.8	2	1.20	14000	0
150	6750	143.8	4	.30	22000	0
300	7000	174.1	2	.60	32000	0
200	6500	165.6	2	.90	18000	0
250	5250	325.1	2	1.20	6000	0
300	8000	362.0	3	.30	32000	0
250	6250	253.7	3	.60	18000	0
169	6500	168.9	5	.90	14000	0
300	4000	204.0	5	.30	14000	0
200	6000	165.7	3	.60	6000	0
90	6000	88.8	1	.90	6000	0
150	4250	236.0	3	1.20	10000	0
350	2600	352.1	6	.60	6000	0
100	4500	98.3	1	.30	3200	0
300	6000	299.5	4	.60	18000	0
200	6000	186.5	2	.90	14000	0
100	6000	102.6	1	.30	3200	0
250	6500	294.2	2	.60	6000	0
170	1800	169.5	3	.90	18000	1
300	4000	334.0	6	1.20	14000	0
50	3250	23.1	2	.30	3200	0
300	5500	276.8	4	.60	18000	0
200	2600	267.9	2	1.20	6000	1

cont./

Table D.1-- Continued

150	6250	161.0	4	.90	18000	1
100	6750	124.4	3	1.20	10000	1
400	5750	546.9	5	.90	3200	0
100	6500	68.9	2	1.20	22000	0
500	6750	466.0	5	.30	18000	0
200	16000	51.7	4	.90	32000	0
100	5500	165.6	4	1.20	22000	0
328	7500	328.5	3	.60	18000	0
200	6000	218.0	2	.90	26000	0
350	10500	264.1	4	.30	26000	0
400	9500	257.6	3	.30	22000	0
150	5500	121.7	3	.60	14000	0
100	4600	60.2	2	.90	10000	0
50	5500	157.9	2	1.20	3200	0
250	5250	255.3	3	.30	18000	0
300	4800	332.8	5	1.20	26000	0
150	3600	100.5	1	.30	14000	0
150	4300	225.6	2	.60	3200	0
200	6000	115.4	4	.90	10000	0
150	4500	120.9	2	1.20	14000	0
50	4800	4.4	2	.30	3200	0
100	7250	154.8	3	.60	18000	0
300	6250	420.6	2	.90	6000	0
100	4500	126.5	1	1.20	3200	0
99	13500	99.2	1	.60	26000	0
299	16500	299.1	2	.60	14000	0
180	12000	167.4	4	.90	32000	1
100	7250	59.2	1	.30	6000	0
186	9000	177.6	4	.60	3200	0
56	6500	56.0	3	.90	6000	0
239	7250	239.5	1	.30	3200	0
150	6250	237.6	2	.60	3200	0
150	6250	249.9	4	1.20	14000	0
200	12000	141.6	2	.30	18000	0
240	7000	364.1	2	.60	6000	0
100	6750	148.2	1	.90	3200	0
45	8750	49.8	1	1.20	3200	0
334	9250	333.9	2	.30	18000	0
180	6250	217.3	1	.60	3200	0
450	8750	611.6	4	.90	32000	0
70	5500	62.0	4	.60	6000	0
300	5750	392.7	6	.90	18000	0
200	5750	215.5	4	1.20	3200	0
315	7250	315.6	3	.30	26000	0
300	7500	295.2	5	.60	32000	0
397	7000	397.7	8	.90	18000	0
400	9000	531.7	5	.60	10000	0
400	8500	308.8	5	.30	22000	0
300	8000	297.6	2	.60	14000	0
600	16000	785.3	4	1.20	32000	0
177	10000	177.0	2	.60	6000	0
578	12000	578.9	2	.90	3200	1
150	7750	92.5	4	1.20	14000	1
275	7500	275.5	4	.60	10000	1
560	10500	560.5	2	.90	14000	0
225	7250	249.8	3	1.20	14000	1
83	6500	82.7	1	.30	3200	0
270	7500	276.0	1	.60	3200	0
160	5250	188.6	1	.90	6000	0
150	6000	188.8	5	1.20	14000	0

cont./

Table D.1-- Continued

150	7500	132.1	2	.90	14000	0
224	5500	224.0	4	.90	3200	0
50	3600	121.3	2	1.20	6000	0
500	7750	396.1	5	.30	18000	0
200	6500	181.5	3	.60	3200	0
150	8500	184.0	3	.90	14000	0
100	5500	168.0	1	1.20	3200	0
100	7500	87.2	1	.60	3200	0
150	10000	104.0	3	.90	3200	0
400	9750	434.0	4	.30	18000	0
70	4700	80.6	1	.60	3200	0
100	4600	100.0	2	.90	3200	0
134	5250	133.6	2	1.20	3200	0
400	7750	369.5	4	.30	32000	0
49	7250	50.1	2	.60	18000	0
300	7000	341.6	3	.90	22000	0
200	8750	321.2	7	1.20	22000	0
211	6250	211.5	2	.30	10000	0
214	4500	224.6	4	.60	14000	0
260	6750	304.7	4	.90	14000	0
150	9000	234.4	1	1.20	6000	0
55	8000	56.2	2	.30	22000	0
312	7250	319.2	4	.60	18000	0
45	6250	44.4	3	.90	3200	0
150	8500	119.1	3	.30	6000	0
247	7500	247.0	2	.60	22000	0
75	7750	75.3	5	.90	14000	0
44	8250	44.1	3	1.20	14000	0
40	8250	33.4	1	.30	26000	0
200	8000	217.0	4	.60	14000	0
130	6500	160.0	2	.90	22000	0
180	7000	167.9	3	.30	6000	0
170	7250	170.8	2	.60	14000	0
136	8500	136.6	4	.90	18000	0
90	7250	95.7	2	1.20	3200	0
120	8500	118.3	2	.30	22000	0
300	7000	300.5	2	.60	3200	0
50	6500	75.9	1	.90	6000	0
380	4750	379.9	5	1.20	10000	0
57	15000	56.5	2	.30	14000	0
150	12500	194.5	1	.60	6000	0
150	6750	130.8	3	.90	14000	0
232	6000	232.3	2	.30	3200	1
208	6000	311.4	2	.60	3200	1
14	6750	28.2	2	.90	3200	1
200	5750	270.0	4	1.20	22000	0
140	5500	140.4	2	.30	18000	0
264	10500	264.9	4	.60	14000	1
250	5500	211.1	4	.30	14000	0
250	7500	161.7	3	.60	32000	1
340	4500	339.9	2	.30	3200	1
197	7750	197.0	3	1.20	22000	1
435	10500	433.8	2	.60	14000	0
104	14000	104.0	2	.90	3200	1
75	23000	40.8	1	.90	3200	1
400	23000	400.1	9	1.20	32000	1
400	11000	415.0	1	.30	3200	0
160	10000	160.8	2	.60	6000	0
71	25000	70.9	1	.90	10000	1
220	5250	219.8	3	.60	22000	0

