CANADIAN MUNICIPAL RESIDENTIAL WATER CONSUMPTION AND PRICING: A TIME SERIES INVESTIGATION AND ESTIMATION OF PRICE METHOD SPECIFIC WATER DEMAND DETERMINANTS

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1. INTRODUCTION

Water delivery networks are long-term investments connecting accessible water sources and the human population through provision of fresh-water and sewage, treatment and delivery services. Adequate functionality is ensured through regular maintenance and upgrades requiring a steady flow of financial revenues which are, in turn, dependant on user fee collection and allocation of public subsidies. Although a link exists between financial health of a water delivery network and consequential service quality, the National Round Table on the Environment and the Economy estimated the domestic national water infrastructure deficit at $38 to $49 billion (NRTEE 1996), a financial estimate required to maintain a standardized level of water services. The scenario may be explained by a lacking domestic strive toward improvements in municipal water management, observed and exemplified by Canada's relatively high level of per-capita consumption (Boyd 2001) and low consumption costs (Bakker 2007, 48), among the OECD group of countries. External factors, such as global warming, are also strong contributors toward necessity of higher standards in systemic maintenance possible only through costly technological upgrades (Schindler 2001). Therefore, domestic water utilities are faced with increasing pressures to address financial shortages required to maintain adequate service levels. A possibility in improving the situation is through inducement of conservative consumption, introduction of price increases and implementation of increasingly efficient pricing methods. Increasingly optimal pricing schemes include perspectives of demand/supply side management and incorporate financial sense, economic efficiency and environmental sustainability (Bakker 2007, 263). Although in some parts of the world water is indeed priced according to such elaborate schemes (European Union Water Framework Directive, 2000, Article 9), domestic methods are mainly differentiated between volumetric or non-volumetric with the former method widely regarded as most effective in inducement of conservative consumption and higher financial revenues (Dalhuisen et al, 2003).

To appropriately reflect on this country's commitment to address the aforementioned scenario, this study quantitatively investigates recent domestic municipal household water consumption and various dimensions of pricing trends. Municipal residential water use and pricing time-series data capturing the 1991-2006 and 1991-2001 timeframes, respectively, are utilized to present variables describing time-dependant water use, introduction of varying pricing methods and resulting consumption costs. Further, the study investigates effects of price changes and introduction of advanced pricing methods on municipal consumption. Specifically, the study attempts to estimate price method specific[1] demand of municipal residential per-capita water consumption. Price method categorized consumption is modeled to be described by inflation adjusted consumption costs[2], constitution of charges, household socioeconomic and climatic data in large municipalities[3] within Western and Central Canadian regions throughout the 1991-2001 timeframe[4]. Overall, quantitative trends, econometric modeling and demand estimation results presented within this study, for selected combinations of sample years and pricing method types, are highly comparable to selected government publications and academic research[5].

Prior to the brief presentation of key findings, an introduction to water pricing is considered beneficial. This study concentrates on quantifying relationships between household consumption (per-capita residential use), consumption costs (monthly charges), constitution of charges (share of fixed costs), and introduction of increasingly efficient pricing methods (volumetric versus non-volumetric pricing). In the latter case, the non-volumetric pricing method is implemented using a FLAT pricing scheme, which is defined, such that charges are not associated with volume. Volumetric pricing is increasingly complex, such that total costs are associated with household use. This method implemented using an Increasing Block Rate (IBR), Decreasing Block Rate (DBR) and Constant Unit Cost (CUC) pricing schemes. Specifically, the IBR pricing scheme defines a constant relationship between costs and volume, given pre-defined "blocks" of water[6]. The opposite scenario describes the DBR scheme, such that costs decrease with increases in volume. The CUC pricing method differs as all defined consumption "blocks" are priced equivalently. An effective way to differentiate between volumetric pricing methods is with reference to marginal costs of consumption, such that, costs are decreasing, increasing and constant with respective reference to IBR, DBR and CUC pricing schemes.

[1] Utilized data describes consumption data categorized by Volumetric and Non-Volumetric pricing methods. The two price methods have different underlying mechanics and are thus kept separate throughout estimation.
[2] Endogeneity between per-capita consumption and monthly residential total consumption costs is considered
[3] This paper defines large municipalities to be comprised on at least 20,000 residents
[4] Canadian Western and Central regions consist of British Columbia, Alberta and Ontario, Quebec respectively
[5] Please see sections 4.2 and 4.3 below.
[6] Illustrated by a discontinuously increasing curve

In order to effectively and accurately concentrate the analysis on domestic household consumption, focus is maintained on residential units located within large municipalities in Central and Western Canada[7]. Consequent quantitative analysis revealed notably lower per-capita consumption associated with implementation of volumetric pricing and higher consumption costs, in both Canadian regions[8]. Furthermore, introduction of volumetric pricing is aligned with increasing consumption costs in both regions. Effects of volumetric pricing are most evident in Central Canada, such that consumption and consumption costs are lower than in Western Canada. This observation is attributed to a notably higher presence of volumetric pricing in Ontario versus British Columbia, the two provinces contributing most towards Central and Western Canadian data respectively. Therefore, from a combined perspective of environmental sustainability and financial sense, the resulting observations support metering and volumetric pricing as significantly more efficient than their alternatives.

