CHAPTER 6: RESULTS OF DEMAND ESTIMATIONS

6.1 Overview of the chapter

Different combinations of the stipulated demand function were estimated using three different functional forms mentioned in chapter five. The logarithmic functional forms were accepted as the most useful for the purposes of this study, especially as the statistical results differed insignificantly from those of the linear or translog functional forms. The OLS estimation yielded results that ranged widely from significant to insignificant for the respective variables. Some of the variables were lagged to obtain better t-values and appropriate signs. Accordingly, the rainfall variable was lagged by one month as this ensured that the two sets of data corresponded by monthly reporting, the price variables were lagged in order to capture the assumption that consumers change their responsiveness over time thereby allowing comparison of both long-run and short-run price elasticities of demand. The goodness of fit of each equation varied and some were limited by the extent to which the data is aggregated. The Durban-Watsin test was carried out on some of the variables to test for serial correlation and indicated that the degree to which serial correlation became problematic varied between estimations and it was therefore dealt with on case specific basis.

This chapter reports results of the single equation OLS estimations. Estimations were run for each scale of user within Tshwane and their respective user classes. A fuller discussion on the price elasticities follows after the general models for the different user classes have been discussed.

6.2 Scale A: Agricultural Small-holdings

Agricultural small-holdings are defined by the Tshwane municipality as large plots of land that fall within the residential area. It is expected that many of these small-holdings have boreholes and are characterised as large users of water for outdoor purposes, due to their access to other sources of water it is expected that they may not be as responsive to pricing as initially hypothesised. Scale A users are divided into two classes of use namely, the first 0,2 kilolitres of daily consumption (low category) and more than 0,2 kilolitres of the daily consumption (high category).

6.2.1 Low class users

Table 6-1 shows the results of the OLS regression for low category demand users for agricultural small-holdings. These are users that demand up to 0,2 kilolitres of the daily allowance. The adjusted-R^2 of 88 percent indicated that the variables represented the demand relationship well. The Durban-watson statistic was used to test for serial correlation in this time series regression and indicated that the level of serial correlation between the relevant variables was small. The seasonal dummy variables proved to be statistically insignificant and had the wrong signs, but were retained as they improved the goodness of fit. The temperature coefficient also showed an unexpected negative sign but this may be linked to the fact that Tshwane has a summer rainfall, this increase in rainfall with temperature increases may very well lead to a reduction in outdoor water demand on residential properties such as small-holdings. The short-run average price variable also showed a positive sign instead of a negative sign but this was common for many of the estimations and was explained by the increasing block rate tariff and the fact that consumers are initially unaware of the price to which they are responding and merely consume according to needs. This however changes in the long-run as the sign for the lagged average price variable becomes negative over six months. Consumers respond directly to the marginal price reducing consumption as price increases in both the short and long run, but their responsiveness unexpectedly tends to be greater in the short-run. The data plot (figure 6-1) depicts the relationship between the actual and fitted results of the estimation for low category agricultural small-holding users. The results indicate a relatively good fit.

Table 6-1: Modified Logarithmic OLS demand function for Scale A – Low class users

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	14.07	1.30	10.85	0.00
2	P^*_{APALOW}	α_1	2.85	0.62	4.62	0.00
3	P^*_{MPALOW}	α_2	-3.04	0.38	-8.11	0.00
4	$P^*_{APALOW(-6)}$	α_3	-1.41	0.56	-2.53	0.02
5	$P^*_{MPALOW(-6)}$	α_4	-0.92	0.38	-2.46	0.02
6	$Rainfall_{(-5)}$	α_5	-0.03	0.02	-1.20	0.24
7	Temperature	α_6	-1.15	0.39	-2.96	0.00
8	D1nl	α_7	0.05	0.10	0.46	0.65
9	D2	α_8	0.27	0.14	1.86	0.07
10	D3	α_9	0.30	0.11	2.70	0.01
11	UserA	α_{10}	-	-	-	-
12	Dependent Variable	QALOW		R^2		0.90
13	Mean	8.21		R^2-adjusted		0.88
14	Standard Deviation	0.58		S.E. of regression		0.19
15	Sample size	54		Akaike info criterion		-0.27
16	Error Sum of Squares	1.67		Durbin-watson		1.89

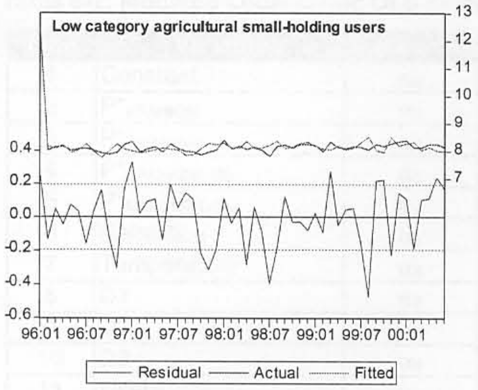


Figure 6-1: Low class users for agricultural small-holdings

6.2.2 High class users

Table 6-2 shows the results of the OLS regression for high category demand users for agricultural small-holdings. These are users that demand more than the first 0,2 kilolitres of the daily allowance. The adjusted-R^2 of 26 percent indicated that the variables represented the demand relationship poorly. The price coefficients showed expected signs except for the short run average price coefficient which was positive, once again this may be explained by the increasing block rate pricing system. The rainfall coefficient showed a negative sign, which was expected but was poorly significant, while temperature was highly significant it showed a negative sign. The confusion of signs within the weather variables may be due to the influence of summer rainfall patterns in the region, where increases in temperature are associated with increases in rainfall. The only significant dummy variable was that for summer with a coefficient of 0.32 (2.00 t-statistic), indicating that increases in temperature lead to small increases in the demand for water. The data plot in figure 6-2 represents the above-mentioned relationship graphically.

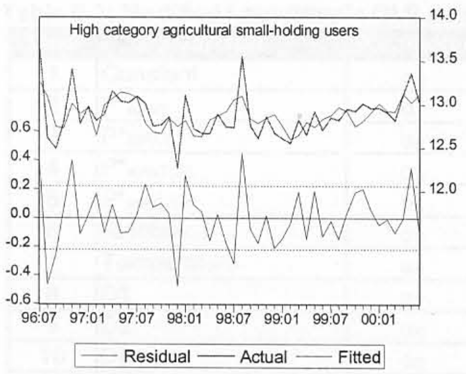


Figure 6-2: High class users for agricultural small-holdings

Table 6-2: Modified Logarithmic OLS demand function for Scale A – High class users

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	18.23	1.66	10.98	0.00
2	$P^*_{APAHIGH}$	α_1	3.05	1.55	1.96	0.06
3	$P^*_{MPAHIGH}$	α_2	-1.53	1.41	-1.08	0.29
4	$P^*_{APAHIGH(-12)}$	α_3	-2.02	1.05	-1.92	0.06
5	$P^*_{MPAHIGH(-12)}$	α_4	-0.16	-0.17	-0.96	0.34
6	$Rainfall_{(-1)}$	α_5	-0.01	-0.03	-0.35	0.73
7	Temperature	α_6	-1.70	0.45	-3.79	0.00
8	D1	α_7	0.11	0.12	0.90	0.37
9	D2	α_8	0.32	0.16	2.00	0.05
10	D3	α_9	0.24	1.53	1.56	0.13
11	UserA	α_{10}	-	-	-	-
12	Dependent Variable	QALOW		R^2		0.40
13	Mean	12.88		R^2-adjusted		0.26
14	Standard Deviation	0.26		S.E. of regression		0.22
15	Sample size	48		Akaike info criterion		0.00
16	Error Sum of Squares	1.86		Durbin-watson		2.30

6.2.3 Aggregated demand across all classes

The aggregated OLS demand function is shown in Table 6-3. This demand function gives the results of for all agricultural small-holdings user classes and categories. Once again, the rainfall and temperature coefficients showed negative signs with rainfall being statistically insignificant and temperature significant. The short run price variables showed unexpected positive signs, while the long run price variables corrected for this and showed negative signs. The short run average price proved to be more statistically significant that the short run marginal price, as users are probably initially unaware of the marginal price. However in the long run users become more responsive to the marginal price for water than the average price for water. However, the adjusted-R^2 of 32 percent indicated a poor goodness of fit.

Table 6-3: Modified Logarithmic OLS demand function for Scale A – Total

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	17.34	1.36	12.71	0.00
2	P^*_{APAT}	α_1	0.79	0.33	2.38	0.02
3	P^*_{MPAT}	α_2	0.17	0.28	0.60	0.55
4	$P^*_{APAT(-6)}$	α_3	-0.36	0.27	-1.32	0.19
5	$P^*_{MPAT(-6)}$	α_4	-0.53	0.18	-2.92	0.00
6	$Rainfall_{(-1)}$	α_5	-0.00	0.02	-0.00	0.99
7	Temperature	α_6	-1.51	0.41	-3.67	0.00
8	D1	α_7	0.10	0.11	0.93	0.36
9	D2	α_8	0.29	0.15	1.97	0.05
10	D3	α_9	0.27	0.13	2.06	0.04
11	UserA	α_{10}	-	-	-	-
12	Dependent Variable	QALOW		R^2		0.43
13	Mean	12.94		R^2-adjusted		0.32
14	Standard Deviation	0.26		S.E. of regression		0.21
15	Sample size	54		Akaike info criterion		-0.07
16	Error Sum of Squares	2.02		Durbin-watson		2.11

The data plot in figure 6-3 represents the above-mentioned relationship graphically.

