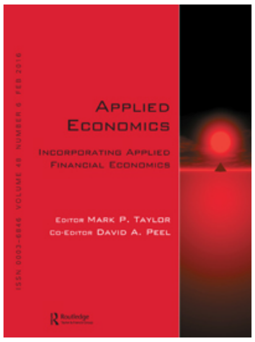

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Estimation of the effects of price on apartment water demand using cointegration and error correction techniques

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ABSTRACT

Water price is a key instrument in regulating water demand in the residential sector. Many empirical studies have assessed the effects of price through quantifying the price elasticity of water demand. However, most of these studies have mainly focused on the single-family housing rather the multifamily housing. An in-depth understanding of the price elasticity of multifamily housing water demand is paramount for water planners in order to properly manage water use in the fast growing intensive housing developments in urban areas. This study investigates both the long-term and short-term price elasticities of water demand in the residential apartments in Auckland central city. Using 6 years of monthly time series data, the price elasticities were estimated through cointegration and error correction methods. The results showed that the price elasticities of water demand were −0.14 and −0.12 in the short term and the long term, respectively. The price is inelastic yet negative and statistically significant, thus it can play a role in demand management.

KEYWORDS

Apartment buildings; cointegration analysis; price elasticity; water demand management

JEL CLASSIFICATION

C22; D12; Q25

I. Introduction

The rapid population growth in urban areas and the necessity of confining urban sprawl due to social, economic and environmental reasons have promoted the development of multifamily housing (e.g. apartments, flats, etc.) in many cities around the world (Randolph 2006; Haarhoff et al. 2012). In order to properly supply water and manage consumption in this growing sector, urban water planners need to understand the price elasticity of multifamily housing water demand. While many empirical studies have investigated the price elasticity of residential water demand (Arbués et al. 2003; Dalhuisen et al. 2003; Worthington and Hoffman 2008), a limited number of studies have distinguished the multifamily housing from the single-family housing. This segregation is necessary since the price elasticity of water demand in the multifamily housing may be different from the price elasticity in the single-family housing. This discrepancy may be attributed to the type of water use in these two housing groups. In general, in the multifamily housing the water is used for basic needs, thus there is not much room for water conservation in the response to the price signals. However, in the single-family housing, the water may be used for gardening or in the swimming pools in addition to the basic uses. Thus, there are more opportunities for responding to price signals through reducing the excessive water use (Arbués et al. 2003; Billings and Jones 2008; Corbella and Pujol 2009).

In a study of water use in apartment complexes in Tucson, Arizona, Agthe and Billings (2002) showed that the water price was significantly and negatively correlated to the apartment water use. A comprehensive study in 13 cities in USA also estimated an average price elasticity of −0.27 in the multifamily housing sector (Mayer et al. 2004, 2006). However, to the authors' knowledge none of the previous water demand studies has exclusively investigated the effects of water price on the high-rise apartments water use. The price elasticity of high-rise apartments water demand may be different from other types of the multifamily housing with fewer units (e.g. flats and townhouses) due to the differences in the physical characteristics of housings and the socioeconomic features of occupants. In general, smaller apartment complexes with fewer housing

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units are more likely to show similar water use habits to single-family units (Wentz et al. 2014).

The present study estimates the price elasticity of high-rise apartments water demand in the central city of Auckland using time series econometric analysis techniques. The study uses the monthly time series of average water use per bedroom, water price, wastewater price, household median weekly income, rental property vacancy rate and average daily maximum temperature for the years of 2008 to 2013. Cointegration and error correction techniques (Engle and Granger 1987, 1991) are used to estimate the price elasticity of water demand. These methods are employed because the time series are nonstationary. In general, if nonstationary time series are used in a regression model, the results may spuriously indicate a significant relationship when there is none (i.e. spurious regression) (Hill, Griffiths, and Lim 2011; Koop 2013). However, by using the cointegration analysis not only the problem of spurious regression is avoided, but also it provides a rigorous way to investigate both the short-term and long-term effects of the variables (Martínez-Espiñeira 2007; Koop 2013).