An appropriate choice of economic and socioeconomic determinants, as well as their individual contribution, was established through price method specific demand estimation using 1991-2001 data. Under both pricing methods and across sample years, costs of consumption are negatively inelastic in their relationship with per-capita consumption and are hypothesized to coincide with a non-maximal point of use reductions. Further, income estimates are also inelastic and switch signs across sample years, implying that residential use is neither normal nor inferior, possibly due to its small proportion in a representative household's income (<1%). In addition, fixed proportions of total costs described by share of sewage service charges are not observed to contribute toward variation in residential consumption signifying a consumer's disregard for composition of monthly household costs. Therefore, considering influence of economic variables on per-capita residential use in large municipalities, types of pricing methods and total costs of consumption are observed to be the most effective contributors toward inducement of conservation and revenue increases, rather than household changes in income or constitution of monthly charges.

Although, quantitative analysis and demand estimation confirm volumetric methods as superior, expansion of this category of pricing is not continuously positive throughout the

[7] Particular reasons behind such specific selection of data are addresses in Section 3 of this paper.
[8] Preferences of residential water consumption are addressed in estimation of demand.

sample years. Hence, as the only other effective method of conservation inducement and revenue increases consists of positive changes in user charges, most noticeable under non-volumetric pricing, Canada's lacking drive to improve the aforementioned relative scenario is indeed confirmed through completion of analysis using this particular data. This conclusion is discussed in greater detail within Section 4 of this paper.

The remainder of this paper is organized as follows. The immediately following Section-2, introduces all utilized data focusing on sources and pertinent shortcomings. Section-3 concentrates on graphical presentation and analysis of time series domestic municipal water use and pricing datasets, highlighting key observations pertaining to the relationship between residential consumption and pricing in conjunction with social and economic variables of interest. Section-4, presents an attempt of annual municipal residential water demand estimation using a composite dataset encapsulating water use and pricing as well as climate, social and economic data. Section-5, the paper's conclusion, presents all significant trends, observations and statistical findings regarding domestic residential water use in large municipalities within Western and Central Canada. In support of all significant findings the paper also includes a number of appendices, all of which are referenced in due time.

2. DATA SOURCES

2.1. WATER USE DATASET (1991-2006)

Section-3 relies on a summary dataset compiled by Environment Canada using the Municipal Water Use Database (MUD) containing data obtained from the Municipal Water Use and Pricing Survey. The summary dataset, comprised of observations from 7 sample years over the 1991-2006 timeframe, was extracted and manipulated to obtain specific variables of interest. These include municipal location identifiers, population served with water services, consumption estimates and its relevant constituents (residential, commercial and other water uses[9]).

The Municipal Water Use and Pricing Survey has been completed every two to three years by municipal water and wastewater authorities since 1981 and consists of a series of smaller sub-surveys pertaining to the many facets of overall water supply infrastructure with a focus on fresh water treatment and use, wastewater management, pricing and metering of services.

[9] "Other" category of water use refers to systemic leaks, occurring with delivery of water, and firefighting activity

Sampling included municipalities consisting of at least 1000 residents in early survey years, with smaller municipalities being included in later sample years as well. Call-backs and imputation algorithms were employed by survey administrators to complete incomplete entries. Throughout its existence, the survey has experienced significant modifications resulting in increasing complexity reflected in the resulting data and structure of MUD.

Regarding manipulation, data pertaining to Yukon, Northwest Territories and Nunavut were excluded from the resulting dataset, just as were municipalities with populations less than 1000. These population groups were deemed as outliers of water use, climatic trends and household income. A number of additional records were removed due to null or erroneous entries. As a result, 8,098 records comprise the municipal water use time series dataset.

2.2. WATER PRICING DATASET (1991-2001)

A separate dataset is utilized to complete analysis and statistical modeling of municipal water pricing. Although pricing figures are extracted from the same summary dataset as water consumption, the resulting dataset spans a lesser time frame than water use data. In addition to those variables of interest mentioned in the immediately above subsection, data describing pricing schemes, derived cost calculations and metering statistics were also obtained. As a result, a total of 5,950 records describe municipal pricing data during the 1991-2001 timeframe. Given the same origin, Municipal Water Pricing summary data underwent similar manipulation as water use data. However, unlike data describing consumption, the pricing time series is utilized in estimation of domestic residential water demand.

2.3. HOUSEHOLD AND DWELLING CHARACTERISTICS DATASET (1991, 1996, 2001)

Data originating from three sample years of the Canadian Census was utilized in estimation of municipal residential water demand. Overall, 17,256 records were gathered to represent variables of interest. Due to the timing of the domestic Census, the estimation process was constrained to three sample years representing the 1991-2001 time period. The variables, obtained from the Census, are on a municipal level and include mean gross household income, average number of household residents and ownership and distribution of municipal dwellings. However, given differing descriptive power, pairs-wise correlation statistics and relevant literature references, only a subset of all gathered variables was utilized in modeling and estimation of water demand.

2.4. ADJUSTED HISTORICAL CANADIAN CLIMATE DATASET (1991, 1996, 2001)

Additional data were gathered to describe climatically induced water use differences. After numerous differing attempts to extract raw data directly from Environment Canada's Climate Database (CDCD), the Adjusted Historical Canadian Climate Data (AHCCD) was utilized to compile the municipal level time series dataset. Overall, 1068 and 1940 observations describe temperature and precipitation data respectively, in 3 sample years throughout the 1991-2006 timeframe. This resulting dataset consists of variables pertaining to annual mean temperature, total precipitation and weather station location identifiers.