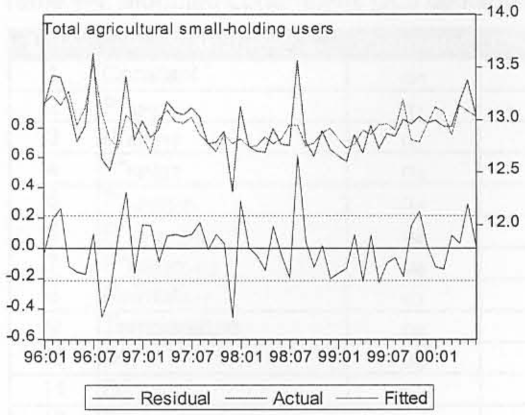


Figure 6-3: Total for agricultural small-holding users

6.3 Scale B: Residential housing

Residential housing incorporates all forms of residence within the Pretoria municipal area except for old age homes and multi-story complexes. This study reports on three categories, namely houses, duets and home-industries.

6.3.1 Aggregated residential demand across all classes

Table 6-4 shows the aggregated OLS demand for residential housing in Pretoria, with an adjusted-R^2 of 52 percent. The estimation for scale B aggregated the user classes identified in Table 5-2. The short run price elasticities proved to be insignificant, but showed the correct signs, while the long run price elasticities were statistically significant but the average price showed an unexpected positive sign. The long run average price variable was lagged for 3 months, while both the marginal price variables were lagged for 12 months. The marginal price variables reflect the change in price from user class 1 to user class 2, and from user class 2 to 3. Both rainfall and temperature were statistically significant and showed the expected signs. The dummy variables were insignificant and only the spring dummy showed the expected sign. The number of users was shown to be statistically significant but had an unexpected negative sign.

Table 6-4: Modified Logarithmic OLS demand function for Scale B – Total

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	26.40	6.36	4.15	0.00
2	P^*_{APBT}	α_1	-0.32	0.33	-0.96	0.34
3	P^*_{MPB1T}	α_2	-0.09	0.20	-0.47	0.64
4	P^*_{MPB2T}	α_3	-	-	-	-
5	$P^*_{APBT(-3)}$	α_4	0.94	0.31	3.01	0.00
6	$P^*_{MPB1T(-12)}$	α_5	-	-	-	-
7	$P^*_{MPB2T(-12)}$	α_6	-0.90	0.35	-2.61	0.01
8	$Rainfall_{(-1)}$	α_7	-0.04	0.01	-3.31	0.00
9	Temperature	α_8	0.77	0.21	3.64	0.00
10	D1	α_9	-0.03	0.08	-0.35	0.73
11	D2	α_{10}	0.05	0.11	0.48	0.63
12	D3	α_{11}	-0.06	0.11	-0.55	0.59
13	UserA	α_{12}	-1.24	0.57	-2.18	0.03
14	Dependent Variable	QB		R^2		0.62
15	Mean	15.05		R^2-adjusted		0.52
16	Standard Deviation	0.15		S.E. of regression		0.10
17	Sample size	48		Akaike info criterion		-1.48
18	Error Sum of Squares	0.41		Durbin-watson		1.79

The data plot in figure 6-4 represents the above-mentioned relationship graphically.

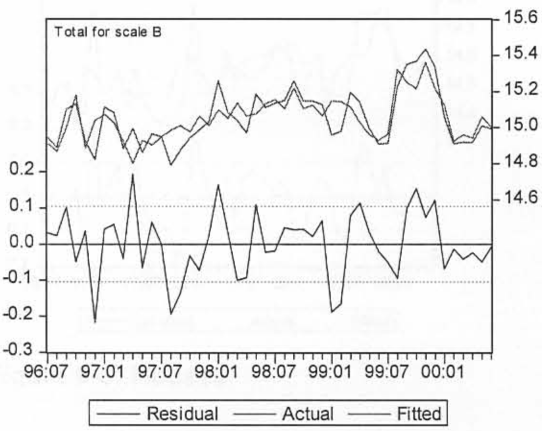


Figure 6-4: Total residential housing

6.3.2 OLS demand for residential users

Table 6-5 shows the demand for residential users. The adjusted-R^2 of 30 percent shows a poor goodness of fit. The short run price variables showed unexpected positive signs and were statistically insignificant. However, when the marginal price variables were lagged by 12 months, the signs became positive and the marginal price for user classes 2 to 3 became statistically significant. This shows that overtime the consumers respond more to marginal price but this is more strongly felt by consumers in the higher user classes. Both the rainfall and maximum temperature coefficients showed the expected signs, but proved to be statistically insignificant.

Table 6-5: Modified Logarithmic OLS demand function for Scale B – Houses

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	13.93	0.45	31.00	0.00
2	P^*_{APBT}	α_1	0.08	0.29	0.27	0.79
3	P^*_{MPB1T}	α_2	0.23	0.16	1.42	0.16
4	P^*_{APB2T}	α_3	0.18	0.46	0.39	0.70
5	$P^*_{APBT(-6)}$	α_4	0.38	0.27	1.40	0.17
6	$P^*_{MPB1T(-12)}$	α_5	-0.01	0.14	-0.10	0.92
7	$P^*_{MPB2T(-12)}$	α_6	-0.67	0.31	-2.18	0.04
8	$Rainfall_{(-1)}$	α_7	-0.00	0.01	-0.92	0.35
9	Temperature	α_8	0.06	0.14	0.47	0.64
10	D1	α_9	-	-	-	-
11	D2	α_{10}	0.14	0.05	2.49	0.02
12	D3	α_{11}	-	-	-	-
13	UserB	α_{12}	-	-	-	-
14	Dependent Variable	QB		R^2		0.43
15	Mean	14.55		R^2-adjusted		0.30
16	Standard Deviation	0.12		S.E. of regression		0.10
17	Sample size	48		Akaike info criterion		-1.64
18	Error Sum of Squares	0.36		Durbin-watson		1.85

The data plot in figure 6-5 represents the above-mentioned relationship graphically.

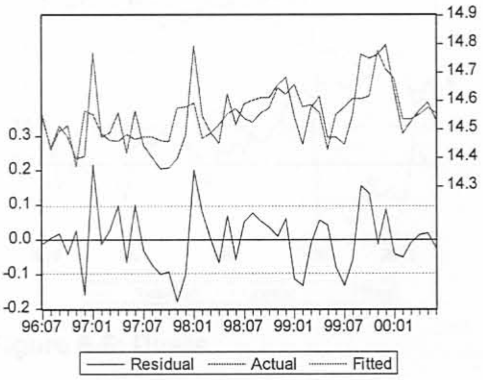


Figure 6-5: Houses

6.3.3 OLS demand for duets

Table 6-6 shows the demand for semi-attached houses. The adjusted-R^2 of 61 percent shows an average goodness of fit. The short-run average price showed an unexpected positive sign, but consumers were shown to be highly responsive to the short-run marginal price. It proved to be highly statistically significant and held a negative sign. In the longer term however, consumers tended to respond more strongly to the average price with it being more statistically significant. Both long-run price variables showed the expected signs, there was however a certain degree of serial correlation within this user category.

Table 6-6: Modified Logarithmic OLS demand function for Scale B - Duets

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	16.27	2.50	6.52	0.00
2	P^*_{APAT}	α_1	4.51	2.54	1.77	0.08
3	P^*_{MPAT}	α_2	-13.48	4.35	-3.10	0.00
4	$P^*_{APAT(-6)}$	α_3	-5.08	2.14	-2.38	0.02
5	$P^*_{MPAT(-6)}$	α_4	-3.59	3.79	-0.95	0.35
6	$Rainfall_{(-1)}$	α_5	-0.03	0.05	-0.62	0.54
7	Temperature	α_6	-0.08	0.75	-0.11	0.92
8	D(SUMMER)	α_7	O.18	0.29	0.64	0.52
9	D2	α_8	-	-	-	-
10	D3	α_9	-	-	-	-
11	UserA	α_{10}	-	-	-	-
12	Dependent Variable	Qduettes		R^2		0.66
13	Mean	10.21		R^2-adjusted		0.61
14	Standard Deviation	0.80		S.E. of regression		0.50
15	Sample size	54		Akaike info criterion		1.58
16	Error Sum of Squares	0.50		Durbin-watson		0.63

The data plot in figure 6-6 represents the above-mentioned relationship graphically.

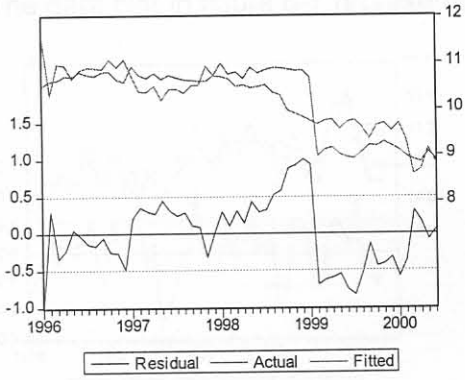


Figure 6-6: Duets

6.3.4 OLS demand for home industries

Table 6-7 shows the demand for home industries. The adjusted-R^2 of 46 percent shows a poor goodness of fit. The short-run marginal price variables showed unexpected positive signs and were statistically insignificant, while the short-run average price variable showed a negative sign but was also statistically insignificant. However, when the marginal price variables were lagged by 6 months, the signs became positive and the marginal price for user classes 2 to 3 was almost statistically significant. The weather variables showed expected signs with only temperature being statistically significant. The user and dummy variables were not statistically significant.