In general, the estimated value of the price elasticity of water demand is higher in the long term than in the short term (Nauges and Thomas 2003; Martínez-Espiñeira 2007; Musolesi and Nosvelli 2007). This is because in the short term, a significant increase in the water price may only change customer behaviours. These changes may include taking shorter showers or reducing car washing and lawn watering. However, in the long term a substantial price increase may provide additional financial incentives for consumers to make capital investments in water-saving (e.g. water-efficient appliances, low flow faucets, low flow toilets and drip irrigation) in order to reduce water use (Billings and Jones 2008).

Cointegration analysis has been extensively used for estimation of demand functions in energy resources such as power and fuel (Bentzen 1994; Beenstock, Goldin, and Nabot 1999) but rarely used in the field of water demand. Martínez-Espiñeira (2007) pioneered the use of cointegration technique in the water demand studies. Using the monthly time-series observations from Seville, Spain, they obtained a long-run price elasticity of −0.5 using a cointegration model. They also estimated a short-run price elasticity of −0.1 using the error correction method. Binet and Ben Zaied (2011) also used the cointegration and the error correction models (ECMs) to estimate the price elasticity using the quarterly time series from Tunisia. They investigated the effects of water price on two consumption blocks (lower and upper blocks). They identified a long-run relationship between water price and consumption in the lower block only, where the estimated long-run price elasticity was −0.15 but the corresponding short-run elasticity was very small.

One of the main reasons that caused the study of apartment water demand remains relatively unexplored in comparison to single-family housing is the lack of household socio-demographics information and individually metered water use data in this sector. This study investigates the effect of price on apartment water use through the analysis of average water use per bedroom using the time series economic techniques. This study estimates the price elasticity of water demand in the high-rise apartments in the central city of Auckland, an area with a large student population where most of the apartments are rental. The study investigates the effects of student population on apartment water use by using a time series dummy variable distinguishing the months of the tertiary academic calendar in New Zealand. Additionally, this study uses the cointegration and the error correction techniques to estimate the short-run and long-run price elasticities of demand which have not been applied in the multifamily housing sector.

This article is organized in the following order. After the introduction, the study area and the data set used in this study are discussed. Then, cointegration and error correction techniques are briefly discussed. Finally, the results and the conclusions are presented.

II. Study area

This study focuses on the central city of Auckland, also referred to as Central Business District (CBD). Auckland CBD has the highest population density in New Zealand (Statistics-NZ 2014). It has experienced fast growth rates both in population and in the housing stock in the last two decades. The population of Auckland CBD has almost tripled since 2001, reaching around 30 000 people in 2013. More than 85% of this population are living in the multifamily houses which are predominantly high-rise buildings. Around 80% of residences in the Auckland CBD are rental. In general the rental vacancy rate in Auckland city is low where the rate has been gradually falling since 2007, reaching 2.4% in March 2013 (MBIE 2013).

Auckland CBD has a large student population. According to the 2013 Census more than 30% of the Auckland CBD residents are student while there are several tertiary institutions within the Auckland CBD. The median age of population in Auckland CBD is around 30 years. On average, two persons are living in each dwelling (Statistics-NZ 2014).

In Auckland there is year-round precipitation. The average annual precipitation is around 1240 mm. The average annual maximum temperature is around 15°C. The coldest month is usually July and the warmest month is usually January or February (NIWA 2014).

III. Data

This study investigates the water consumption in 66 high-rise apartment buildings in Auckland CBD. The sample includes around 8000 apartments, which is more than 60% of the total number of apartments in the CBD. The study only focuses on the private residential apartments occupied either by owners or renters. Thus, serviced apartments, apartment hotels, hotels, hostels and dedicated student accommodations were excluded from the analysis. This is because the water use in these sectors may be substantially influenced by the number of tourists or students. In each building on average, there are 122 apartments unit where each apartment has 1.64 bedrooms on average. The outdoor spaces in the apartment complexes are limited and they are mainly used as car parks. Most of the apartments do not have swimming pools. The size of gardens is small and the vegetated landscaping is limited to the planting of shrubs and trees, which basically do not require much water. These characteristics imply that the water demand in the Auckland CBD high-rise apartments is mainly related to the indoor uses rather than the outdoor uses.