cont./

Table D.1-- Continued

50	7750	125.0	1	1.20	3200	0
250	8000	175.9	2	.30	6000	0
300	9250	311.0	4	1.20	32000	0
308	10000	308.7	2	.30	18000	0
80	11500	80.1	1	.90	22000	0
400	9000	509.3	3	.30	32000	0
342	8750	342.1	3	.60	18000	0
150	6500	220.4	2	.90	6000	0
300	10000	264.3	4	1.20	32000	0
171	9500	171.6	3	.30	22000	0
190	4300	189.7	1	.60	3200	0
125	9000	143.9	2	.90	32000	0
225	9000	307.6	3	1.20	32000	0
130	6500	130.2	1	.30	6000	0
200	6500	189.7	2	.60	22000	0
400	8000	501.4	4	1.20	18000	0
416	11000	416.5	3	.30	10000	0
150	7750	135.7	2	.60	22000	0
50	7750	67.4	2	.90	3200	0
350	7250	377.7	4	1.20	14000	0
250	8000	276.3	4	.30	18000	0
110	6750	108.7	2	.60	6000	0
200	6750	234.9	2	.90	6000	0
210	8750	209.7	2	.30	26000	0
84	8500	77.8	2	.60	3200	0
100	8000	136.2	2	1.20	3200	0
236	5250	271.7	2	.30	3200	0
200	7750	305.3	4	.60	14000	0
300	9500	315.4	6	.90	22000	0
100	7000	92.7	2	1.20	32000	0
175	7250	188.8	5	.30	22000	0
250	6500	221.5	4	.90	10000	0
150	6500	120.5	2	.30	14000	0
250	6250	273.5	8	.60	10000	0
100	6250	76.5	5	1.20	22000	0
410	7250	410.8	2	.30	26000	0
270	8750	274.3	2	.60	6000	0
200	7000	246.8	4	.90	10000	0
300	7500	296.3	4	.30	26000	0
50	9000	57.2	6	.60	18000	0
60	6500	20.0	1	.90	32000	0
160	7750	168.0	4	1.20	6000	0
200	5750	117.0	4	.60	32000	0
200	7500	254.9	2	1.20	6000	0
250	15000	228.3	2	.30	6000	0
500	11500	523.0	5	.60	6000	0
75	14000	73.4	2	.90	22000	0
200	14500	235.5	2	1.20	26000	0
100	9250	67.1	1	.30	3200	0
420	18000	422.3	6	.60	32000	0
50	12500	34.7	3	.90	32000	0
300	13000	231.4	3	.30	22000	0
300	11500	390.6	4	.60	14000	0
70	8500	70.0	1	.90	3200	0
270	18500	271.2	4	1.20	32000	0
250	18000	236.5	2	.30	10000	0
200	12500	198.3	2	.60	18000	0
75	15000	91.5	3	.90	18000	0
320	12500	327.9	1	.30	6000	0
127	7250	126.9	2	.60	26000	0