Table 6-7: Modified Logarithmic OLS demand function for Scale B – Home industries

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	21.75	7.86	2.77	0.01
2	P^*_{APAT}	α_1	-0.25	0.33	-0.75	0.46
3	P^*_{MPAT1}	α_2	0.18	0.18	1.01	0.32
4	P^*_{MPAT2}	α_3	0.10	0.54	0.18	0.86
5	$P^*_{APAT(-6)}$	α_4	0.78	0.35	2.23	0.03
6	$P^*_{MPAT1(-6)}$	α_5	-0.28	0.16	-1.70	0.10
7	$P^*_{MPAT2(-6)}$	α_6	-0.16	0.38	-0.42	0.67
8	$Rainfall_{(-1)}$	α_7	-0.02	0.01	-1.13	0.27
9	Temperature	α_8	0.61	0.24	2.57	0.01
10	D1	α_9	0.07	0.09	0.79	0.44
11	D2	α_{10}	-0.05	0.13	-0.39	0.70
12	D3	α_{10}	-0.16	0.11	-1.44	0.16
13	UserA		-0.81	0.70	-1.16	0.25
14	Dependent Variable	Qhomeind		R^2		0.59
15	Mean	15.03		R^2-adjusted		0.46
16	Standard Deviation	0.16		S.E. of regression		0.12
17	Sample size	54		Akaike info criterion		-1.27
18	Error Sum of Squares	0.12		Durbin-watson		1.44

The data plot in figure 6-7 represents the above-mentioned relationship graphically.

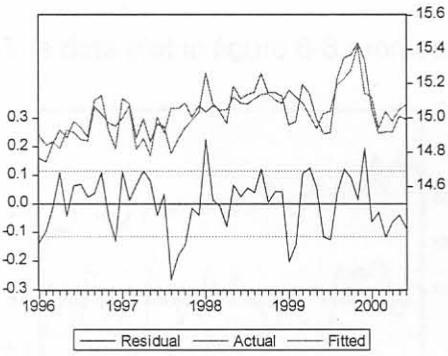


Figure 6-7: Home industries

6.4 Scale C: Duplexes / simplexes

Scale C identifies multi-level housing complexes. Consumers are often metered through one or two points and are billed based on the complex average.

6.4.1 OLS demand for low class users

Table 6-8 shows the OLS demand for consumers of the first 30 percent of daily demand. The adjusted-R^2 of 64 percent indicated that the variables represented the demand relationship fairly well. As this was the first user class, no marginal price variables were included in the estimation. The average price coefficients for both the long-run and the short-run proved to be statistically significant with expected signs. When average price was lagged by 18 months, the consumer proved to be less responsive to price changes than in the short-run, this was unexpected. The weather variables and dummy variables proved to be statistically insignificant and showed both expected and unexpected signs.

Table 6-8: Modified Logarithmic OLS demand function for Scale C – Lifeline rebate

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	28.66	12.41	2.31	0.03
2	P^*_{APCLR}	α_1	-3.14	0.55	-5.74	0.00
3	P^*_{MPCLR}	α_2	-	-	-	-
4	$P^*_{APCLR(-18)}$	α_3	-1.86	0.60	-3.11	0.00
5	$P^*_{MPCLR(-18)}$	α_4	-		-	
6	Rainfall	α_5	-0.01	0.02	-0.31	0.76
7	Temperature	α_6	-0.54	0.33	-1.61	0.12
8	D1	α_7	0.12	0.08	1.51	0.14
9	D2	α_8	0.15	0.12	1.25	0.22
10	D3	α_9	0.11	0.11	1.05	0.29
11	UserC	α_{10}	-1.44	1.66	-0.86	0.40
12	Dependent Variable	QCLR		R^2		0.70
13	Mean	12.49		R^2-adjusted		0.64
14	Standard Deviation	0.24		S.E. of regression		0.15
15	Sample size	42		Akaike info criterion		-0.83
16	Error Sum of Squares	0.70		Durbin-watson		1.75

The data plot in figure 6-8 represents the above-mentioned relationship graphically.

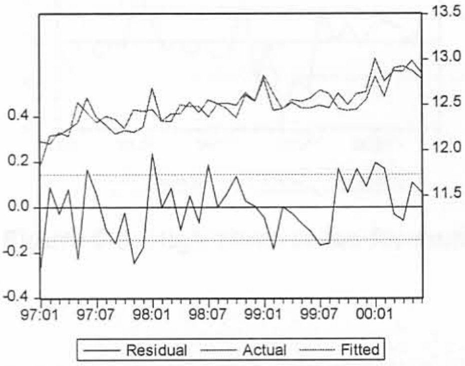


Figure 6-8: Low class users for multi-level residential complexes

6.4.2 OLS demand for high class users

Table 6-9 shows the results of the demand estimation for scale C. The adjusted-R^2 showed an excellent fit of 95 percent. The short run price variables showed the expected signs but were not statistically significant. The long run price variables were lagged for 30 months and the average price showed the correct sign but was also statistically insignificant while the marginal price variable was just statistically significant it did not have the expected sign. Rainfall and the dummy variables were not statistically significant.

Table 6-9: Modified Logarithmic OLS demand function for Scale C – High class users

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	15.49	0.93	16.64	0.00
2	P^*_{APC}	α_1	-0.95	0.72	-1.32	0.20
3	P^*_{MPC}	α_2	-0.28	0.52	-0.53	0.60
4	$P^*_{APC(-30)}$	α_3	-0.77	0.93	-0.83	0.42
5	$P^*_{MPC(-30)}$	α_4	1.11	0.55	2.00	0.06
6	Rainfall	α_5	-0.00	0.01	-0.24	0.82
7	Temperature	α_6	-	-	-	-
8	D1	α_7	0.06	0.06	1.04	0.31
9	D2	α_8	0.02	0.06	0.26	0.80
10	D3	α_9	-0.05	0.05	-0.97	0.34
11	UserC	α_{10}	-	-	-	-
12	Dependent Variable	QC		R^2		0.96
13	Mean	13.63		R^2-adjusted		0.95
14	Standard Deviation	0.37		S.E. of regression		0.08
15	Sample size	30		Akaike info criterion		-1.85
16	Error Sum of Squares	0.15		Durbin-watson		1.83

The data plot in figure 6-9 represents the above-mentioned relationship graphically.

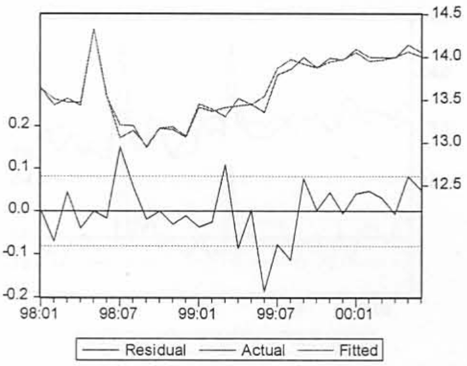


Figure 6-9: High class users for multi-level residential complexes

6.4.3 Aggregated demand for scale C

The aggregated demand for Scale C is shown in Table 6-10, with a poor adjusted-R^2 of 28 percent. The price variables showed expected negative signs and the long run average price variable was statistically significant. The long run price variables were lagged for 8 months. Both the maximum temperature variable and the spring season dummy were statistically significant and showed the correct signs.

Table 6-10: Modified Logarithmic OLS demand function for Scale C – Total

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	-7.09	13.94	-0.51	0.61
2	P^*_{APC}	α_1	0.50	0.67	0.75	0.46
3	P^*_{MPC}	α_2	-0.14	0.10	-1.38	0.18
4	$P^*_{APC(-8)}$	α_3	-2.13	0.65	-3.26	0.00
5	$P^*_{MPC(-8)}$	α_4	-0.01	0.10	-0.10	0.92
6	$Rainfall_{(-1)}$	α_5	-0.01	0.02	-0.45	0.65
7	Temperature	α_6	0.76	0.35	2.15	0.04
8	D1	α_7	-0.23	0.09	-2.35	0.02
9	D2	α_8	-0.21	0.13	-1.66	0.10
10	D3	α_9	-0.22	0.12	-1.85	0.07
11	UserC	α_{10}	2.71	1.88	1.44	0.16
12	Dependent Variable	QC		R^2		0.42
13	Mean	13.53		R^2-adjusted		0.28
14	Standard Deviation	0.21		S.E. of regression		0.18
15	Sample size	52		Akaike info criterion		-0.38
16	Error Sum of Squares	1.36		Durbin-watson		1.94

The data plot in figure 6-10 represents the above-mentioned relationship graphically.

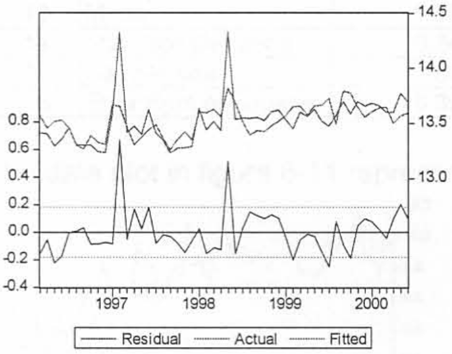


Figure 6-10: Total for multi-level residential complexes

6.5 Scale D: Residential businesses

Due to the data limitations the estimations for small residential businesses could not be run.

6.6 Scale E: Retirement villages

Retirement villages are metered separately in the Pretoria City Council and hence the demand results are recorded below:

6.6.1 OLS demand for low class users

Table 6-11 shows the results for the first 30 percent demanded of daily water consumption. The adjusted-R^2 of 60 percent indicates a fair fit. The price variables all show negative signs except for the short run average price variable that shows a positive sign. This may also be attributed to the increasing block rate system where as one moves to a higher level of consumption one pays more for the water. Rainfall and temperature show the expected signs but are not statistically significant. The dummy and user variables are also not statistically significant and show unexpected signs.