Watercare Services Limited, an Auckland Council organization that is in charge of supplying water and collecting wastewater in the Auckland region, provided the monthly water consumption data for the apartment buildings for the period of 2008–2013. Watercare reads the domestic accounts every three months up until July 2012. From July 2012, the domestic accounts are read every two months. To estimate the monthly water use for each individual meter, Watercare first estimates the average daily use during the reading period (i.e. the usage on the meter is divided by the number of days between the two readings). Then, this average use is allocated to each month according to the number of days corresponding to that month in that particular reading period. Watercare only measures the total water use in apartment buildings through a master meter and does not meter apartments individually. However, the apartment units can be charged individually by the building managers by providing submetering.

The study developed a monthly time series of average water consumption per bedroom for the high-rise apartments. The per bedroom water consumption was used in this study since it is closer to a per capita assessment that is common in the water demand studies. In addition, assessing the per bedroom water use is better than the per apartment water use in which the varying number of bedrooms per apartment may obscure per capita water use (Wentz et al. 2014). Analysis of per bedroom water use is the best practice in the case of Auckland CBD apartments. This is because Auckland CBD apartments are mainly rental and the occupants are transient, thus the estimation of per capita water use, which required the time series of number of people living at apartments, is implausible.

To estimate the time series of water use per bedroom, the total water use of these 66 apartment buildings in each month was divided by the total number of bedrooms in these buildings. Figure 1 shows the time series of average per bedroom water consumption in the Auckland CBD.

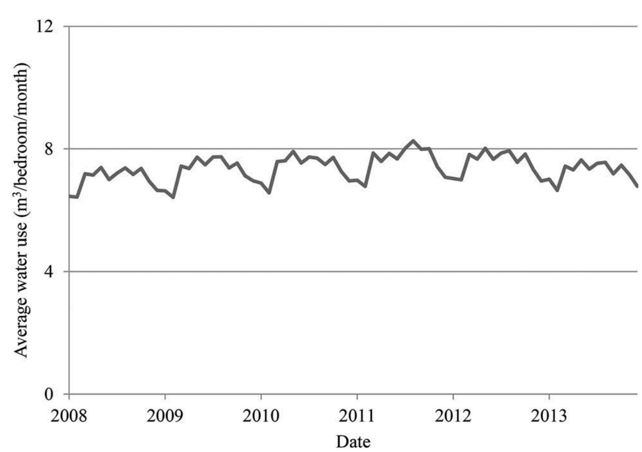

Figure 1. Time series of monthly average water use per bedroom.

As shown in Fig. 1, the time series revealed a small positive trend in the water use from 2008 to 2011, where the trend was flattening and eventually started slightly declining towards the end of 2013. Moreover, the time series showed a marked seasonal pattern in the water use. In general, the seasonal component of residential water use is influenced by local climates (Billings and Jones 2008). In the single-family housing, water consumption is normally higher in summer than winter. The higher summer water demand can be attributed to the higher water use arising from outdoor activities including lawn watering, gardening and filling swimming pools. Conversely, in the multifamily housing, where the indoor usage is predominant, water use is likely to remain relatively stable across the different seasons (Domene and Saurí 2006). However, in the case of Auckland apartments the water consumption increases each year around March, stays relatively constant until November and then declines. This pattern closely follows the tertiary academic calendar in New Zealand rather than the usual summer and winter seasons. Therefore, in order to incorporate seasonality in the modelling, a dummy variable with value of 1 for months March to October (i.e. tertiary academic calendar in New Zealand) and value of zero for the remainders was considered. This dummy variable, referred to as academic dummy variable in this article, may reveal the effects of large student population of Auckland CBD on the apartment water use.