cont./

Table D.1-- Continued

305	5750	305.5	5	.60	18000	0
70	5750	69.5	1	.90	6000	0
200	6000	299.6	5	1.20	18000	0
400	6750	371.6	3	.30	18000	0
130	13000	130.1	1	.60	10000	0
100	6000	160.0	2	.90	18000	0
400	7250	346.2	3	.30	6000	0
292	8250	292.0	4	.90	26000	0
195	6500	195.4	2	1.20	18000	0
207	6750	207.8	1	.30	3200	0
101	6750	101.4	3	.90	6000	0
300	7500	403.6	5	1.20	32000	0
422	5750	422.3	2	.30	10000	0
264	7000	264.5	4	.60	22000	0
150	14500	225.2	2	.90	18000	1
241	7250	241.1	4	1.20	26000	0
118	6500	118.3	5	.30	14000	0
259	6500	259.0	4	.60	18000	0
261	5500	261.8	5	.90	18000	0
150	4750	190.8	2	1.20	22000	0
179	6750	179.1	2	.30	14000	0
225	6250	225.0	4	.60	18000	0
317	7500	317.3	3	.90	32000	0
200	8000	268.5	2	1.20	14000	0
275	9250	275.1	4	.30	14000	0
71	4700	71.0	2	.60	6000	0
150	8250	217.2	5	1.20	22000	0
130	9000	130.4	1	.30	18000	0
416	9500	416.6	2	.60	3200	0
253	9500	253.4	3	.90	14000	0
297	8500	297.1	4	1.20	18000	0
526	9250	526.5	5	.30	14000	0
214	6250	214.9	1	.60	10000	0
320	7250	320.8	5	.90	10000	0
150	8500	216.0	7	1.20	18000	0
297	4200	297.1	5	.30	22000	1
257	7250	257.5	2	.60	6000	0
623	7750	623.1	7	.90	22000	0
100	7000	193.3	2	1.20	3200	0
450	7500	450.0	2	.30	10000	0
222	7250	222.4	2	.60	6000	0
100	6500	98.1	3	.90	3200	0
250	5000	311.1	4	1.20	14000	0
120	7250	120.5	2	.30	10000	0
56	8250	56.6	4	.60	14000	0
106	8250	106.2	1	.90	3200	0
300	7750	310.8	6	1.20	26000	0
219	8500	219.2	2	.30	6000	0
238	9000	238.4	3	.60	32000	0
132	7000	162.6	4	.90	18000	0
307	8000	307.2	2	1.20	10000	0
344	7500	344.0	3	.30	18000	0
412	6750	412.4	4	.60	26000	0
225	11000	222.3	3	.90	18000	0
300	6250	302.0	4	.30	3200	0
400	8500	347.5	5	.90	14000	0
150	9250	65.5	4	1.20	18000	0
450	10500	438.8	5	.30	32000	0
195	8500	195.0	3	.60	10000	0
150	8750	233.9	2	.90	26000	0

cont./

Table D.1-- Continued

400	5000	443.7	4	.30	14000	0
157	4750	157.9	3	.90	10000	0
200	8000	199.7	2	1.20	18000	0
339	7750	339.5	4	.30	22000	0
320	11000	320.4	2	.60	22000	0
182	16000	182.5	2	.90	6000	1
150	7000	133.2	2	.30	18000	1
150	5000	115.0	3	.60	14000	1
90	8750	131.0	1	.90	6000	0
120	7000	141.4	2	1.20	26000	1
103	17500	103.7	2	.30	18000	1
150	9000	170.3	2	.60	6000	1
250	8500	311.0	2	.90	10000	1
355	5750	355.6	4	1.20	22000	0
300	18000	168.2	2	.30	32000	0
165	6250	165.2	4	.60	22000	0
90	10500	90.7	2	.90	14000	0
190	8500	200.2	2	1.20	6000	0
481	20000	481.7	3	.30	18000	1
300	13000	348.0	1	.60	6000	1
112	20000	132.7	4	.90	22000	1
106	12000	116.0	1	1.20	22000	0
400	11000	358.8	4	.30	26000	0
150	7000	193.4	1	.60	6000	0
200	6500	163.4	2	.90	22000	0
548	35000	548.0	9	1.20	32000	0
100	6250	84.9	4	.30	6000	0
206	7250	206.3	2	.60	6000	0
104	8250	104.9	2	.90	22000	1
150	16500	208.6	4	1.20	22000	1
222	7750	222.1	4	.30	32000	1
541	26000	541.7	4	1.20	14000	0
426	7500	426.4	5	.30	22000	0
195	5000	195.2	4	.60	18000	0
125	5800	241.1	2	.90	3200	0
100	8000	37.5	2	1.20	18000	0
400	6500	307.9	2	.30	14000	0
150	11000	203.8	3	.60	10000	0
200	8000	147.3	3	.90	18000	0
100	4600	111.6	2	1.20	6000	0
150	9000	68.6	2	.30	6000	0
295	9500	295.1	3	.90	6000	0
77	5250	77.1	2	1.20	14000	0
150	6500	167.3	2	.90	6000	0
200	7500	243.7	2	1.20	14000	0
131	8500	131.8	2	.30	6000	0
200	25000	250.0	3	.60	14000	0
62	4900	72.4	1	.90	6000	0
100	7500	81.0	3	1.20	22000	0
300	8000	269.9	4	.30	26000	0
219	7750	219.7	5	.60	18000	0
150	6000	194.0	3	.90	18000	0
268	7750	268.8	4	.30	14000	0
350	7500	429.5	6	.60	18000	0
75	6750	85.4	2	.90	10000	0
455	19000	455.4	5	1.20	22000	0
200	7000	119.0	4	.30	18000	0
366	14000	366.0	2	.60	18000	1
350	8000	350.7	1	1.20	32000	0
74	5750	74.2	4	.30	14000	0