Table 6-11: Modified Logarithmic OLS demand function for Scale E – Low class users

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	8.53	1.11	7.68	0.00
2	P^*_{APELOW}	α_1	1.99	0.58	3.42	0.00
3	P^*_{MPELOW}	α_2	-0.09	0.32	-0.28	0.78
4	$P^*_{APELOW(-9)}$	α_3	-0.51	0.48	-1.05	0.30
5	$P^*_{MPELOW(-9)}$	α_4	-0.62	0.46	-1.35	0.18
6	$Rainfall_{(-1)}$	α_5	-0.01	0.02	-0.89	0.72
7	Temperature	α_6	0.11	0.33	0.34	0.73
8	D1	α_7	-0.10	0.11	-0.89	0.38
9	D2	α_8	-0.06	0.14	-0.42	0.68
10	D3	α_9	-0.01	0.14	-0.10	0.92
11	UserE	α_{10}	-0.02	0.05	-0.3	0.67
12	Dependent Variable	QELOW		R^2		0.68
13	Mean	9.78		R^2-adjusted		0.60
14	Standard Deviation	0.24		S.E. of regression		0.15
15	Sample size	51		Akaike info criterion		-0.78
16	Error Sum of Squares	0.89		Durbin-watson		1.37

The data plot in figure 6-11 represents the above-mentioned relationship graphically.

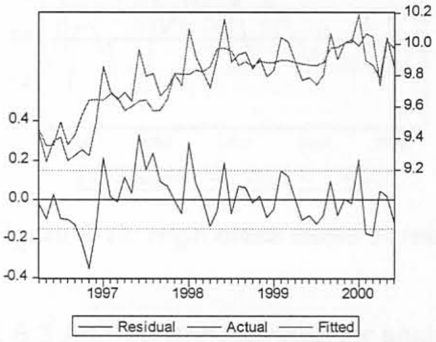


Figure 6-11: Low class users in retirement villages

6.6.2 OLS demand for high class users

Table 6-12 shows the results for water demanded over the first 30 percent of daily water consumption. The adjusted-R^2 of 77 percent indicates a good fit. The price variables all show the expected negative signs except for the short run average price. The short run marginal price variable is statistically significant with a t-value of –2.68. It also indicates that consumers at this level are highly responsive to marginal price changes, with an elasticity of –1.27. Rainfall and maximum temperature show the expected negative and positive signs respectively but are not statistically significant. The seasonal dummy variables and the user variables all show negative signs which is unexpected for users and for autumn and winter as a fall in rainfall should lead to an increase in the demand for water.

Table 6-12: Modified Logarithmic OLS demand function for Scale E – High class users

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	8.04	1.01	7.97	0.00
2	$P^*_{APEHIGH}$	α_1	2.39	1.25	1.92	0.06
3	$P^*_{MPEHIGH}$	α_2	-1.27	0.47	-2.68	0.01
4	$P^*_{APEHIGH(-1)}$	α_3	-0.33	0.28	-0.28	0.78
5	$P^*_{MPEHIGH(-1)}$	α_4	-0.05	0.32	-0.14	0.89
6	$Rainfall_{(-1)}$	α_5	-0.01	0.02	-0.35	0.73
7	Temperature	α_6	0.34	0.28	1.21	0.23
8	D1	α_7	-0.17	0.12	-1.49	0.14
9	D2	α_8	-0.09	0.14	-0.62	0.54
10	D3	α_9	-0.04	0.12	-0.30	0.76
11	UserE	α_{10}	-0.07	0.03	-2.37	0.02
12	Dependent Variable	QEHIGH		R^2		0.80
13	Mean	10.54		R^2-adjusted		0.77
14	Standard Deviation	0.31		S.E. of regression		0.15
15	Sample size	59		Akaike info criterion		-0.78
16	Error Sum of Squares	1.09		Durbin-watson		1.46

The data plot in figure 6-12 represents the above-mentioned relationship graphically.

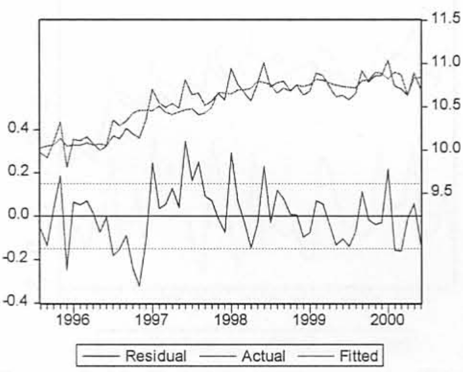


Figure 6-12: High class users at retirement villages

6.6.3 Aggregated demand for scale E

Table 6-13 shows the results for the first 30 percent demanded of daily water consumption. The adjusted-R^2 of 72 percent indicates a good fit. These results are very similar to those recorded in Table 6-12 with all the price variables except for short-run average price showing negative signs. The short-run and average long-run average price variables are statistically significant at 3.78 and –2.97 respectively. Rainfall and temperature show the expected signs but are not statistically significant. The seasonal dummy variables are all insignificant. The user variable however is significant at 5.36 and shows the expected positive sign, indicating that at this demand level the number of water users does directly lead to an increase in the demand for water and this increase is almost unitarily elastic.

Table 6-13: Modified Logarithmic OLS demand function for Scale E - Total

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	5.21	0.87	5.98	0.00
2	P^*_{APE}	α_1	1.94	0.51	3.78	0.00
3	P^*_{MPE}	α_2	-0.34	0.30	-1.13	0.26
4	$P^*_{APE(-12)}$	α_3	-1.14	0.38	-2.97	0.00
5	$P^*_{MPE(-12)}$	α_4	-0.15	0.18	-0.83	0.41
6	Rainfall	α_5	-0.01	0.01	-1.15	0.26
7	Temperature	α_6	0.33	0.23	0.23	0.15
8	D1	α_7	-0.06	0.09	-0.74	0.46
9	D2	α_8	0.07	0.12	0.64	0.53
10	D3	α_9	-0.08	0.10	-0.84	0.41
11	UserE	α_{10}	0.89	0.17	5.36	0.00
12	Dependent Variable	QE		R^2		0.77
13	Mean	11.00		R^2-adjusted		0.72
14	Standard Deviation	0.21		S.E. of regression		0.11
15	Sample size	48		Akaike info criterion		-1.27
16	Error Sum of Squares	0.49		Durbin-watson		2.00

The data plot in figure 6-13 represents the above-mentioned relationship graphically.

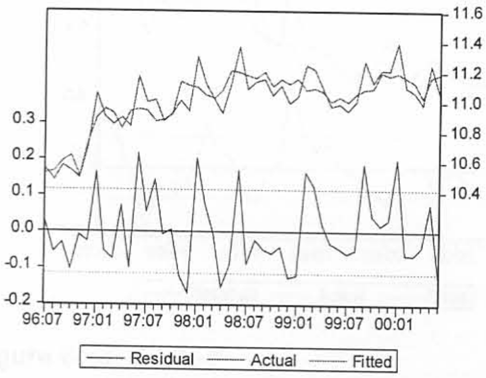


Figure 6-13: Total for retirement villages across all classes

6.7 Scale F: Industry

The accounts for a number of industrial users are recorded by the municipality. One of these accounts is for a large industrial company situated in Centurian. Table 6-14 shows a preliminary estimation for the price elasticity of water demand for industrial users in South Africa based on this user. The adjusted-R^2 of 74 percent indicates a good fit. Only average price was used in this estimation as the industry faces one user charge. Both the short-run and the long-run price variables were statistically significant at –5.24 and –3.50 respectively. The elasticities also indicate that the industry is much more responsive to price changes in the long-run than in the short-run, shifting from an absolute elasticity of 1.61 to 2.18. The rainfall variable was statistically significant and showed the correct sign, while the temperature variable was statistically insignificant and showed the incorrect sign. The seasonal dummy variables were all statistically insignificant.

Table 6-14: Modified Logarithmic OLS demand function for Scale F

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	16.80	2.33	10.70	0.00
2	P^*_{APH}	α_1	-1.61	0.34	-5.24	0.00
3	$P^*_{APH(-24)}$	α_2	-2.18	0.57	-3.50	0.26
4	Rainfall	α_3	-0.03	0.68	-1.16	0.25
5	Temperature	α_4	-0.49	0.03	-1.15	0.00
6	D1	α_5	-0.04	0.15	-0.30	0.76
7	D2	α_6	0.07	0.22	0.30	0.76
8	D3	α_7	-0.01	0.21	-0.05	0.96
9	Dependent Variable	Qindustry		R^2		0.79
10	Mean	10.90		R^2-adjusted		0.74
11	Standard Deviation	0.45		S.E. of regression		0.24
12	Sample size	36		Akaike info criterion		0.13
13	Error Sum of Squares	1.81		Durbin-watson		0.91

The data plot in figure 6-14 represents the above-mentioned relationship graphically.