Water and wastewater charges for the residential sector in Auckland city, which encompasses Auckland CBD, were also provided by Watercare. The water tariff in Auckland city consisted of the annual fixed charges and the volumetric charges for water and wastewater. Watercare adjusts these charges annually (i.e. in July each year). Watercare calculates the domestic wastewater volume based on the water volume, as measured by the water meter (Watercare 2014).

In New Zealand, the property owners are responsible to pay the annual fixed water and waste water charges (MBIE 2014). Therefore, in the rental properties the tenants may just pay for the volumetric charges. Since the majority of the Auckland CBD apartments are rental, this study only investigates the effects of changes in the water and the wastewater volumetric charges on the per bedroom water use. Figure 2 shows the changes of the volumetric charges of water (PW) and wastewater (PWW)

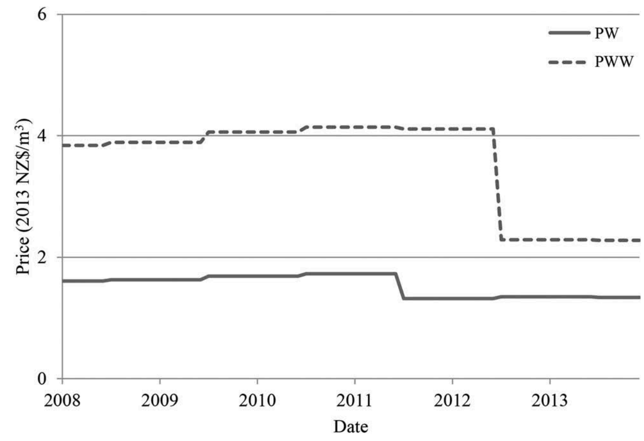

Figure 2. Time series of price of water (PW) and wastewater (PWW) in 2013 NZ dollar.

between the years 2008 to 2013. The prices were deflated into real 2013 terms using the customer price index (CPI) (Statistics-NZ 2014).

Statistics New Zealand (Statistics-NZ 2014) provided the information on household median weekly income for the Auckland region. The income data is provided on the annual basis, thus the estimated time series of monthly income includes the constant values for each year. The data is deflated into real 2013 terms using CPI.

The time series of rental vacancy rate is provided by the Ministry of Business, Innovation and Employment (MBIE 2013). The rental vacancy rate shows an estimate of the proportion of the private rental properties in Auckland City that remains vacant at a point in time.

Finally, the monthly time series of average daily maximum temperature was provided by the New Zealand's National Climate Database (CliFlo 2014). The data covers the period of 2008–2013 for the Auckland City.

Figure 3 shows the time series of household income, rental vacancy rate, temperature and the academic dummy variable. Table 1 provides basic descriptive statistics for the studied variables.

IV. Models

This study used the time series of average water use per bedroom, prices of water and wastewater, household income, rental vacancy rate, temperature and a dummy variable representing the academic year in New Zealand to build the water demand models.

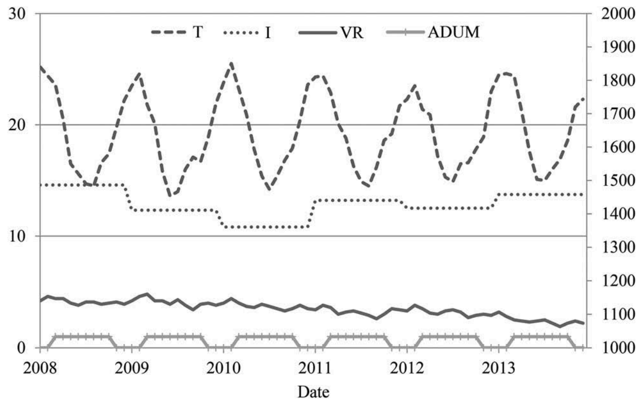

Figure 3. Time series of household median weekly income, I, in 2013 NZ dollar (the right axis), average daily maximum temperature, *T*, rental vacancy rate, VR, and academic dummy, ADUM (the left axis).

Table 1. Description of the variables and basic descriptive statistics.