cont./

Table D.1-- Continued

50	5250	114.3	1	.30	6000	1
147	5250	147.5	7	.60	14000	1
50	5500	128.3	1	.90	10000	1
400	5500	306.3	2	.30	26000	1
600	20000	788.7	2	.60	6000	1
47	11000	47.5	1	.90	3200	1
200	5750	273.2	5	1.20	18000	1
317	5000	317.0	3	.30	10000	1
250	9750	259.4	2	.60	26000	1
150	14500	205.6	3	.90	14000	1
50	6500	129.7	2	1.20	10000	0
150	5750	139.4	5	.30	26000	0
400	5250	474.7	4	.60	22000	0
200	6750	236.8	2	.90	18000	0
50	4800	149.8	1	1.20	3200	0
130	6500	129.7	1	.30	10000	0
500	9000	532.9	2	.60	18000	0
250	7000	322.4	3	.90	22000	0
150	8750	164.8	1	1.20	3200	0
230	7000	230.7	2	.30	18000	0
250	7250	279.2	2	.60	26000	0
250	9000	232.8	4	.90	14000	0
460	7250	460.6	3	.30	32000	0
150	6750	219.2	4	.60	18000	0
75	8000	83.6	2	.90	3200	0
250	7250	271.3	2	1.20	26000	0
500	8250	471.8	4	.30	26000	0
300	8500	319.1	5	.60	22000	0
95	6250	159.7	5	.90	18000	0
70	5000	77.9	4	1.20	14000	0
380	10500	361.6	4	.30	18000	0
400	11500	396.3	2	.60	26000	0
120	9000	84.1	3	.90	18000	0
100	10000	120.7	2	1.20	10000	0
250	16500	209.7	2	.30	32000	1
300	6250	328.8	4	.60	22000	0
600	25500	592.4	6	.60	32000	0
420	20000	367.2	2	.90	32000	0
200	8750	310.8	3	1.20	14000	0
250	7250	203.4	3	.30	18000	0
500	8250	479.8	6	.30	18000	0
250	8250	246.9	4	.60	14000	0
225	9000	224.8	4	.90	26000	0
50	9250	56.9	2	.30	10000	0
400	8000	313.2	5	.60	22000	0
400	9500	480.5	3	.90	18000	0
100	8000	24.5	1	1.20	26000	0
200	8000	133.3	4	.30	26000	0
150	10000	226.4	3	.90	14000	0
300	14500	324.9	2	.30	22000	0
500	7000	425.8	2	.60	32000	1
350	10000	344.4	6	.90	18000	0
200	12000	234.3	2	1.20	26000	0
250	7500	250.9	1	.30	6000	0
300	11000	176.0	6	.60	32000	0
125	8250	122.4	5	.90	22000	0
100	9250	95.8	2	1.20	18000	0
400	9250	292.4	4	.30	14000	0
200	9500	223.8	2	.60	18000	0

Table D.2

Means and Standard Deviations of Regression Variables

	Mean	Standard deviation
WTPUSE	223.41	123.86
UCV	8.21	3.86
USE82	231.70	130.16
RES83	2.99	1.49
P _v	0.72	0.33
HEADINC	15.36	8.86
D _s	0.12	0.32

REFERENCES

- Allen, R.G.D. and Bowley, A. (1935), Family Expenditure, P.S.King and Son, London.
- Allen, R.G.D. and Hicks, J.R. (1934), 'A reconsideration of the theory of value', Economica 1(1,2), 52-76, 196-219
- Barnes, R., Gillingham, R. and Hagemann, R. (1981), 'The short-run residential demand for electricity', Review of Economics and Statistics 63(4), 541-51.
- Batchelor, R.A. (1975), 'Household technology and domestic demand for water', Land Economics 51(3), 208-22.
- Baumol, W.J. (1965), Economic Theory and Operations Analysis, 2nd edn, Prentice-Hall, Englewood Cliffs.
- Becker, G.S. (1965), 'A theory of the allocation of time', The Economic Journal 75(299), 493-517.
- Beierlein, J.G., Dunn, J.W. and McConnon, J.C. Jr (1981), 'The demand for electricity and natural gas in the Northeastern United States', Review of Economics and Statistics 63(3), 403-8.
- Bera, A.K. and Jarque, C.M. (1981), 'An efficient large-sample test for normality of observations and regression residuals', Working Paper 040, Australian National University, Canberra.
- Bernoulli, D. (1738), 'Specimen theoriae novae de mensura sortis', Commentarii academiae Scientiarum imperialis Petropolitanae 1738 (English translation by L. Somer (1954), Econometrica 22(1), 23-36).
- Berry, D.W. and Bonem, G.W. (1974), 'Predicting the municipal demand for water', Water Resources Research 10(6), 1239-42.
- Billings, R.B. and Agthe, D.E. (1980), 'Price elasticity for water: a case of increasing block rates', Land Economics 56(1), 73-84.
- Bohm, P. (1971), 'An approach to the problem of estimating demand for public goods', Swedish Journal of Economics 73(1), 55-66.

- Bonbright, J.C. (1940), 'Major controversies as to the criteria of reasonable public utility rates', Papers and Proceedings of the American Economic Association 30, 379-89.
- Box, G.E.P. and Cox, D.R. (1964), 'An analysis of transformations', Journal of the Royal Statistical Society Series B, 26(2), 211-43.
- Box, G.E.P. and Tidwell, P.W. (1962), 'Transformation of the independent variables', Technometrics 4(4), 531-50.
- Box, G.E.P. and Watson, G.S. (1962), 'Robustness to non-normality of regression tests', Biometrika 49(1,2), 93-106.
- Bradford, D.F. (1970), 'Benefit-cost analysis and demand curves for public goods', Kyklos 23(4), 775-91.
- Breusch, T.S. and Pagan, A.R. (1979), 'A simple test for heteroscedasticity and random coefficient variation', Econometrica 47(5), 1287-94.
- Brown, A. and Deaton, A. (1972), 'Surveys in applied economics: models of consumer behaviour', Economic Journal 82(328), 1145-236.
- Cargill, T.F. and Meyer, R.A. (1971), 'Estimating the demand for electricity by time of day', Applied Economics 3(4), 236-46.
- Carver, P.H. and Boland, J.J. (1980), 'Short run and long run effects of price on municipal water use', Water Resources Research 16(4), 609-16.
- Cassuto, A.E. and Ryan, S. (1979), 'Effect of price on the residential demand for water within an agency', Water Resources Bulletin 15(2), 345-53.
- Chiang, A.C. (1974), Fundamental Methods of Mathematical Economics, 2nd edn, McGraw-Hill Kogakusha, Tokyo.
- Chipman, J.A. and Moore, J.C. (1980), 'Compensating variation, consumer's surplus, and welfare', American Economic Review 70(3), 933-49.
- Christensen, L.R., Jorgenson, D.W. and Lau, L.J. (1975), 'Transcendental logarithmic utility functions', American Economic Review 65(3), 367-83.
- Ciriacy-Wantrup, S.V. (1967), 'Water policy and economic optimising: some conceptual problems in water research', American Economic Review 57(2), 179-96.