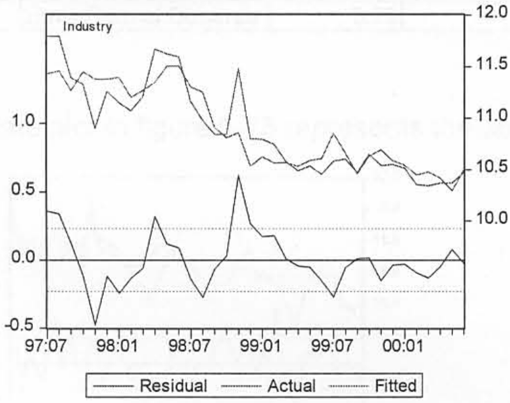


Figure 6-14: Scale F

6.8 Scale G: Attridgeville

6.8.1 OLS demand for high class users

Table 6-15 shows the results for the high class users for Attridgeville. This is the user class level 4, those who use more than 0,1 kiloliters of the daily allowance. The adjusted-R^2 of 50 percent indicates a relatively poor fit. All three marginal price variables and the average price variable were initially incorporated in the estimation, however the removal of the marginal price variables improved the adjusted R^2 and the significance of the average price variables, hence only average prices were incorporated in the model. These both showed the expected sign and the long run average price was statistically significant, it also showed that elasticity of response over time becomes more elastic for this user class. The rainfall, temperature and seasonal dummies were all statistically insignificant and only the spring dummy showed the correct sign.

Table 6-15: Modified Logarithmic OLS demand function for Scale G – High class users

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	1.72	10.76	0.16	0.87
2	P^*_{APELOW}	α_1	-0.42	0.56	-0.74	0.46
3	P^*_{MPELOW}	α_2	-	-	-	-
4	$P^*_{APELOW(-6)}$	α_3	-1.28	0.44	-2.90	0.00
5	$P^*_{MPELOW(-9)}$	α_4	-	-	-	-
6	$Rainfall_{(-1)}$	α_5	0.00	0.02	0.38	0.71
7	Temperature	α_6	0.08	0.24	0.33	0.75
8	D1	α_7	-0.08	0.10	-0.80	0.43
9	D2	α_8	0.10	0.12	0.84	0.40
10	D3	α_9	-0.05	0.11	-0.40	0.70
11	UserG	α_{10}	1.07	0.92	1.17	0.25
12	HH income	α_{11}	0.25	0.71	0.36	0.72
13	Dependent Variable	QELOW		R^2		0.58
14	Mean	11.64		R^2-adjusted		0.50
15	Standard Deviation	0.18		S.E. of regression		0.13
16	Sample size	54		Akaike info criterion		-1.13
17	Error Sum of Squares	0.79		Durbin-watson		1.33

The data plot in figure 6-15 represents the above-mentioned relationship graphically.

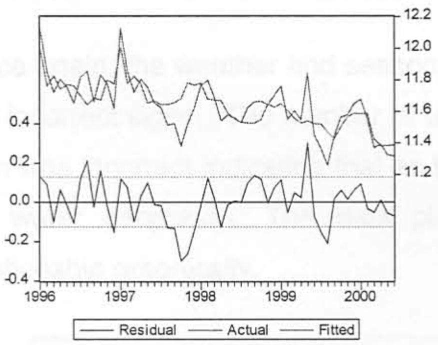


Figure 6-15: High class users for Attridgeville

6.8.2 Aggregated demand across all classes for Attridgeville

Table 6-16 shows the results for the aggregated demanded over all user classes for Attridgeville. The users in this category cover the full range of consumer classes identified in Table 5-2. The adjusted-R^2 of 28 percent represented a poor fit. Both the long-run and short-run average price variables showed positive signs and were statistically insignificant. Two marginal price variables were included in the estimation and the second lagged long-run price variable was statistically significant with a t-statistic of –2.04.

Table 6-16: Modified Logarithmic OLS demand function for Scale G – Total

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	37.67	9.78	3.85	0.00
2	P^*_{APELOW}	α_1	0.42	0.26	1.62	0.11
3	P^*_{MP1}	α_2	-0.06	0.37	-0.16	0.87
4	P^*_{MP2}	α_3	-0.43	0.91	-0.47	0.64
5	P^*_{MP3}	α_4	-	-	-	-
6	$P^*_{AP(-6)}$	α_5	0.22	0.21	1.08	0.29
7	$P^*_{MP1(-6)}$	α_6	-0.07	0.37	-0.20	0.84
8	$P^*_{MP2(-6)}$	α_7	-1.90	0.93	-2.04	0.05
9	$P^*_{MP3(-6)}$	α_8	-	-	-	-
10	$Rainfall_{(-1)}$	α_9	0.02	0.02	0.97	0.33
11	Temperature	α_{10}	0.65	0.31	2.10	0.04
12	D1	α_{11}	0.04	0.12	0.36	0.72
13	D2	α_{12}	-0.12	0.15	-0.82	0.42
14	D3	α_{13}	-0.15	0.14	-1.08	0.29
15	UserG	α_{14}	-2.89	1.01	-2.85	0.00
16	HHI	α_{15}	0.67	0.55	1.22	0.23
17	Dependent Variable	Qattridge		R^2		0.46
18	Mean	12.90		R^2-adjusted		0.28
19	Standard Deviation	0.18		S.E. of regression		0.15
20	Sample size	54		Akaike info criterion		-0.71
20	Error Sum of Squares	0.93		Durbin-watson		1.31

Once again, the weather and seasonal variables were statistically insignificant and showed the incorrect signs. The number of users in Attridgeville was statistically significant but the sign was incorrect indicating that as the number of users of water increase as the demand for water decreases. The data plot in figure 6-16 represents the above-mentioned relationship graphically.

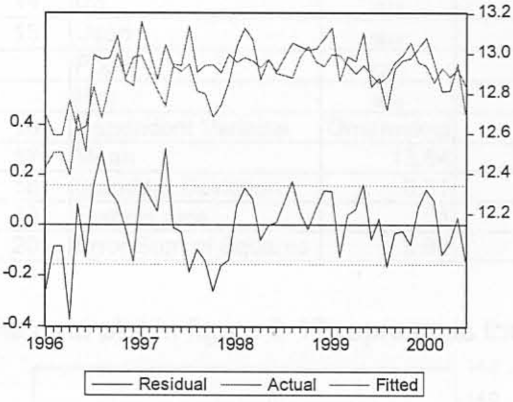


Figure 6-16: Total users across all classes for Attridgeville

6.9 Scale H: Mamelodi

Table 6-17 shows the results for the aggregated demanded over all user classes for Mamelodi. The adjusted-R^2 of 43 percent indicates a poor goodness of fit. All three marginal prices and the average price for Mamelodi were included in the estimation. All the short-run prices showed unexpected positive signs, a result of the increasing block rate tariff consumers face. All the long-run prices showed the expected negative signs. The weather and seasonal variables also proved to be statistically insignificant with rainfall and the spring dummy having the correct negative signs. The user variable was also statistically insignificant but not far from 2.0, the sign was negative. Both a population variable and a household variable were included in this model. The population variable proved to have a t-value of 32.60 but the sign was incorrect. The income variable however was also statistically significant with a t-value of 2.79 and a coefficient of 34.47 indicating that consumers are highly responsive to changes in income, as a 1 unit increase in income will lead to 34.47 unit change in their demand for water.

Table 6-17: Modified Logarithmic OLS demand function for Scale H – Total

Line	Variable	Parameter	Coefficient	Std. Error	T-statistic	Prob.
1	Constant	α_0	512.31	165.91	3.09	0.00
2	P^*_{APELOW}	α_1	0.76	0.49	1.54	0.13
3	P^*_{MP1}	α_2	15.17	5.33	2.84	0.01
4	P^*_{MP2}	α_3	5.39	4.05	1.33	0.19
5	P^*_{MP3}	α_4	1.42	2.38	0.60	0.55
6	$P^*_{AP(-6)}$	α_5	-0.23	0.42	-0.53	0.60
7	$P^*_{MP1(-4)}$	α_6	-5.69	6.56	-0.87	0.39
8	$P^*_{MP2(-3)}$	α_7	-2.09	3.95	-0.53	0.60
9	$P^*_{MP3(-3)}$	α_8	-1.28	2.52	-0.51	0.61
10	$Rainfall_{(-1)}$	α_9	-0.00	0.02	-0.09	0.93
11	Temperature	α_{10}	-0.18	0.35	-0.50	0.62
12	D1	α_{11}	-0.04	0.13	-0.28	0.78
13	D2	α_{12}	0.07	0.17	0.43	0.67
14	D3	α_{13}	0.04	0.15	0.24	0.81
15	UserH	α_{14}	-0.71	0.47	-1.52	0.14
	PopH	α_{15}	-95.16	32.60	-2.92	0.00
	HHI	α_{16}	34.47	12.37	2.79	0.01
16	Dependent Variable	Qmamelodi		R^2		0.61
17	Mean	13.54		R^2-adjusted		0.43
18	Standard Deviation	0.21		S.E. of regression		0.16
19	Sample size	54		Akaike info criterion		-0.63
20	Error Sum of Squares	0.90		Durbin-watson		1.85

The data plot in figure 6-17 represents the above-mentioned relationship graphically.