The AHCCD was chosen for its superiority in having been statistically adjusted for changes in measurement methods, instrumentation and positioning of weather stations. Although such homogenized data presents less observations and variation than raw data, it is considered more accurate in the case of time-series data obtained from numerous neighboring stations.

Regarding quantitative shortcomings, climatic data is also expressed in annual rather than seasonal form. Further, time series weather data is lacking desired variation within the dataset utilized in estimation of residential water demand, due to the difference in the number of unique municipalities and measurement stations. Attempts to minimize effects of such shortcomings are discussed in due time.

2.5. ADDITIONAL DATA (1991, 1996, 2001)

Various related data are also referenced, such as the annual provincial population and per-capita GDP estimates. Further, CPI inflation estimates (2002 base year) were gathered and utilized to adjust various derived costs of water consumption and household income data. The source of all such data is the CANSIM database.

2.6. RESIDENTIAL WATER DEMAND ESTIMATION DATASET (1991, 1996, 2001)

In order to complete annual residential water demand estimation, specific to large municipalities within Western and Central domestic regions, some of the abovementioned data was aligned. Specifically, the water pricing dataset (1991-2001, 5 sample years) was merged with Census data (1991-2001, 3 sample years) and the AHCCD weather data (1991-2001, 3 sample years). This resulted in a time series dataset (1991-2001, 3 sample years) describing municipal water consumption, pricing, household, dwelling and climatic data.

Regarding the aggregation method, Canadian Census Subdivision Codes were used to accurately merge municipal water pricing and Census data. In rare cases when subdivision codes failed to match, the process was completed using minimal distance calculation between two geographical points on a sphere, using corresponding degree coordinates. In the case of AHCCD weather data, temperature and precipitation figures were merged with water data using only distance minimization. A threshold level of 75 kilometers was used as a general rejection level for a distance between a municipality and a weather station.

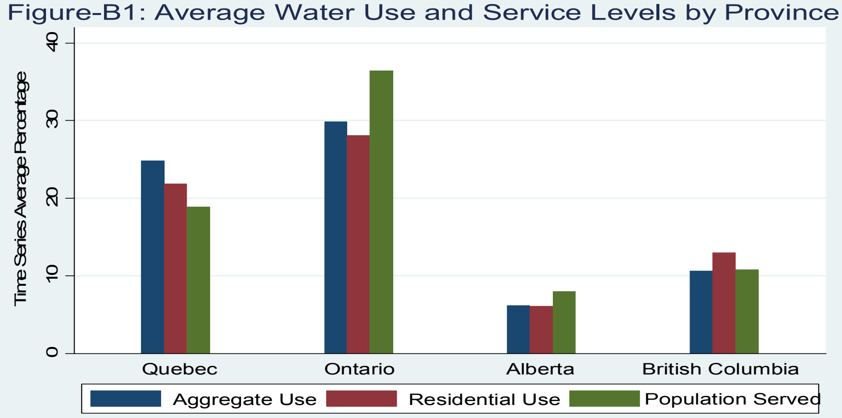
As the data utilized to estimate municipal water demand is a composite of the abovementioned datasets, it exhibits not only the very same but also additional shortfalls. One such disadvantage is the absence of seasonally adjusted figures. Although water use indeed increases during the warmer months, the increase is attributable to residential properties associated with green-space and private swimming pools, whereas “internal” residential consumption is observed to be stable throughout the year (Domene and Sauri, 2006). However, this is considered a strong disadvantage of the data as, on average throughout the time series, three quarters of all residential properties are those most likely to be associated with such amenities. An equivalently significant drawback is the distribution of climate data across the dataset describing water use and pricing. Specifically, only 75 unique weather stations, representing total annual precipitation figures, are aligned with 179 unique municipalities across all three sample years. To accommodate for data variability issues, as well as other data related disadvantages, differing approaches have been attempted during modeling and estimation of residential water demand.

3. DOMESTIC MUNICIPAL RESIDENTIAL WATER USE AND PRICING

3.1. DOMESTIC MUNICIPAL WATER CONSUMPTION

This subsection focuses on presentation and analysis of prevalent water use trends specific to residential consumption in large municipalities within Western and Central domestic regions. Using quantitative and graphical means, concentration on the four most populous domestic provinces and the residential market is established. Further, quantitative trends are discussed and linked to municipal pricing, infrastructure and socioeconomic factors. This is accomplished using a time series domestic municipal water use dataset comprised of 7 sample years representing the 1991-2006 timeframe[10]. In particular, provincial and population categories are employed to attain a subset of data, based on its contribution toward consumption and service levels described within the domestic municipal water use dataset. Figure-B1[11], shown immediately below, shows the strong prevalence of selected provinces in their contribution toward aggregate and residential consumption categories as well as service levels, within the entire time series dataset describing water use[12]. In particular, on average throughout the time series, Ontario and Quebec are the highest contributors of municipal water services in large urban centers (36%, 19% respectively). These two provinces also contribute significantly higher toward aggregate water use (30%, 25% respectively) and residential consumption (28%, 22% respectively).