- Cochran, W.G. (1965), Sampling Techniques, 2nd edn, Wiley, New York.
- Codner, G.P. (1979), A Dynamic Programming Approach to the Optimisation of a Complex Urban Water Supply Scheme, Australian Water Resources Council Technical Paper No. 47, Australian Government Publishing Service, Canberra.
- Cory, D.C., Gunn, R.L., Martin, W.E. and Brokken, R.F. (1981), 'Simplified measurement of consumer welfare change', American Journal of Agricultural Economics 63(4), 715-7.
- Currie, J.M., Murphy, J.A. and Schmitz, A. (1971), 'The concept of economic surplus and its use in economic analysis', Economic Journal 81(324), 741-99.
- Danielson, L.E. (1979), 'An analysis of residential demand for water using micro time-series data', Water Resources Research 15(4), 763-7.
- Darr, P., Feldman, S.L. and Kamen, C. (1976), The Demand for Urban Water, Martinus Nijhoff Social Sciences Division, Leiden, Israel.
- Davenant, C. (1699), An Essay upon the Probable Methods of Making a People Gainers in the Balance of Trade, London (cited in Brown and Deaton 1972).
- Davis, O.A. and Winston, A.B. (1967), 'On the distinction between public and private goods', American Economic Review 57(2), 360-73.
- Dixit, A.K. and Weller, P.A. (1979), The three consumer's surpluses, Economica 46(182), 125-35.
- Durbin, J. (1970), Testing for serial correlation in least-squares regression when some of the regressor variables are lagged dependent variables, Econometrica 38(3), 410-21.
- Durbin, J. and Watson, G.S. (1951), 'Testing for serial correlation in least squares regression II', Biometrika 38(1), 159-78.
- Eastman, C., Hoffer, P. and Randall, A. (1974), 'A socio-economic analysis of environmental concern: case for the 4 Corners electric power complex', Agricultural Experimental Station Bulletin 626, New Mexico State University.
- Engel, E. (1875), 'Die productions und consumptionsverhaltnisse des Konigreichs Sachsen', Zeitschrift des Statistischen Bureaus des Koniglich Sachsischen Ministerium des Inneren Nos. 8 und 9 (cited in Brown and Deaton 1972).

- Farrell, M.J. (1958), 'In defence of public-utility price theory', Oxford Economic Papers 10, 109-23, amended and reprinted in Turvey, R. (1968), Public Enterprise, Penguin, Harmondsworth.
- Ferguson, C.E. and Maurice, S.C. (1974), Economic Analysis, Irwin, Homewood.
- Fisher, I. (1892), 'Mathematical investigations in the theory of value and prices', Transactions of Connecticut Academy of Arts and Sciences 9 (cited in Brown and Deaton 1972).
- Foote, R.J. (1958), 'Analytical tools for studying demand and price structures', United States Department of Agriculture Agricultural Handbook 146, Washington D.C..
- Foster, H.S. and Beattie, B.R. (1979), 'Urban residential demand for water in the U.S.', Land Economics 55(1), 43-58.
- Foster, H.S. and Beattie, B.R. (1981), 'Urban residential demand for water in the United States: reply', Land Economics 57(2), 257-65.
- Fox, I.K. and Herfindahl, D.C. (1964), 'Attainment of efficiency in satisfying demands for water resources', American Economic Review 54(1), 198-208.
- Gallagher, D.R. (1980), 'Price and investment policies for urban water supply enterprises', Ph.D. thesis, University of New South Wales, Kensington.
- Gallagher, D.R. (1982), 'Urban water supply', in Webb, L.R. and Allan, R.H. (eds) (1982), Industrial Economics: Australian Studies, Allen and Unwin, Sydney, 209-16.
- Gallagher, D.R. and Robinson, R.W. (1977), 'The influence of pricing policies and incentives on water use efficiency', Australian Water Resources Council Technical Paper No. 19, Canberra.
- Gallagher, D.R., Boland, J.J., le Plastrier, B.J. and Howell, D.T. (1981), 'Methods for forecasting urban water demands', Australian Water Resources Council Technical Paper No. 59, Canberra.
- George, P.S. and King, G.A. (1971), 'Consumer demand for food commodities in the United States with projections for 1980', Giannini Foundation Monograph No. 26, Division of Agricultural Sciences and Giannini Foundation of Agricultural Economics, University of California, Berkeley.