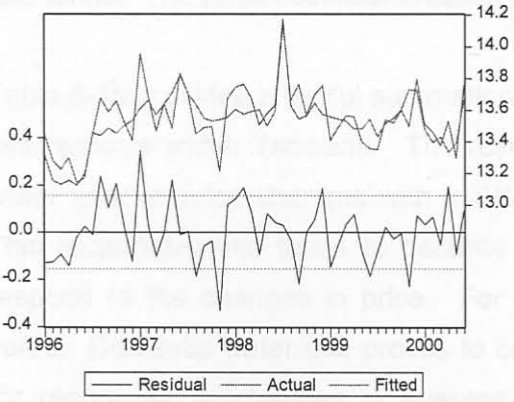


Figure 6-17: Total users across all classes for Mamelodi

6.10 Elasticity results for Tshwane

The elasticity results for all the estimations are tabulated below and allow for comparison over time and between user groups. From the above-mentioned studies, it is evident that for domestic water use rainfall, temperature and seasons have a relatively minor effect on demand. This result is in line with other studies. The number of users in each category proved to be puzzling as it frequently produced a negative sign and was statistically significant. This result is not in line with those of previous studies (section 5-3), which stated that as the number of users increases, the demand for water increases. Only water demanded for old age homes in Pretoria showed a significant response to income changes, with an income elasticity of 0.89 at a five percent significance level, with a t-statistic of 5.36. The population variables behaved as expected and concurred with the results of the other studies. Only a few of the estimations incorporated income variables which also proved to be statistically significant on average and indicated that an increase in income for any user group in turn increases the demand for water.

6.10.1 Price elasticities of demand for Tshwane

The price variables varied widely in terms of statistical significance and sign. On average, the average price variable tended to support the increasing block rate premise in the SR, indicating that as demand increases price also increases because consumers are moving into the next consumption class. In the LR this tended to change and people responded more directly to the price by decreasing demand as it increased. The marginal price variables were valuable as economists are interested in these prices. They also tended on average to encourage demand to move downwards as they increased. The trend in all the studies that lead to a positive sign for many of the average price coefficients is consistent with other urban water demand studies and is congruent with increasing block rate tariffs. The price coefficient results for all the studies are outlined in table 6-18.

Table 6-19 provides a useful summation of the different elasticities of demand for different user sectors within Tshwane. The results indicate that industry is the most responsive water user to price changes with a SR elasticity of -1.79 and a LR elasticity of –2.04. This responsiveness tends to become even more elastic as the user is given time to respond to the changes in price. For this study the time period for adjustment was 2 years. Domestic water use proves to be the least elastic of all users at –0.32 in the SR, for responses to changes in average price. Interestingly, domestic users are more responsive than agricultural small-holding users in the LR, when response comparisons are made between marginal price responses.

Table 6-18: Price elasticities of demand calculated from the various estimation results for the Logarithmic specifications[16].

		Short run				Long run				
Line	$E(q_i / p_j)$	P_{AP}	P_{MP1}	P_{MP2}	P_{MP3}	P_{AP}	P_{MP1}	P_{MP2}	P_{MP3}	Source
1	$Q_{agriculture - low}$	2.85 (0.62)	-3.04 (0.38)	-	-	-1.41 (0.56)	-0.92 (0.38)	-	-	Table 6-1
2	$Q_{agriculture - high}$	3.05 (1.54)	-1.54 (1.93)	-	-	-2.02 (1.93)	-0.16 (0.97)	-	-	Table 6-2
3	$Q_{total\ agriculture}$	0.79 (0.33)	0.17 (0.28)	-	-	-0.36 (0.27)	-0.53 0.18)	-	-	Table 6-3
4	$Q_{total - domestic}$	-0.32 (0.33)	-0.09 (0.20)	-	-	0.94 (0.31)	-	-0.90 (0.35)	-	Table 6-4
5	Q_{houses}	0.08 (0.29)	0.23 (0.16)	0.18 (0.46)	-	0.38 (0.27)	-0.01 (0.14)	-0.67 (0.31)	-	Table 6-5
6	Q_{duets}	4.51 (2.54)	-13.48 (4.35)	-	-	-3.59 (3.79)	-3.59 (3.79)	-	-	Table 6-6
7	$Q_{home\ industries}$	-0.25 (0.33)	0.18 (0.18)	0.10 (0.54)	-	0.78 (0.35)	-0.28 (0.16)	-0.16 (0.38)	-	Table 6-7
8	$Q_{duplexes - low}$	-3.14 (0.55)	-	-	-	-1.86 (0.12)	-	-	-	Table 6-8
9	$Q_{duplexes - high}$	-0.95 (0.72)	-0.28 (0.52)	-	-	-0.77 (0.93)	1.11 (0.55)	-	-	Table 6-9
10	$Q_{total\ duplexes}$	0.50 (0.67)	-0.14 (0.10)	-	-	-2.13 (0.65)	-0.01 (0.10)	-	-	Table 6-10
11	$Q_{old\ age\ homes - low}$	1.99 (0.58)	-0.09 (0.32)	-	-	-0.51 (0.48)	-0.62 (0.46)	-	-	Table 6-11
12	$Q_{old\ age\ homes - high}$	2.39 (1.25)	-1.27 (0.47)	-	-	-0.33 (0.28)	-0.05 (0.32)	-	-	Table 6-12
13	$Q_{old\ age\ homes - total}$	1.94 (0.51)	-0.34 (0.30)	-	-	-1.14 (0.38)	-0.15 (0.18)	-	-	Table 6-13
14	$Q_{industry}$	-1.79 (0.34)	-	-	-	-2.04 (0.42)	-	-	-	Table 6-14
15	$Q_{attridgeville - high}$	-0.42 (0.56)	-	-	-	-1.28 (0.44)	-	-	-	Table 6-15
16	$Q_{attridgeville - total}$	0.42 (0.26)	-0.06 (0.37)	-0.43 (0.91)	-	0.22 (0.21)	-0.07 (0.37)	-1.90 (0.93)	-	Table 6-16
17	$Q_{mamelodi - total}$	0.76 (0.49)	15.17 (5.33)	5.40 (4.05)	1.42 (2.38)	-0.23 (0.42)	-5.67 (6.56)	-2.09 (3.95)	-1.28 (2.52)	Table 6-17

When comparing the water use for domestic consumers in Pretoria central and Mamelodi, it becomes evident that in the long-run both users respond more elastically to marginal price changes. With a clear indication that lower income users respond almost twice as strongly to price changes with a long run marginal price elasticity of –2.09 compared to that for Pretoria of –0.90. The results are highly dependent on the user class selected hence elasticities for some of the other models outlined in the table above, show different results.

[16] All bracketed numbers are t-values

Table 6-19: Comparative sectoral price elasticities of demand for selected studies and prices

		Short run				Long-run				
Line	E (q_i / p_j)	P_{AP}	P_{MP1}	P_{MP2}	P_{MP3}	P_{AP}	P_{MP1}	P_{MP2}	P_{MP3}	Source
1	$Q_{agriculture}$	-	-	-	-	-0.36	-0.53	-	-	Table 6-3
2	$Q_{domestic}$	-0.32	-0.09	-	-	-	-	-0.90	-	Table 6-4
3	$Q_{industry}$	-1.79	-	-	-	-2.04	-	-	-	Table 6-14
4	$Q_{mamelodi}$	-	-	-	-	-0.23	-5.67	-2.09	-1.28	Table 6-17

This comparative table can be further disaggregated to reflect the differences between industrial / commercial water use and domestic water use across the case study and the international literature.

Table 6-20 shows the price elasticities of demand for industrial or commercial use. The SR price elasticities range between –0.5 in Massachusetts, USA to –1.79 in Tshwane, RSA. Interestingly, the Tshwane elasticities are considerably more elastic than those observed in the USA studies, this may be indicative of the nature of the industries being compared. None of the other studies estimated LR price elasticities of demand and hence it was not possible to provide a comparative judgement on the LR responsiveness of these consumers.

Table 6-20: Comparative Industrial and commercial price elasticities of demand

		Short run				Long-run				
Study	E (q_i / p_j)	P_{AP}	P_{MP1}	P_{MP2}	P_{MP3}	P_{AP}	P_{MP1}	P_{MP2}	P_{MP3}	Year
King	$Q_{industry}$	-1.79	-	-	-	-2.04	-	-	-	2002
Turnovsky	$Q_{industry}$	-0.5	-	-	-	-	-	-	-	1969
Lynn et al.	$Q_{commercial}$	-0.17	-	-	-	-	-	-	-	1978

Table 6-21 shows the comparative domestic indoor price elasticities of demand across the case study, national studies and the international literature. The indoor price elasticities of demand for Tshwane were comparatively similar to those of other studies. They were however considerably less elastic than the Dockel (1973) study and higher than the Veck and Bill (1999) study. The LR price elasticity of demand for Attridgeville (lower income group user) also showed a significant change from a relatively inelastic response to a more elastic response of –1.28. The SR marginal price elasticities of demand were also similar for all the respective studies but were surprisingly less elastic than the average price responses, this may be attributable to the fact that in the SR most users are unaware of the impacts of marginal price on their bills. For Mamelodi, the LR responses to marginal price changed dramatically, indicating that a lower income levels, over time, responses to the marginal price of water become extremely elastic, ranging from between –2.09 to –5.67.