Figure-B1: Average Water Use and Service Levels by Province



Although the Western region contributes least in all three measures toward domestic municipal use, its weight throughout the dataset significantly prevails over the excluded provinces. From a combined geographical perspective, and on average throughout the time series, 74% of those served with water services, 69% of all domestic aggregate use and 71.5% of all residential water consumption is attributed to large municipalities within the selected four provinces[13].

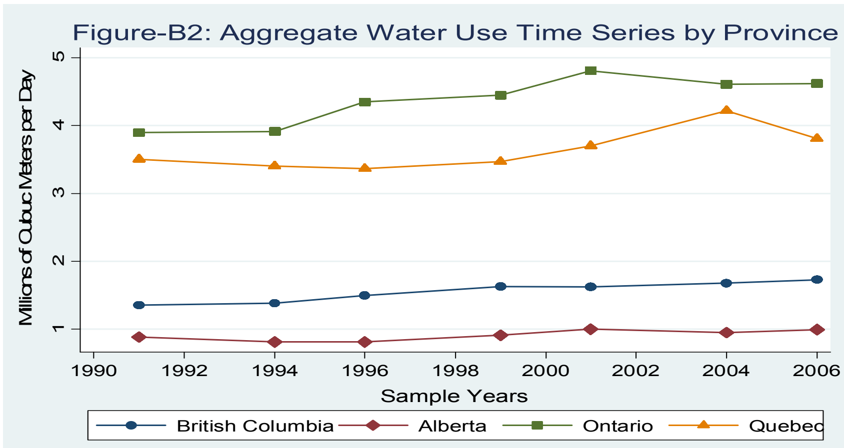
[10] The domestic Municipal Water Use Dataset was described in Subsection 2.1

[11] Figure-B1 is based on Table-B1 presented within Appendix-B

[12] Figure-B1 and the associated Table-B1specifically present quantitative evidence to support selection of residential consumption data within the four most populous domestic provinces

[13] Use of data describing excluded provinces is not likely to yield observations directly attributable to such regions

Figure-B2[14], shown immediately below, presents a time series perspective of the most general representation of domestic aggregate water use specific to large municipalities in Western and Central domestic regions. This measure is unadjusted for population growth and is comprised of categories describing residential and commercial consumption, as well as systemic losses. In long run, domestic aggregate water use in large municipalities has increased across the timeframe within all four provinces. Further, annual use trends are also similar in bordering provinces and are in-line with Census population estimates[15]. A notable difference in aggregate consumption between Western and Central regions is observed.

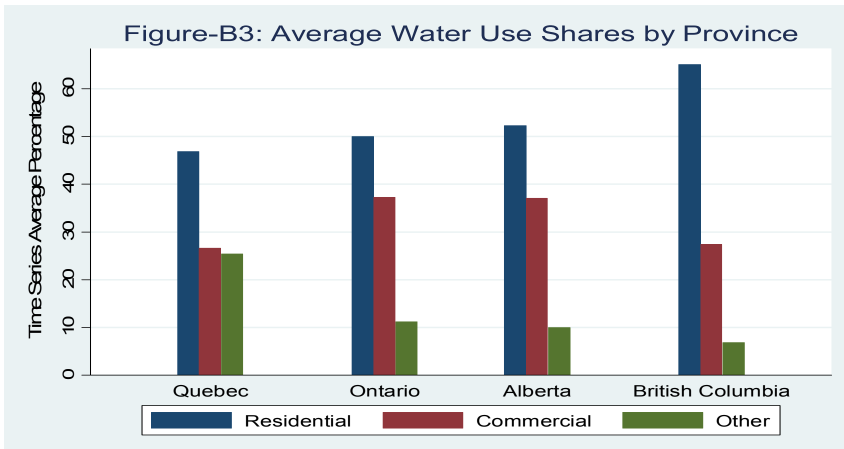


The uneven distribution of aggregate consumption, observed in Figure-B2, leads to the following logical outcomes. Firstly, in reference to aggregate consumption in large municipalities within the four provinces, considering a predominant share within the overall dataset (Figure-B1) and nearly continuous positive trends (Figure-B2) of aggregate consumption, relevant municipal water utilities deserve strong policy attention to ensure improvement in measures utilized in international comparisons. Secondly, the above distribution coincides with geographical location of Canadian provinces. As this may be influenced by a number of factors, such as similar preferences and/or population, it is beneficial to form aggregations represented by Western and Central Canadian regions. Lastly, as the immediately above presentation is closely related to population trends, survey response rates and imputation methods, the following quantitative analysis is accomplished using an increasingly concentrated dataset and measures.

[14] Figure-B2 is based on Table-B2 presented within Appendix-B

[15] Aggregate water use and population estimates are strongly positively correlated throughout the time series

As a time series average, residential consumption comprises 50.7% toward aggregate consumption in large municipalities within the four provinces. Figure-B3[16], shown immediately below, presents an average time series distribution of residential, commercial use as well as systemic losses among the four provinces. Note that Figure-B3 is compiled using interprovincial time series averages rather than average provincial contributions to the time series dataset, as shown above in Figure-B2[17].



In large municipalities within the four largest Canadian provinces, the residential market, dominates aggregate consumption. Although, on average, British Columbia contributes only 10.5% toward aggregate use, its residential client base is the highest in the country (65%). At the other extreme, Ontario contributes 30% toward time series average aggregate water use, with nearly half attributed to residential use. Overall, 48.6% of all consumption in large municipalities of the four provinces is directly attributable to residential consumption.