- Gibbs, K.C. (1978), 'Price variable in residential demand models', Water Resources Research 14(1), 15-18.
- Gibson, B.B. (1980), 'Estimating demand elasticities for public goods from survey data', American Economic Review 70(5), 1069-76.
- Goldfeld, S.M. and Quandt, R.E. (1965), 'Some tests for heteroscedasticity', Journal of the American Statistical Association 60(310), 539-47.
- Gossen, H.H. (1854), Entwicklung der Gesetze des menschlichen Verkehrs, und der daraus fließenden Regeln für menschliches Handeln, Druck und Verlag von Friedrich Vieweg und Sohn, Braunschweig (cited in Brown and Deaton 1972).
- Griffin, A.H. and Martin, W.E. (1981), 'Price Elasticities for water: a case of increasing block rates: comment', Land Economics 57(2), 266-77.
- Grima, A.P. (1972), Residential Water Demand: Alternative Choices for Management, Toronto University Press, Toronto.
- Guise, J.W.B. (1982), Unpublished course notes for Economic Statistics 465-1 (Applied Econometrics) at the University of New England, Armidale.
- Halvorsen, R. (1975), 'Residential demand for electric energy', Review of Economics and Statistics 57(1), 12-8.
- Hank, S.H. (1970), 'Demand for water under dynamic conditions', Water Resources Research 6(5), 1253-61.
- Hanke, S.H. (1975), 'Water rates: an assessment of current issues', Journal of American Water Works Association 67(5), 215-9.
- Hanke, S.H. (1978), 'A method for integrating engineering and economic planning', Journal of American Water Works Association 70(9), 487-91.
- Hanke, S.H. (1980), 'A cost-benefit analysis of water use restrictions', Water Supply and Management 4, 269-74.
- Hanke, S.H. and Davis, R.K. (1971), 'Demand management through responsive pricing', Journal of American Water Works Association 63, 550-6.
- Hanke, S.H. and Mehrez, A. (1979), 'An optimal sampling procedure for collection of residential water use data', Water Resources Research 15(6), 1343-8.

- Hanke, S.H. and Mehrez, A. (1979), 'The relationship between water use restrictions and water use', Water Supply and Management 3, 315-21.
- Hanke, S.H. and de Mare, L. (1982), 'Residential water demand: a pooled time series, cross section study of Malmo, Sweden', Water Resources Bulletin 18(4), 621-6.
- Hanson, R. and Narayanan, R. (1981), 'A monthly time series model of municipal water demand', Water Resources Bulletin 17(4), 578-85.
- Hausman, J.A. (1981), 'Exact consumer's surplus and deadweight loss', American Economic Review 71(4), 662-76.
- Heaps, D.P. (1977), 'Efficiency in industrial, municipal and domestic water use', Australian Water Resources Council Technical Paper No. 20, Canberra.
- Henderson, J.M. and Quandt, R.E. (1980), Microeconomic Theory: A Mathematical Approach, 3rd edn, McGraw-Hill, Tokyo.
- Henderson, P.D. (1965), 'Notes on public investment criteria in the United Kingdom', Bulletin of the Oxford Institute of Economics and Statistics 27, 55-89, amended and reprinted in Turvey, R. (1968), Public Enterprise, Penguin, Harmondsworth.
- Hicks, J.R. (1942), 'Consumer's surplus and index numbers', Review of Economic Studies 9, 126-37.
- Hicks, J.R. (1943), 'The four consumer surpluses', Review of Economic Studies 11, 31-41.
- Hicks, J.R. (1953), Value and Capital: An Enquiry into Some Fundamental Principles of Economic Theory, 2nd edn, Oxford University Press, London.
- Hirshleifer, J. (1980), Price Theory and Applications, 2nd edn, Prentice-Hall, London.
- Hirshleifer, J. and Milliman, J.W. (1967), 'Urban water supply: a second look', American Economic Review 57(2), 169-78.
- Hirshleifer, J., de Haven, J.C. and Milliman, J.W. (1960), Water Supply: Economics Technology and Policy, University of Chicago Press, Chicago.
- Hoaglin, D.C. and Welsch, R.E. (1978), 'The hat matrix in regression and ANOVA', American Statistician 32(1), 17-22.

- Hogarty, T.F. and Mackay, R.J. (1975), 'The impact of large temporary rate changes on residential water use', Water Resources Research 11(6), 791-4.
- Hotelling, H. (1932), 'Edgeworth's taxation paradox and the nature of demand and supply functions', Journal of Political Economy 40(5), 577-616.
- Hotelling, H. (1938), 'The general welfare in relation to problems of taxation and of railway and utility rates', Econometrica 6(2), 242-69.
- Houthakker, H.S. (1950), 'Revealed preference and the utility function', Economica 17(66), 159-74.
- Houthakker, H.S. and Taylor, L.D. (1970), Consumer Demand in the United States: Analyses and Projections, 2nd edn, Harvard University Press, Cambridge, Mass.
- Howe, C.W. and Linaweaver, F.P. (1967), 'The impact of price on residential water demand and its relation to system design and price structure', Water Resources Research 3(1), 13-32.
- Hunter District Water Board (1982a), An Equity Based Water and Sewer User-Pays Tariff, Hunter District Water Board, Newcastle, New South Wales.
- Hunter District Water Board (1982b), Annual Report 1981/82, Newcastle, New South Wales.
- Hunter District Water Board (1982c), Water Development Plan to 2010, Newcastle, New South Wales.
- Hunter District Water Board (1983), Water restriction summary, Unpublished paper.
- Intriligator, M.C. (1978), Econometric Models, Techniques and Applications, Prentice-Hall, Englewood Cliffs.
- Intriligator, M.D. (1971), Mathematical Optimization and Economic Theory, Prentice-Hall, Englewood Cliffs.
- Jarque, C.M. and Bera, A.K. (1980), 'Efficient tests for normality, homoscedasticity and serial independence of regression residuals', Economics Letters 6, 255-9.
- Jevons, W.S. (1871), The Theory of Political Economy, Macmillan, London.