Variable	Description	Mean	SD	Variable unit
WB	Average apartment water use per bedroom per month	7.36	0.43	m^3/bedroom/month
PW	Price of one unit of water	1.53	0.17	\$NZ 2013/m^3
PWW	Price of one unit of wastewater	3.59	0.77	\$NZ 2013/m^3
I	Household median weekly income	1428.9	39.83	\$NZ 2013
VR	Rental vacancy rate	3.46	0.67	% of rental stock
T	Average daily maximum temperature	19.28	3.51	°C
ADUM	Binary variable with value 1 in March to October (academic year in NZ)	0.67	0.47	dummy

The main aim of the models is to understand the effects of water price on the apartment water use. To accomplish this, the cointegration and the error correction techniques were used (Engle and Granger 1987, 1991). In general, these techniques are applicable where the time series variables are nonstationary in the levels but are stationary in the first differences (i.e. they are integrated of order 1) and the linear combination of them is stationary (i.e. they are cointegrated) (Hill, Griffiths, and Lim 2011; Koop 2013).

In the cointegration analysis, the first step is to determine whether a series is stationary or nonstationary. This is achieved by conducting tests usually known as unit root tests for stationarity. In this study, Augmented Dickey–Fuller (ADF) test (Dickey and Fuller 1979) and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test (Kwiatkowski et al. 1992) are used to examine the stationarity of variables. Since these tests use two different null hypotheses, they may help to draw a reliable conclusion about the stationarity and order of integration of variables (ADF test use a null hypothesis of nonstationary but KPSS test use a null hypothesis of stationary) (Martínez-Espiñeira 2007).

If the unit root tests suggest that the series are integrated of order one, $I(1)$ (i.e. they are nonstationary in the levels but are stationary in the first differences), then a cointegration test can be conducted to examine if the linear combination of the nonstationary variables is itself stationary. This study uses Engle–Granger test of cointegration (Engle and Granger 1987). According to this approach, a unit root test is applied on the residual of regression with the integrated variables. If the residuals are stationary, it means the series are cointegrated and the estimated coefficients of regression model provide the measures of long-run effects. In general, cointegrated series tend to come back to the trend in the long run, even though they deviate from each other in the short run (Hill, Griffiths, and Lim 2011; Koop 2013).

The residual of cointegrating regression subsequently can be used as an error correction term in the ECM. The ECM may reveal the short-run effect of variables and the speed of adjustment towards the long-run values.

As a simple model, if Y_t and X_t represent nonstationary I(1) time-series variables, the long-run relationship of them can be investigated through applying the Ordinary Least Squares (OLS) on the following model:

$$Y_t = \alpha + \beta X_t + e_t \tag{1}$$

In the above equation, α and e_t are the constant and the error term, respectively. If the residual of this model was stationary, the variables are cointegrated and the estimation of the β coefficient provides a measure of the long-run effect of X_t on Y_t.

The corresponding ECM also can be expressed by the following equation (Koop 2013):

$$\begin{aligned} \Delta Y_t &= \varphi + \lambda e_{t-1} + \omega_0 \Delta X_t + \varepsilon_t \\ t &= 1, \ldots, T \end{aligned} \tag{2}$$

In this equation, Δ represents the difference operator, e_{t-1} is the error correction term defined as $e_{t-1} = Y_{t-1} - \alpha - \beta X_{t-1}$ (i.e. the residual of the cointegration model (Equation 1) lagged one period). φ and ε_t are the constant and error term in ECM, respectively. From the ECM, the OLS estimations of ω_0 and λ would represent the short-run effect of X_t on Y_t and the speed of adjustment of model.

V. Results and discussion

In general, ADF and KPSS tests can include or exclude a constant term, a time trend or seasonal dummy variables for the assessment of the stationarity of time series. This study conducted two variations of tests: with and without time trends. In addition, for the variables WB, VR and T, the seasonal dummy variables were included in the tests to capture the seasonal pattern of the time series. The lags of the variables also can be used in the tests to eliminate the autocorrelation in the errors (Hill, Griffiths, and Lim 2011; Koop 2013). The number of lagged terms can be determined based on the modified Akaike Information Criterion (AIC) and the modified Bayesian Information Criterion (BIC) (Ng and Perron 2001). A maximum of 12 lags was considered in the tests. Table 2 shows the unit root test results.