Thus far, prevalence of the four largest domestic provinces and the corresponding residential market, within the entire time-series data set, is firmly established. This is a crucial step in the analysis as data describing this sub-set of data is used to reference water consumption in large settlements throughout Canada. Furthermore, an identical selection made within the Water Pricing dataset and is employed with confidence in statistical estimation.

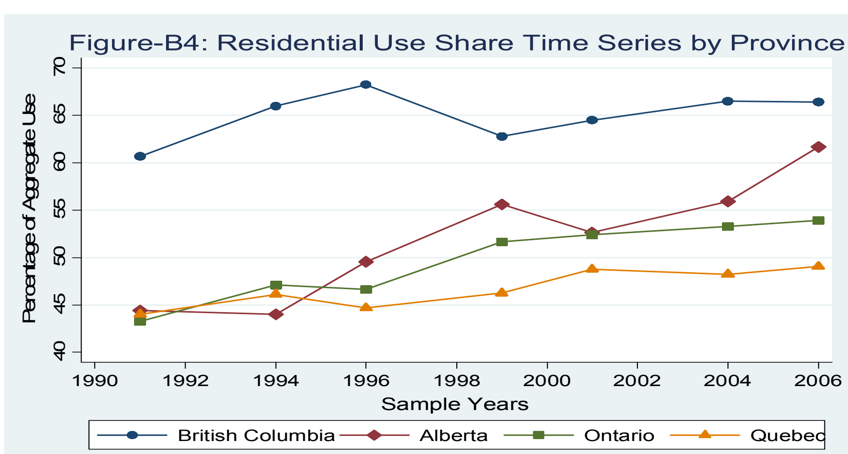
Although the focus of this study is residential water use and pricing, systemic leaks contribute to aggregate use figures and financial revenues. The "Other" category partially represents systemic leaks, which are a proxy for the state of a water infrastructure, and comprises 17.5%

[16] Figure-B3 is based on Table-B3 presented within Appendix-B

[17] The discussion now focuses on data representing selected provinces and away from quantitative analysis of the entire time series dataset. This is to be maintained throughout the remainder of the paper.

of all consumption in large municipalities of the four provinces. For example, 25.4% of aggregate consumption in Quebec is classified as "Other", a significant portion considering this province's 25% contribution towards the entire time series aggregate water use dataset. Lax pricing is observed to contribute toward higher per-capita use and lower financial revenues. Therefore, inducement of increasingly conservative consumption and improvement of water delivery infrastructures are interrelated with financial revenues as a consequence of increasingly accountable pricing methods. Relationships between pricing and corresponding consumption are presented within the following subsection of the study.

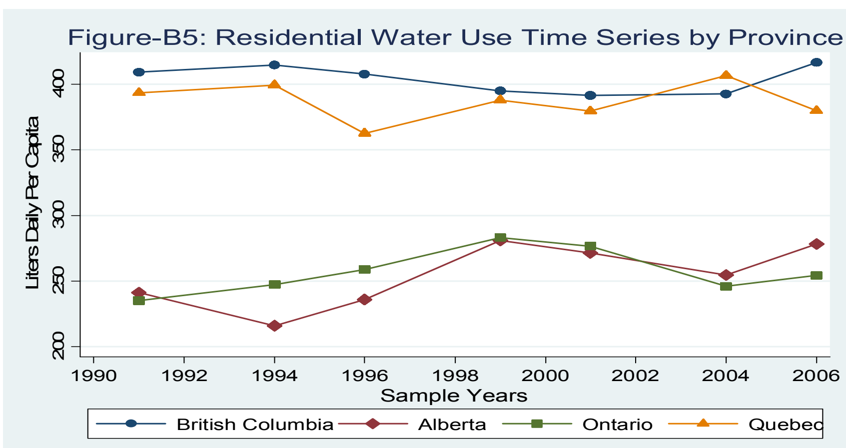
A time dependant representation of residential consumption, shown in Figure-B4[18], illustrates historic and increasing dominance of this consumption category observed within large municipalities of the four provinces. In reference to recent data, in particular to Ontario and Quebec, residential consumers contribute 54% and 49.1% toward aggregate use respectively. Also in reference to most recent sample year, British Columbia's and Alberta's residential clients present 67% and 61% respectively, of corresponding aggregate use. Average and time-dependent residential consumption is worthy of policy attention, which is presently not the case when compared to other OECD member countries (McFarlane and Nilson 2003). Overall, observed increases in the residential share are partially attributed to a decrease in the average number of household residents and an increasing proportion of private dwellings[19] (Hillenbrand and Schleich 2008). Observed shifts in household level characteristics are considered in modeling and estimation of residential water demand.



[18] Figure-B4 is based on Table-B4 presented within Appendix-B
[19] Observation based on Census Household and Dwelling Dataset described in 2.3.

In conjunction with above highlighted dominance of residential market, Figure-B5[20] is included immediately below, showing per-capita time series residential water use within large urban centers among the selected four provinces. This quantitative measure is adjusted for population growth and is employed throughout the remaining analysis including statistical modeling and estimation within the following section of the paper.