- Johnston, J. (1963), Econometric Methods, McGraw Hill Kogakusha, Tokyo.
- Judge, G.G., Griffiths, W.E., Hill, R.C. and Lee, T. (1980), The Theory and Practice of Econometrics, Wiley, U.S.A..
- Kasulis, J.J., Huettner, D.A. and Dikeman, N.J. (1981), 'The feasibility of changing electricity consumption patterns', Journal of Consumer Research 8(3), 279-90.
- Koutsoyiannis, A. (1977), Theory of Econometrics, 2nd edn, Macmillan, London.
- Koutsoyiannis, A. (1981), Modern Microeconomics, 2nd edn, Macmillan, London.
- Kuenne, R.F. (1968), Microeconomics Theory of the Market Mechanism: A General Equilibrium Approach, Macmillan, New York.
- Ladd, G.W. and Suvannunt, V. (1976), 'A model of consumer goods characteristics', American Journal of Agricultural Economics 58(3), 504-10.
- Laitinen, K. (1978), 'Why is demand homogeneity so often rejected?', Economics Letters 1, 187-91.
- Lancaster, K.J. (1966), 'A new approach to consumer theory', Journal of Political Economy 74(2), 132-57.
- Layard, P.R.G. and Walters, A.A. (1978), Micro-economic Theory, McGraw-Hill, London.
- Leftwich, R.H. (1975), The Price System and Resource Allocation, 5th edn, Dryden, London.
- Lehfeldt, R.A. (1914), 'The elasticity of demand for wheat', Economic Journal 24(June), 212-7.
- Leontief, W. (1929), 'Ein Versuch zur Statischen analyse von Angebot und Nachfrage', Weltwirtschaftliches Archiv 30, (cited in Brown and Deaton (1972)).
- Lillard, L.A. and Acton, J.P. (1981), 'Seasonal electricity demand an pricin analysis with a variable esponse model', Bell Journal of Economics 12(1), 71-92.
- Lloyd, C. (1967), Microeconomic Analysis, Irwin, Homewood.

- Mack, R.P. and Leighland, T.J. (1982), '"Optimising" in households: toward a behavioural theory', American Economic Review 72(2), 103-6.
- Marshall, A. (1949), Principles of Economics, 8th edn, Macmillan, London (first edition published in 1890).
- Martin, W.E., Ingram, H. and Laney, N.K. (1982), 'A willingness to play: analysis of water resource development', Western Journal of Agricultural Economics 7(1), 133- 9.
- McShane, R.W. (1971), 'Demand function restriction for empirical studies', Australian Economic Papers 10(17), 161-74.
- Mood, A.M., Graybill, F.A. and Boes, D.C. (1974), Introduction to the Theory of Statistics, 3rd edn, McGraw-Hill, U.S.A..
- Moore, H.L. (1929), Synthetic Economics, Macmillan, New York.
- Morgan, W.D. (1973), 'Residential water demand: the case for micro data', Water Resources Research 9(4), 1065- 7.
- Muth, R.F. (1966), 'Household production and consumer demand functions', Econometrica 34(3), 699-708.
- Nerlove, M. (1960), 'The market demand for durable goods', Econometrica 28(1), 132-42.
- Ng, Y-K and Weisser, M. (1974), 'Optimal pricing with a budget constraint - the case of the two-part tariff', Review of Economic Studies 41(3), 337-45.
- Opaluch, J.J. (1982), 'Urban residential demand for water in the U.S. Further discussion, Land Economics 58(2), 225-7.
- Pareto, V. (1906), Manuali di Economia Politica, con una Introduzione alla Scienza Sociale, Societa Editrice Libreria, Milan (English translation by A.S. Schwier (1972), Manual of Political Economy, Macmillan).
- Parti, M. and Parti, C. (1980), 'The total and appliance-specific conditional demand for electricity in the household sector', Bell Journal of Economics 11(1), 309-21.
- Pearce, I.F. (1961), 'An exact method of consumer demand analysis, Econometrica 29(4), 499-516.
- Pearson, E.S. (1931), 'The analysis of variance in cases of non-normal variation', Biometrika 23(1), 114-33.

- Pigou, A.C. (1910), A method of determining the numerical value of elasticities of demand, Economic Journal 20(September), 358-70.
- Pindyck, R.S. and Rubinfeld, D.L. (1981), Econometric Models and Economic Forecasts, 2nd edn, McGraw-Hill Kogakusha, Tokyo.
- Pitts, R.E., Willenborg, J.F. and Sherrell, D.L. (1981), 'Consumer adaptation to gasoline price increases', Journal of Consumer Research 8(3), 322-30.
- Powell, A. (1977), Patterns in Household Demand and Saving, Oxford University Press, New York.
- Pullinger, B.F. (1978), Residential water demand: alternatives for planning and management, M.Nat.Res. thesis, University of New England, Armidale.
- Randall, A. (1981), 'Property entitlements and pricing policies for a maturing water economy', Australian Journal of Agricultural Economics 25(3), 195-220.
- Randall, A., Ives, B. and Eastman, C. (1974), 'Bidding games for valuation of aesthetic environmental improvements', Journal of Environmental Economics and Management 1(2), 32-49.
- Reynolds, R.G. (1979), 'Retail demand for meats in Australia: a study of the theory and application of consumer demand, M.Ec. thesis, University of New England, Armidale.
- Ritchie, J.R.B., McDougall, G.H.G. and Claxton, J.D. (1981), 'Complexities of household energy consumption and conservation', Journal of Consumer Research 8(3), 233-42.
- Robinson, R.W. (1981), Residential Water Demand, PhD thesis, University of Sydney, Sydney.
- Ruggles, N. (1949-50), 'Recent developments in the theory of marginal cost pricing', Review of Economic Studies 17, 107-26, Reprinted in Turvey, R. (1968), Public Enterprise, Penguin, Harmondsworth.
- Samuelson, P.A. (1938), 'A note on the pure theory of consumer behaviour', Economica 5(17), 61-71.
- Samuelson, P.A. (1950), 'The problem of integrability in utility theory', Economica 17(68), 355-85.
- Samuelson, P.A. (1970), Foundations of Economic Analysis, Harvard University Press, New York.