Table 6-21: Comparative domestic (indoor) price elasticities of demand

		Short run			Long-run			
Study	**E (q_i / p_j)**	P_{AP}	P_{MP1}	P_{MP2}	P_{AP}	P_{MP1}	P_{MP2}	**Year**
King	$Q_{domestic}$	-0.32	-0.09	-	-	-	-0.90	2002
King	$Q_{mamelodi}$	-	-	-	-0.23	-5.67	-2.09	2002
King	$Q_{attridgeville}$	-0.42	-	-	-1.28	-	-	2002
Dockel	$Q_{witwatersrand}$	-0.63 to-0.84	-	-	-	-	-	1973
Veck & Bill	Q_{indoor}	-0.12 to-0.14	-	-	-	-	-	2000
Gibbs	$Q_{domestic}$	-0.62	-0.51	-	-	-	-	1978
Nieswiadomy	$Q_{domestic}$	-0.22 to -0.6	-0.1to-0.17	-	-	-	-	1992
Howe et al.	$Q_{domestic}$	-0.23	-	-	-	-	-	1967
Turnovsky	$Q_{domestic}$	-0.3	-	-	-	-	-	1969
Wong	$Q_{domestic}$	-0.26 to-0.82	-	-	-	-	-	1972
Young	$Q_{domestic}$	-0.63 to-0.41	-	-	-	-	-	1973
Katzman	$Q_{domestic}$	-0.1 to -0.2	-	-	-	-	-	1977
Foster & Beattie	$Q_{domestic}$	-0.35 to-0.76	-	-	-	-	-	1979
Agthe & Billings	$Q_{domestic}$	-0.12 to-0.22	-	-	-0.27to-0.49	-	-	1980
Carver & Boland	$Q_{domestic}$	-0.1	-	-	-0.2 to –0.7		-	1980
Howe	$Q_{domestic}$	-0.52 to-0.86	-	-	-	-	-	1982
Hewitt&Hanemann	$Q_{domestic}$	-0.57 to-0.63	-	-	-	-	-	1995
Hansen	$Q_{domestic}$	-0.003	-	-	-	-	-	1996
Thomas & Syme	$Q_{domestic}$	-0.2	-	-	-	-	-	1988

Table 6-22 shows the comparative outdoor domestic price elasticities of demand for Tshwane, Alberton and Thokoza, and the United States of America. The SR price elasticities of demand for the Tshwane outdoor (agricultural small-holdings) use were not included in this comparative table as they showed a positive sign, indicating discrepancies in the data. The LR marginal and average price elasticities were however, included. In the longer run it appears that outdoor users for Tshwane adjust there consumption patterns, becoming more elastic in their responses to price changes. They become less elastic in their responses to marginal price changes, however, this may be indicative of their ignorance regarding the marginal prices and the fact that they merely respond directly to the average price reported on their monthly water bills. The studies by Veck and Bill (2000) and Howe and Linaweaver (1967) are included in the table below for illustrative purposes only, it must however be noted that outdoor water use defined in these studies does not equate to what is referred to as outdoor water use for Tshwane, namely water use for agricultural small-holdings. This explains some of the differences in the elasticities shown below.

Table 6-22: Comparative domestic (outdoor) price elasticities of demand

		Short run			Long-run			
Study	**E (q_i / p_j)**	P_{AP}	P_{MP1}	P_{MP2}	P_{AP}	P_{MP1}	P_{MP2}	**Year**
King	$Q_{agriculture-high}$	-	-1.54	-	-2.02	-0.16	-	2002
King	$Q_{agriculture}$	-	-	-	-0.36	-0.53	-	2002
Veck & Bill	$Q_{outdoor}$	-0.19 to-0.47	-	-	-	-	-	2000
Howe et al.	$Q_{sprinkling}$	-0.16 to -0.7	-	-	-	-	-	1967

6.10.2 Income elasticities for Tshwane

Table 6-23 shows the comparative income price elasticities for Tshwane, Alberton and Thokoza, and the other water demand studies reviewed in Table 6-18. The income elasticities for Tshwane were only estimated for Attridgeville and Mamelodi as disaggregated data for the other user categories was not available. The results indicate that consumers in Attridgeville are relatively inelastic when it comes to changes in income due to the nature of the good being demanded – water is regarded as a necessity. The sign is positive, reiterating that as income increases the demand for water also increases. The range of elasticities for Attridgeville also correspond well with those reported in the national and international literature despite being insignificant. The income elasticity for Mamelodi was however significant, showed the expected positive sign, but fell greatly outside the ranges reported in the literature review. This indicated that water consumers in Mamelodi are extremely elastic in their responses to changes in income and their associated consumption of water.

Table 6-23: Comparative income elasticities of demand

Study	E (q_i / p_j)	Income	t-statistic	Source
King	$Q_{attridgeville - high}$	0.25	0.36	Table 6-15
King	$Q_{attridgeville - total}$	0.67	1.22	Table 6-16
King	$Q_{mamelodi - total}$	34.47	2.79	Table 6-17
Veck and Bill	$Q_{household\ water\ demand}$	-0.11	-	2000
Average other studies	$Q_{household\ water\ demanded}$	0.2 to 1.03	-	1986 to 2000

6.10.3 Meteorological elasticities for Tshwane

Unlike Hansen (1996), the meteorological variables had an insignificant impact on the household and the industrial demand for water in Tshwane. The estimated coefficients were relatively inconsistent with the accuracy of their signs and failed to be significant at a five percent level of significance. It was expected that the rainfall variables and the spring and summer dummy variables would show negative signs, as rainfall increases demand for water is expected to decrease. Tshwane also falls within the summer rainfall belt within South Africa and hence, higher temperatures are often associated with higher rainfall.

6.11 Relating price elasticities of demand for water to water management decision-making

Relevant to any water resources pricing analyst is the responsiveness of consumers at different consumer classes to changes in the prices of the resource. The results outlined in sections 6-2 through to section 6-9 indicate that pricing can be used to manage demand for water resources in South Africa and that different consumer classes show different levels of responses to price changes. These findings are discussed further in chapter 7. What is however interesting at this point is the fact that the derived elasticities from the above-mentioned models in conjunction with the average prices and quantities of water demanded can be used to determine the willingness to pay by the different consumer classes for water supplied at certain levels, as an extension to merely evaluating their levels of responsiveness. The willingness to pay or marginal values for water for different user categories can be used by pricing decision-makers to inform tariff levels to which consumers will then respond.

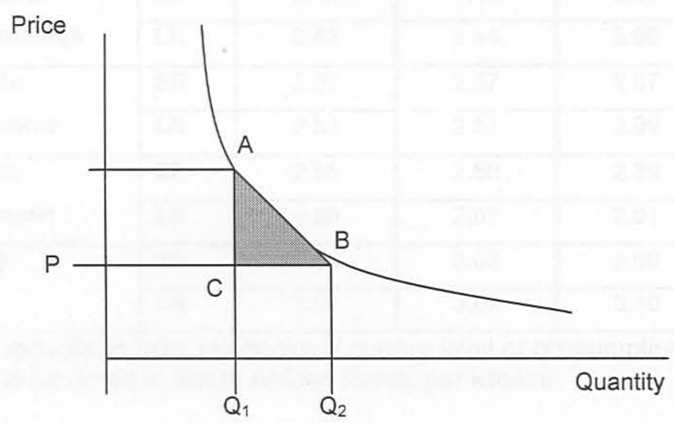
The willingness by consumers to make trade-offs is what determines the marginal value. For marketed goods, this willingness refers to the willingness to pay a particular monetary price for a good (Khan, 1998). Gibbons (1986), defines the total value for water resources as the maximum amount a user would be willing to pay for the resource. Where market transactions are observed, market-clearing prices will represent the value of the respective resource and where markets do not exist, market-like transactions can indicate the amount that consumers are willing to pay for a particular resource and thereby provide a measure of at least a lower bound value. For water, pure[17] markets rarely exist, hence alternative approaches to determining value need to be considered. Three approaches provide more complete demand information they are: the formal demand curve, the production function and the financial budget. Marginal values for water use may be obtained from consumer or producer water demand functions provided sufficient information on prices and quantities is available for demand modelling. Marginal physical product information can be determined from production functions for water, multiplying this with the price of the good produced will in turn yield a marginal product value. Lastly, information on the financial budget of a productive process can be used to determine the maximum economic return to economic inputs of that process once the share of total product value to the input such as water, is known (Gibbons, 1986). Valuing water use is also dependent on the definition of use as it has a number of dimensions namely, quantity, quality, timing and location. Use values need to be adjusted for instream and

[17] Pure markets here, refers to markets that are free of transaction costs and imperfect information with well-defined property rights.

offstream users to reflect the location and the implied costs of transportation. Quality aspects need to be accounted for along with the nature of the quantity used, as water can be withdrawn but not consumed. Hence, the trade-offs between competition and complementarity of users arise (Gibbons, 1986). Furthermore, the different measures of value produce different results of value, which are not always directly comparable. Average and marginal values differ widely as do long-run and short-run values. Where constant returns to scale are exhibited however, these differences may be equated and usually reflect long-run values (Gibbons, 1986). Marginal values may be used to influence policy efficacy and are determined for the Tshwane study for four of the aggregated user categories, namely, agricultural small-holdings demand, residential demand at high income and low income levels and industrial demand.

The approach taken here was based on the methodology outlined by Gibbons (1986) from the report by Young *et al.* (1972), whereby the area under the estimated demand curves is found by taking the integral of the curve, identified as Q_1Q_2AB in figure 6-18 below. This represents the amount that a consumer will actually pay for water including the consumer surplus ABC. The consumer surplus however represents the amount that a consumer would actually be willing to pay for the marginal increase in water supplied from Q_1 to Q_2. It therefore represents the marginal value of an incremental increase in water to that consumer. Where a single point (Q_2, p) on the curve is known and the elasticity, ε, is constant over the incremental increase from Q_1 to Q_2, the area under the demand curve may be calculated using the formula above the line in equation 6-1 (Gibbons, 1986 and Young *et al.*, 1972). This area is then divided by the incremental change in quantity and the price is subtracted to leave us with the marginal value for water.