Significantly differing trends are observed, in particular, geography is no longer an influencing factor, and hence trends of aggregate consumption are indeed heavily influenced by population served with water. Further, provincial grouping also varies such that, a large difference is observed in per-capita use within Ontario and Alberta versus the remaining provinces. In relation to other data, residential consumption trends are also not similar to per-capita provincial GDP estimates[21]. It is shown below that the disparity in the levels of per-capita consumption, between the two groups of provinces, is related to implementation of metering technologies and corresponding pricing methods. Housing type is another factor contributing to the observed difference in per-capita consumption. For example, Quebec and British Columbia contain the highest proportion of detached residential units[22], real estate properties associated with factors contributing to higher water use.



Regarding observed levels of per capita residential water use in large municipalities, Ontario's average resident consumed 254 liters per day in 2006, the lowest in Canada. Most recent highest domestic consumption level of 417 liters is observed in British Columbia. Also, just as in the case of aggregate municipal water use, without any adjustments for population, per capita

[20] Figure-B5 is based on Table-B5 presented within Appendix-B

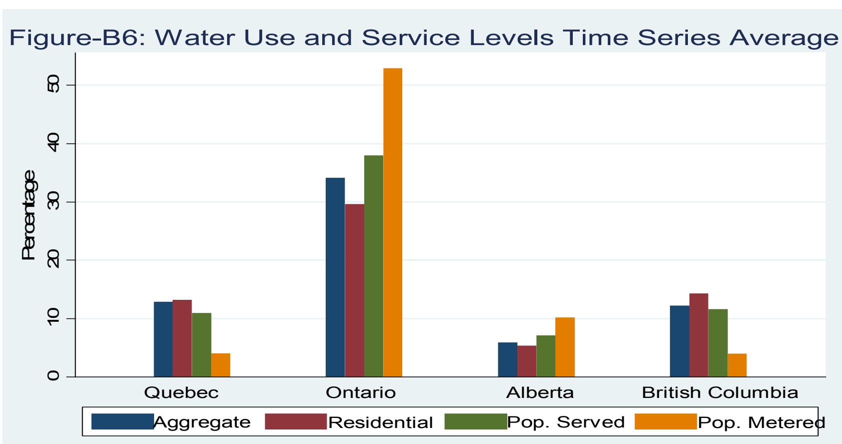
[21] Observation based on provincial per-capita and non per-capita GDP estimates described in 2.4.

[22] Observation based on Census Household and Dwelling Dataset described in 2.3.

residential figures also oscillate but have ultimately increased within three of the four provinces, with a significant recent decrease in Quebec. Residential per-capita trends, shown in Figure-B5, are discussed within the following subsection, alongside with corresponding pricing methods.

3.2. DOMESTIC MUNICIPAL WATER PRICING

This subsection focuses on presentation of municipal residential water pricing trends and relationships between consumption and costs. Similarly to the above discussion of water use, this subsection highlights prevalence of residential consumption, service levels and metering density within large municipalities in the four most populous provinces. Focus is maintained on trends and resulting observations surrounding municipal metering, distribution of pricing schemes, residential use relative to pricing methods and specific costs of consumption, and composition of user fees. Analysis is completed using a dataset consisting of records describing annual municipal pricing, comprised of 5 sample years capturing the 1991-2001 timeframe[23]. Similarly to the above subsection, Figure-B6[24] shows prevalence of the utilized subset of pricing data, in relation to the overall domestic time-series, on the basis of aggregate and residential water use, as well as served and metered population data.



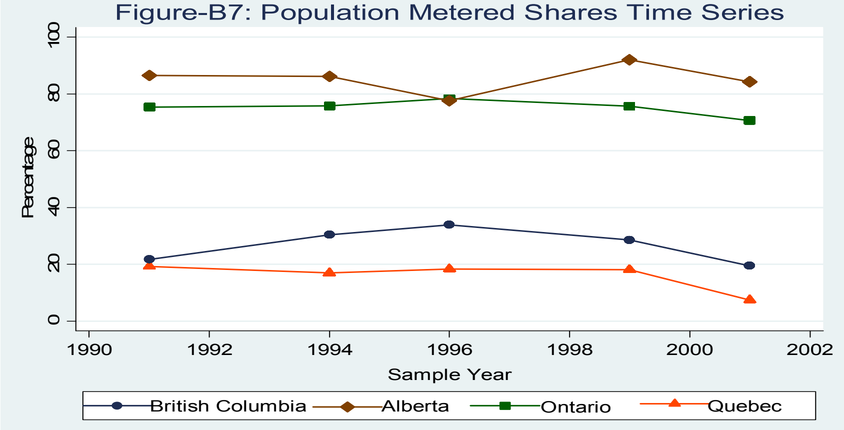
The immediately above distribution effectively illustrates strong prevalence of the selected data describing water pricing. Specifically, 65% and 62% of all domestic aggregate and residential water consumption is represented within this particular subset of data. Provincial contribution of data representing metered residential customers is also included, to represent the collection

[23] The domestic Municipal Water Pricing Dataset was described in Subsection 2.2
[24] Figure-B6 is based on Table-B6 presented within Appendix-B

of metered municipal clients which are either presently under a volumetric pricing scheme or will be so in the future. This variable is instrumental in pricing analysis and 71% of all metered consumers are accounted for within the subset of large municipalities in the chosen provinces.

Analysis of the pricing dataset confirms a negative relationship with per-capita residential consumption (see Figure-B5). Shown immediately below is Figure-B7[25], presenting a time series proportion of metered consumers in large municipalities. In all provinces, a decreasing trend in the share of metering is observed. In particular, British Columbia, with the highest average share of residential consumption data, is lacking positive growth in metering density since the 1996 sample year. Figure-B7 presents a highly suboptimal scenario, considering strong evidence of a negative relationship between metering density and household consumption, attained through provision of information and increased repairs (Bakker 2007, 271)[26].