- Schmid, A.A. (1967), 'Nonmarket values and efficiency of public investments in water resources', American Economic Review 57(2), 158-68.
- Schultz, H. (1928), Statistical Laws of Demand and Supply with Special Applications to Sugar, Chicago University Press, Chicago.
- Seneca, J.J. (1970), 'The welfare effects of zero pricing of public goods', Public Choice 6, 101-10.
- Sewell, W.R.D. and Roueche, L. (1974), 'Peak load pricing and urban water management: Victoria, B.C., a case study', Natural Resources Journal 14(3), 383-400.
- Shapiro, S.S. and Wilk, M.B. (1965), 'An analysis of variance test for normality (complete samples)', Biometrika 52(4), 591-611.
- Sigurdson, D.G. (1982), 'Consumer surplus from public water works', Canadian Journal of Agricultural Economics 30(3), 359-68.
- Slutsky, E. (1915), 'Sulla teoria del bilancio del consumatore', Giornale degli Economiste 5, (English translation in Stigler, G.J. and Boulding, K.E. (eds) (1952), Readings in Price Theory, Irwin, Homewood).
- Smith, A. (1893), An Enquiry into the Nature and Causes of the Wealth of Nations, Routledge, London (first published by Strahan and Cadell, 1776).
- Snedecor, G.W. and Cochran, W.G. (1967), Statistical Methods, 6th edn, Iowa State University Press, Ames.
- Stigler, J.G. and Becker, G.S. (1977), 'De Gustibus Non Est Disputandum', American Economic Review 67(2), 76-90.
- Stone, J.R.N. (1954), 'Linear expenditure systems and demand analysis: an application to the pattern of British demand', Economic Journal 64(September), 511-27.
- Strotz, R.H. (1957), The empirical implications of a utility tree, Econometrica 25(2), 269-80.
- Sukhatme, P.V. and Sukhatme, B.V. (1970), Sampling Theory of Surveys With Applications, 2nd edn, Iowa State University Press, Ames.
- Taylor, L.D. (1975), 'The demand for electricity', Bell Journal of Economics 6(1), 74-110.

- Terza, J.V. and Welch, W.P. (1982), 'Estimating demand under block rates: electricity and water', Land Economics 58(2), 181-8.
- Theil, H. (1971), Principles of Econometrics, Wiley, New York.
- Tisdell, C.A. (1972), Microeconomics: The Theory of Economic Allocation, Wiley, Sydney.
- Tomek, W.G. and Cochrane, W.W. (1962), 'Long-run demand: a concept, and elasticity estimates for water', Journal of Farm Economics 44(3), 717-30.
- Tomek, W.G. and Robinson, K.L. (1981), Agricultural Product Prices, 2nd edn, Cornell University Press, Ithaca.
- Tomek, W.G. and Robinson, K.L. (1977), 'Agricultural price analysis and outlook', in Martin, L.R. A Survey of Agricultural Economics Literature 1(5), 325-409.
- Turnovsky, S.J. (1969), 'The demand for water: some empirical evidence on consumers' response to a commodity uncertain in supply', Water Resources Research 5(2), 350-61.
- Turvey, R. (1971), Economic Analysis and Public Enterprises, Allen and Unwin, Oxford.
- Turvey, R. (ed) (1968), Public Enterprise, Penguin, Harmondsworth.
- Wallace, T.D. (1977), 'Pretest estimation in regression: a survey', American Journal of Agricultural Economics 59(3), 431-43.
- Walras, L. (1874), Elements d'Economie Politique Pure, L. Corbus et Cie, Lausanne (English translation by W. Jaffe (1954), Elements of Pure Economics, or the Theory of Social Wealth, Allen and Unwin, London).
- Walters, A.A. (1968), An Introduction to Econometrics, Macmillan, London.
- Warford, J.J. (1968), 'Water supply', in Turvey, R. (ed), Public Enterprise, Penguin, Harmondsworth, 212-36.
- Watson, D.S. (1968), Price Theory and its Uses, 2nd edn, Houghton Mifflin.
- Williamson, O.E. (1966), 'Peak-load pricing and optimal capacity under indivisibility constraints', American Economic Review 56(4), 810-27, reprinted in Turvey, R. (1968), Public Enterprise, Penguin, Harmondsworth.

- Willig, R.D. (1976), 'Consumer's surplus without apology', American Economic Review 66(4), 589-97.
- Wills, J. (1981), 'Residential demand for electricity', Energy Economics 3(4), 249-55.
- Winch, D.M. (1973), Analytical Welfare Economics, Penguin, Harmondsworth.
- Wold, H. and Jureen, L. (1964), Demand Analysis: A Study in Econometrics (3rd printing), Wiley, New York.
- Wong, S.T. (1972), 'A model on municipal water demand: a case study of northeastern Illinois', Water Resources Research 46(1), 35-44.
- Working, E.J. (1927), 'What do statistical demand curves show?', Quarterly Journal of Economics 41(February), 212-35.
- Yamane, T. (1967), Statistics: An Introductory Analysis, 2nd edn, Harper and Row, New York.
- Young, R.A. (1973), 'Price elasticity of demand for municipal water: a case study of Tucson, Arizona', Water Resources Research 9(4), 1068-72.
- Yule, G.U. (1926), 'Why do we sometimes get nonsense correlations between time series?', Journal of the Royal Statistical Society 89(1), 1-64.