Inspection of Table 2 indicates that the ADF and the KPSS tests confirm that all the variables except T were nonstationary in the levels but stationary in the first differences. This implies that the variables are integrated of order one, $I(1)$. The time series of average daily maximum temperature, T, appears to be stationary in the levels according to the KPSS test although the ADF tests could not reject the null hypothesis of nonstationary for the series.

Since it is not conclusive that whether or not the variable T is nonstationary, considering it in the cointegration analysis is not justifiable. In addition, as discussed in Section III, the seasonal component of water use in the Auckland CBD apartments is not significantly influenced by the local climates rather by the seasonal changes in the student population. Therefore, to account for the seasonality the academic dummy variable is solely used in this study.

While the unit root tests revealed that the time series variables are nonstationary, the next step of the analysis is to investigate the cointegrating relationships (i.e. long-run equilibrium relationship) among the variables.

Including all the nonstationary variables in Equation 1, the long-run cointegration model can be expressed as follows:

$$\mathrm{WB}_t = \alpha + \theta_1 \mathrm{PW}_t + \theta_2 \mathrm{PWW}_t + \theta_3 \mathrm{I}_t + \theta_4 \mathrm{VR}_t + \theta_5 \mathrm{ADUM}_t + \gamma t + e_t \tag{3}$$

where θ_i are the variables coefficients showing the measures of long-run effects, α is the model constant, e_t is the error term, γt is a deterministic time trend. The time trend was included in the model in order to capture the effects of other factors (e.g. the changes in the student population) driving the trend of average water use but was not considered in the modelling due to the lack of data. This model used a quadratic trend to accommodate the nonlinearities in the underlying data. All the variables (except ADUM) were transferred by natural logarithm thus the coefficients can be interpreted as the elasticity.

The estimates of cointegration model revealed that the wastewater price, income and the rental

Table 2. ADF and KPSS unit root test results.

	ADF (no trend)		ADF (trend)		KPSS (no trend)		KPSS (trend)	
Variable	*t*-Stat	lags	*t*-Stat	lags	*t*-Stat	lags	*t*-Stat	lags
WB	−1.587[a]	4	−2.398[a,b]	4	0.804***[a]	3	0.390***[a]	3
ΔWB	−5.455***	1	−5.395***	1	0.104	3	0.025	3
PW	−0.991	1	−2.043	1	1.278***	3	0.244***	3
ΔPW	−5.788***	1	−5.782***	1	0.108	3	0.080	3
PWW	−0.565	1	−1.715	1	1.093***	3	0.367***	3
ΔPWW	−5.788***	1	−5.931***	1	0.184	3	0.055	3
I	−1.921	1	−1.860	1	0.316	3	0.319***	3
Δ*I*	−5.788***	1	−5.895***	1	0.207	3	0.057	3
VR	−0.026[a]	1	−1.263[a]	1	1.639***[a]	3	0.238***[a]	3
ΔVR	−0.397	1	−10.276***	1	0.100	3	0.033	3
T[a]	−1.698[a]	6	−2.369[a]	6	0.390*[a]	3	0.078[a]	3
Δ*T*	−4.047***	1	−4.007***	1	0.050	3	0.026	3

Notes: *, **, *** denote rejection of null hypothesis of test at the 0.1, 0.05 and 0.01 significance level, respectively; Δ represents the difference operator; [a]seasonal dummies were included in the test; [b]quadratic trend was included in the test.

Table 3. Cointegration model.

Variable	Estimate	t-Stat
PW	−0.124***	−2.91
ADUM	0.096***	15.74
Time	0.005***	9.15
Time squared	−0.0001***	−8.16
Constant	1.911***	82.40
Adjusted-R^2	0.83	
F-statistic	88.50***	
Durbin–Watson	2.02	

Note: *** denotes the level of significance at 1%.