Figure-B7: Population Metered Shares Time Series



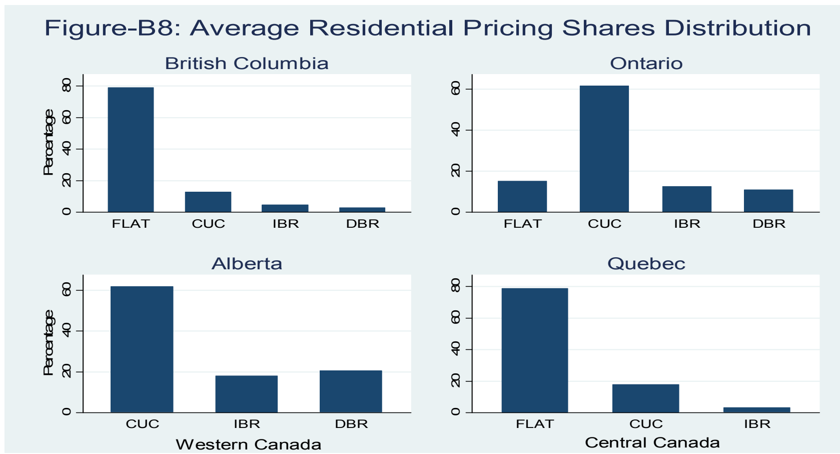
Thus far, the study has presented observations pertaining to domestic residential use in large municipalities of four domestic provinces, continued and increasing dominance of residential consumption and a strong negative relationship between per-capita use and metering density. The following analysis of pricing data highlights a positive relationship between proportion of metered consumers and imposition of volumetric pricing methods, as well as a negative link between volumetric pricing and per-capita residential consumption.

Analysis of residential pricing focuses on differentiation between volumetric and non-volumetric pricing methods. In the latter case, the FLAT pricing instrument is the sole non-volumetric method which is analyzed. In the former case, data describing Increasing Block Rate

[25] Figure-B7 is based on Table-B7 presented within Appendix-B

[26] Although Figure-B5 is generated using the Municipal Water Use database, a -0.95 linear correlation value between per-capita use and proportion of metered clients is observed within the Municipal Water Pricing dataset.

(IBR) and Decreasing Block Rate (DBR) volumetric pricing constructs are dropped from analysis and the Constant Unit Cost (CUC) pricing scheme is used to represent volumetric pricing in entirety. To facilitate this stage of empirical discussion, Figure-B8[27] is shown below to illustrate the distribution of all pricing schemes in large municipalities as an average of provincial residential water consumption across the time series[28]. This representation is also an alternative perspective of relationships between per-capita consumption, metering density and of volumetric pricing implementation.



Alberta and Ontario, provinces with highest metering density and lowest per-capita use, are observed to mainly price water delivery using the volumetric pricing method. Specifically, FLAT pricing is nearly absent in Alberta and 15% of Ontario's residential consumption is priced using this scheme. Instead, consumption in these two provinces is mostly metered and priced using the CUC method. However, Quebec and British Columbia, provinces with lower levels of metering and highest per-capita consumption, exhibit a strong presence of non-volumetric pricing. On average throughout the time-frame, nearly 80% of residential water consumption within these two provinces is observed to be non-volumetric. In particular, IBR and DBR methods contribute less than 8%, with Quebec not employing the DBR method at all. Overall, a markedly different pricing distribution is observed between the two groups of provinces and corresponding per-capita use. In order to adequately capture the relationship between pricing and consumption, Figure-B9[29] is shown below to present a comparison of per-capita residential

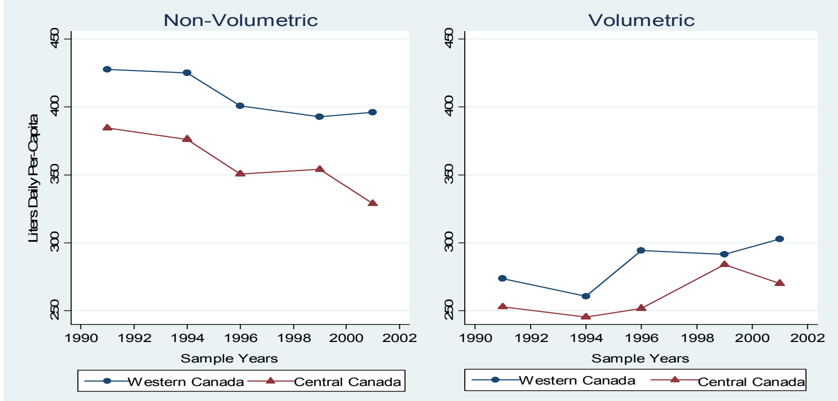
[27] Figure-B8 is based on Table-B8 presented within Appendix-B

[28] Exclusion of data representing IBR & DBR volumetric methods is obvious given Figure-B8.