Figure 6-18: Marginal value for water based on the consumer surplus



$$Marginal\ value\ water = \left[\frac{\frac{P * Q_2^x}{1-x}\left(\frac{Q_2}{Q_2^x} - \frac{Q_1}{Q_1^x}\right)}{(Q_2 - Q_1)} \right] - P \quad \text{where } x = \frac{1}{|\varepsilon|} \qquad (6\text{-}1)$$

The average price for residential water use in Tshwane ranges from 1.81 rands per kilolitre for old age homes to 3.42 rands per kilolitre for agricultural small-holdings. Mamelodi, Attridgeville and Pretoria face similar charges for household water use ranging from 1.22 R/kl at the lower consumption levels to 2.55 R/kl on average and 3.15 R/kl at the highest consumer class. The resultant marginal values for water in Tshwane based on the current level of use, a 1 percent, a 10 percent, a 25 percent and a 50 percent level of reduction from the current levels of water demanded are depicted in figure 6-19 to figure 6-22 below.

Figure 6-19 indicates that agricultural small-holding users are willing to pay R5.21 per kilolitre for a fifty percent increase in the availability of water in the short-run, an increase of 52 percent from the price currently being paid, and R9.35 per kilolitre in the long –run, an increase of 173 percent. Figure 6-20 indicates that residential users at the high-income level are willing to pay R3.59 per kilolitre for a fifty percent increase in availability in the short-run and R8.01 in the long-run. The results of the price changes for the other reductions and user categories are shown in Table 6-24, below.

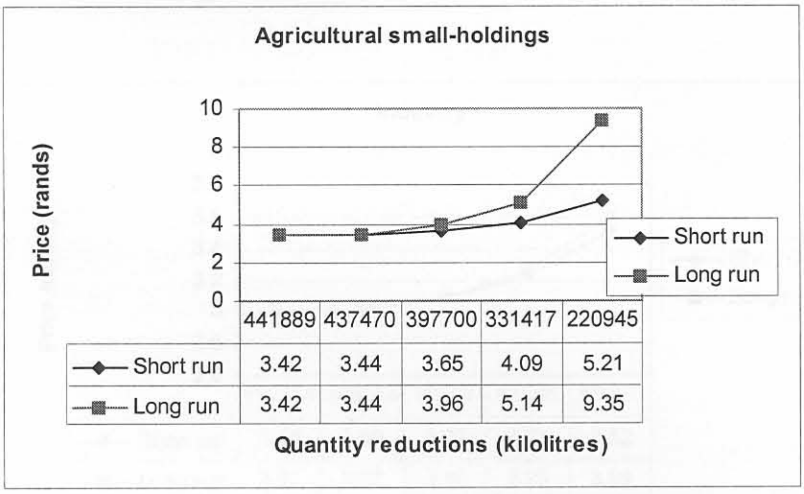
Table 6-24: Willingness to pay for increments in water availability by four user groups

Users	Time	Reductions in water availability from current levels*				
		Current	1%	10%	25%	50%
		Price**	Price	Price	Price	Price
Agricultural small-holdings	SR	3.42	3.44	3.65	4.09	5.21
	LR	3.42	3.44	3.96	5.14	9.35
Domestic High-income	SR	2.53	2.57	2.67	2.94	3.59
	LR	2.53	2.57	2.99	4.01	8.01
Domestic Low-income	SR	2.55	2.58	2.89	3.60	5.93
	LR	2.55	2.61	2.61	5.10	15.36
Industry	SR	3.01	3.02	3.09	3.52	3.52
	LR	3.01	3.02	3.10	3.59	3.59

*Water reductions from the original / current level of consumption in kilolitres
**Price is recorded in South African Rands per kilolitre

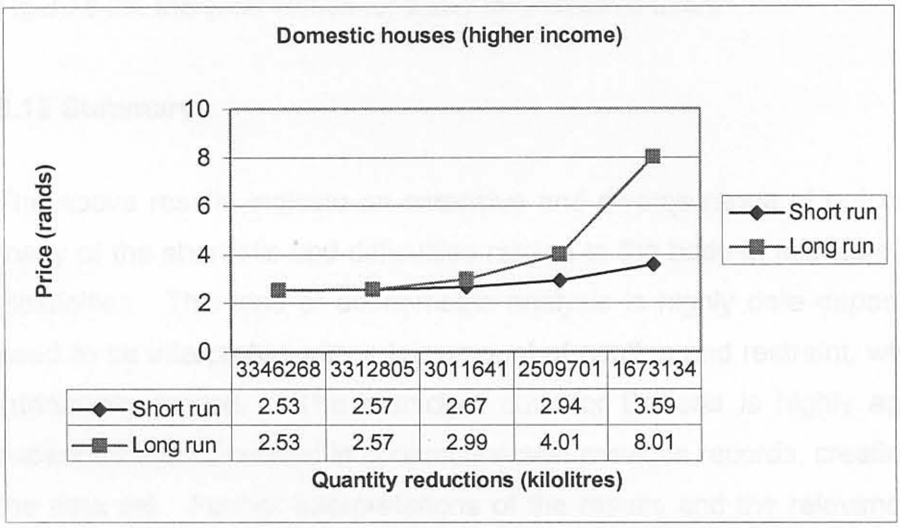
The marginal value estimates indicate that:

- Consumers are responsive to reductions in water availability,
- Consumers are willing to pay more in incrementally larger amounts for greater percentage increases in availability of water demanded,
- Consumers are willing to pay higher prices in the longer run for water,
- Industry is the least willing to pay incrementally more for water, this may be indicative of their ability to change their water consumption patterns through technology changes,
- The low income residential users are the most willing to pay for incrementally more water and this may be attributed to their use of water for basic needs.



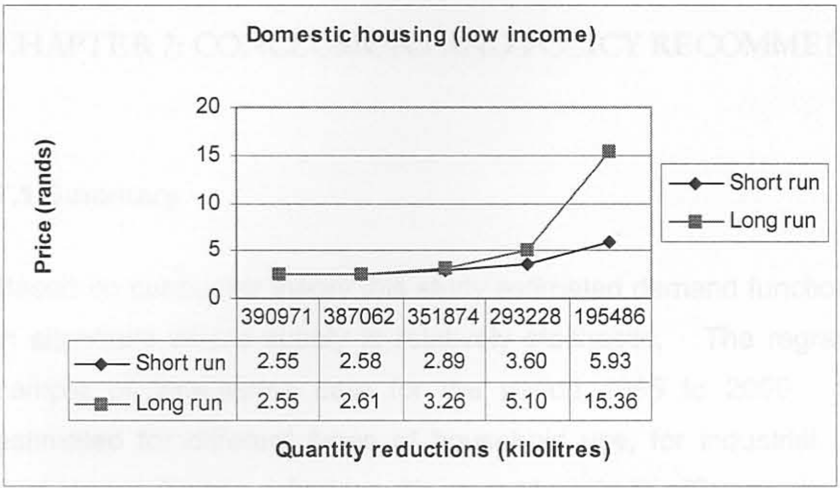
	441889	437470	397700	331417	220945
Short run	3.42	3.44	3.65	4.09	5.21
Long run	3.42	3.44	3.96	5.14	9.35

Figure 6-19: Marginal values for water for agricultural small-holdings users



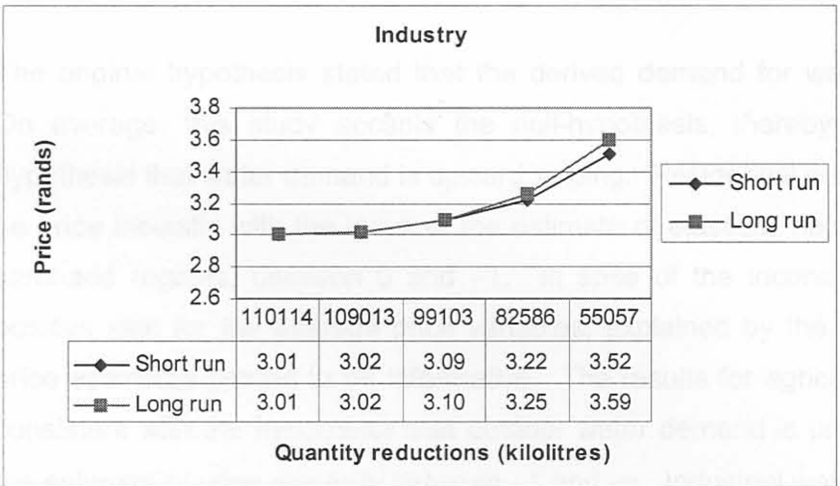
	3346268	3312805	3011641	2509701	1673134
Short run	2.53	2.57	2.67	2.94	3.59
Long run	2.53	2.57	2.99	4.01	8.01

Figure 6-20: Marginal values for water for residential users at higher income levels



	390971	387062	351874	293228	195486
Short run	2.55	2.58	2.89	3.60	5.93
Long run	2.55	2.61	3.26	5.10	15.36

Figure 6-21: Marginal values for water for residential users at lower income levels



	110114	109013	99103	82586	55057
Short run	3.01	3.02	3.09	3.22	3.52
Long run	3.01	3.02	3.10	3.25	3.59

Figure 6-22: Marginal values for water for industrial users

6.12 Summary

The above results indicate an extensive and diverse range of outcomes, consistent with many of the shortfalls and difficulties related to the body of literature on water pricing and elasticities. This kind of econometric analysis is highly data dependent and the results need to be interpreted with a fair amount of caution and restraint, where the base data is intrinsically flawed. The municipal data for Pretoria is highly aggregated and water expenditure is calculated in conjunction with previous records, creating an inherent bias in the data set. Further interpretations of the results and the relevance of these results to the Tshwane municipality is given in chapter seven.