Table 4. Error correction model.

Variable	Estimate	t-Stat
e_{t-1}	−0.859***	−5.24
ΔPW	−0.141**	−2.38
ΔWB_{t-1}	0.003	0.04
ΔWB_{t-2}	0.227**	2.38
ΔWB_{t-3}	0.051	0.61
ΔWB_{t-4}	−0.081	−1.02
ΔWB_{t-5}	0.288**	2.68
ΔWB_{t-6}	0.050	0.59
ΔWB_{t-7}	−0.111	−1.44
ΔWB_{t-8}	0.136	1.51
ΔWB_{t-9}	0.140	1.48
ΔWB_{t-10}	−0.0003	−0.003
ΔWB_{t-11}	0.077	0.91
ΔWB_{t-12}	0.679***	8.72
Constant	−0.002	−0.91
Adjusted-R^2	0.92	
F-statistic	48.44***	
Durbin–Watson	1.67	
Breusch–Godfrey	14.41	
Breusch–Pagan	15.72	
White's general test	28.54	
ARCH	7.03	
Jarque–Bera	3.19	

Note: ***, ** and * denote the level of significance at 1%, 5% and 10%, respectively.

vacancy rate variables were insignificant while the other variables were highly significant. The wastewater price had a small coefficient of 0.001 that was insignificant (t-statistic 0.96) implying that the wastewater price do not affect apartment water use in the Auckland CBD. The income variable had the expected positive sign but was insignificant (the coefficient was 0.09 with t-statistic of 0.53). The VR variable had a coefficient of 0.004 with t-statistic of 0.9. Since PWW, I and VR variables were insignificant they were removed from the final cointegration model. Table 3 shows the OLS estimated coefficients in the final cointegration model.

According to the Engle–Granger cointegration approach, the ADF test (without constant and deterministic trend) was carried out on the model residuals. The ADF test result suggested that the model residuals are stationary (the t-statistic of test was −5.80 rejecting the null hypothesis of nonstationary at the 0.01 significance level). This implies that the variables are cointegrated and the estimated coefficients represent the measures of long-run effects.

The cointegration model revealed a long-run water price elasticity of −0.124, implying that 10% increase in the price of water may reduce the average water use per bedroom by 1.2% in the long term. The academic dummy was strongly significant with the coefficient of 0.096, implying that during the months of academic year (i.e. March–October) the average apartment water use per bedroom increases around 10% in comparison with the other months (i.e. November–February). The increase of average water use can be attributed to the increase of number of occupants in the apartments. The quadratic trend was also strongly significant implying that the other factors rather than the price of water may also affect apartment water use.

While the results of cointegration tests confirmed the existence of long-run relationship, the residuals of long-run cointegration model were used as an error correction term in the ECM. Table 4 shows the OLS estimated coefficients for the ECM. In ECM, the error correction term was strongly significant with the coefficient of −0.859, indicating the water use adjusts quickly if consumption is off the long-run level of demand. The coefficient of ΔPW variable, representing the short-term price elasticity, was significant with the value of −0.14. In order to correct for autocorrelation, 12 lagged of ΔWB were also added to the model. This number of lags was estimated based on AIC and BIC. Similar to the cointegration model the PWW, I and VR variables were insignificant in the ECM thus were removed from the model.

The diagnostic tests used in this study, which include the Breusch–Godfrey test (Breusch 1978; Godfrey 1978) for serial correlation, the Breusch–Pagan test (studentized) (Breusch and Pagan 1979; Koenker 1981) and the White's general test (White 1980) for heteroscedasticity, a test for ARCH (Autoregressive Conditional Heteroscedasticity) (Engle 1982) and the Jacque–Bera test (Jarque and Bera 1980) for normality of the residuals, revealed that the ECM is robust and valid at the 0.05 significance level.

The cointegration and the ECMs revealed that the apartment water demand in Auckland CBD is price inelastic (i.e. the percentage reduction in water use is less than the percentage increase in price). This finding is consistent with previous residential water demand studies (Arbués et al. 2003; Dalhuisen et al. 2003). Since at the apartments the indoor water usage is predominant, the low elasticity of price of water and wastewater were expected. The indoor water use generally exhibits low price sensitivity (Arbués et al. 2003; Mieno and Braden 2011). Another remarkable finding of this study is that the estimated long-term and the short-term price elasticities of apartment water demand are almost equal, where the short-run elasticity was slightly higher. However, in general a higher long-term price elasticity of water demand is expected (Nauges and Thomas 2003; Martínez-Espiñeira 2007; Musolesi and Nosvelli 2007). This discrepancy may be attributed to the characteristics of multifamily housing in Auckland CBD. Generally, in the long-term, water customers may reduce their water use by making some capital investments in water-savings while there is enough incentive due to the water price. However, in the case of Auckland CBD, while most of the apartments are rentals, the occupants do not have enough incentives to increase the efficiency of water appliances by replacing them. Thus, the only way remained for the occupants to reduce their water use is to change their water-use habits. This may explain the similar price elasticities both in the short term and in the long term.

The insignificant effect of income on the apartment water use was expected while in the apartments the majority of water use is the indoor uses. In general, income has little effect on indoor water consumption, but does have significant impacts on outdoor water use (Polebitski and Palmer 2010). Finally, the rental vacancy rate did not show significant effects on apartment water use where the vacancy rate in the Auckland city is generally low.

VI. Conclusions

This study analysed the price elasticity of the demand for water in apartments in the central city of Auckland, New Zealand. The price elasticity was estimated using time series econometric techniques. The key novel aspect of the study was the focus on the high-rise apartment water use in an area with a large student population where the majority of apartments were rental. In addition, this study used the cointegration and error correction techniques to estimate the short-run and long-run price elasticities of demand as appropriate for a nonstationary time series data. Although the cointegration analysis recently received a great deal of attention in the economics and management literatures, it has rarely been applied in the water demand studies. Using this dynamic econometric technique not only avoids the spurious regression problems, but may also provide valuable information regarding the short-run and long-run effects of time series variables.

This study used the time series of average water use per bedroom, the price of water and wastewater, household median income, rental vacancy rate and a dummy variable capturing the seasonal variations in water use to develop the water demand models. Conducting the unit root tests on the time series revealed that they were integrated at order one. Moreover, the Engle–Granger cointegration test showed that the series of water use and the water price were cointegrated. The cointegrated time series tend to trend together. The long-run cointegration model estimated a price elasticity of −0.12, implying that if the price of water increases by 10%, the average water use would decrease by 1.2% in the long term. In order to reveal the short-term behaviours of the series, an ECM was also developed. The ECM estimated a short-run price elasticity of −0.14, implying that the water use would decrease with 1.4% due to a shock of 10% increase in the price of water. The error correction coefficient of the model was −0.86, implying that the water use responded quickly to the changes in price. Generally, in response to the increase in water price, customers may change their water use habits to reduce the water use in the short term. However, in the long term they may achieve more savings through making water-saving capital investments. In the case of Auckland, the long-term price elasticity of water demand did not differ from the short-term. One possible explanation for this is that in Auckland around 80% of apartments are rental where tenants are often young and transient, thus the apartment dwellers have little or no control and incentive over the substitution of water appliances with more efficient ones. Thus, the water saving remains limited to the changing of water use habits or perhaps quicker reporting of plumbing malfunctions.

The results of models also showed that the seasonal pattern of water use in the Auckland CBD is influenced by the change in the student population (i.e. the seasonal trend followed the tertiary academic calendar) rather than the local climate. On average, during the months of academic year (i.e. March–October) the apartment water use in the Auckland CBD increases around 10% in comparison with the other months (i.e. November–February). Finally, the study revealed that the wastewater price, the household income and the rental vacancies did not affect apartment water consumption significantly.

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