[29] Left-hand graph in Figure-B9 is based on Table-B9 presented within Appendix-B
Right-hand graph in Figure-B9 is based on Table-B10 presented within Appendix-B

consumption, expressed in liters consumed daily per person, under volumetric (CUC, IBR, DBR) and non-volumetric (FLAT) pricing schemes. Also, due to the uneven distribution of pricing methods in neighboring provinces, and to utilize the available data to its full potential, provincial data is pooled by geographical proximity resulting in two categories, Western[30] and Central Canada. It is observed that on average, volumetric pricing constitutes 42% and 65% of all residential use in large municipalities within Western and Central regions respectively. Note that data presented in Figure-B9 is utilized in statistical estimation of residential water demand.

Figure-B9: Residential Use Time Series by Pricing Method



A marked difference in trends and levels of residential per-capita consumption is observed under the two pricing methods. Specifically, most recent sample year data shows a difference of 23% and 18% within Central and Western Canadian regions respectively. Further, although non-volumetric per-capita use is decreasing, a generally sustained trend is observed under volumetric consumption. Overall, Central Canada presents relatively lower per-capita use under both pricing methods, with the greatest difference under non-volumetric pricing.

In order to adequately analyze per-capita consumption, Figure-B10[31] is shown to introduce total monthly costs of consuming 25 cubic meters, conditional on pricing method. Briefly, a derived cost of consumption includes charges for estimated minimum water use, sewage service charges as well as the actual water consumption charges. The specific quantity of 25 cubic meters was chosen in consideration to the municipal average number of residents in a household and per-capita daily residential water consumption. The measure of total costs of consumption was chosen to be used in analysis of volumetric pricing, rather than marginal costs

[30] Note that British Columbia constitutes all non-volumetric consumption in Western Canada

[31] Left-hand graph in Figure-B10 is based on Table-B11 presented within Appendix-B
Right-hand graph in Figure-B10 is based on Table-B12 presented within Appendix-B

at a fixed level of consumption, due to the availability of such data across both domestic regions[32]. Data shown within Figure-B10 is also utilized as the price variable in statistical modeling and estimation of municipal residential water demand in large municipalities.

Across the time series, under both pricing methods and in both regions, municipally averaged derived residential costs of consuming an equivalent quantity are rising throughout the time-series. Regardless of the pricing method, costs of consuming an equivalent volume and level of per-capita residential consumption are nearly always higher in Western than in Central Canada. Most important is the observation of higher derived consumption costs and lower levels of per-capita residential consumption, in both regions, under volumetric pricing.

In general, residential water markets are observed to behave differently under individual price methods and this is considered in modeling and estimation of water demand, such that estimation is completed separately for the each pricing category. In particular, regarding non-volumetric pricing and associated per-capita consumption, regional response to price changes is observed to be higher in Central Canada. From a conservation perspective, higher price responsiveness is in fact desirable within the Central region due to its significantly higher contribution toward aggregate water consumption.

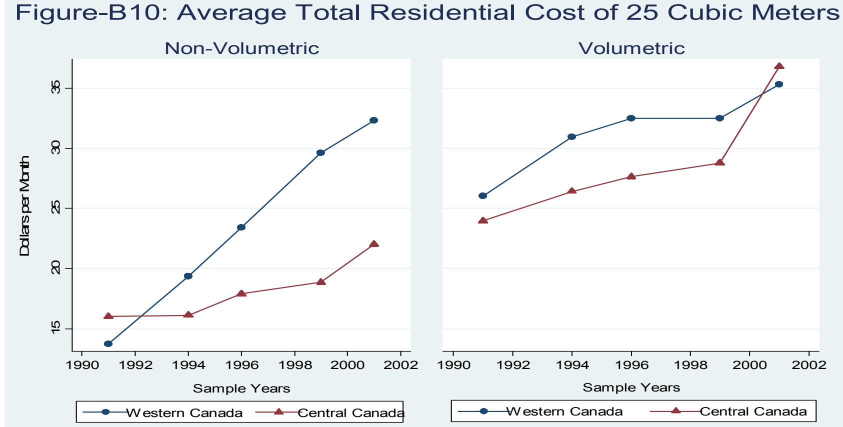
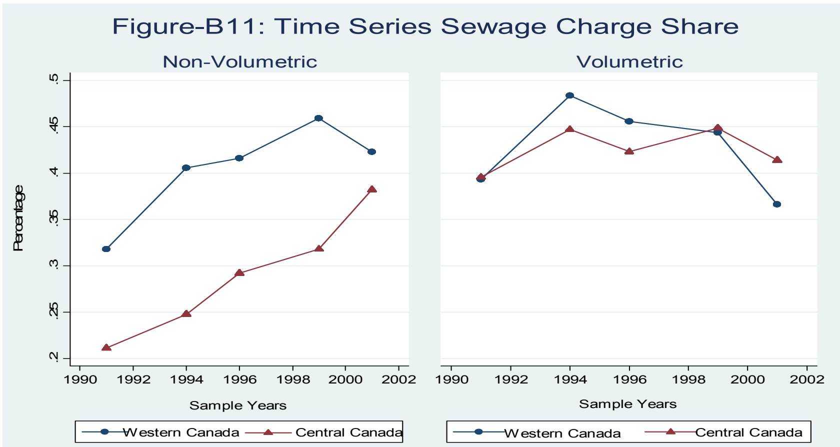


Figure-B10: Average Total Residential Cost of 25 Cubic Meters

In the case of volumetric methods, a positive relationship is observed between costs and per-capita use in both regions. Further, the seemingly weak relationship between price and quantity is highly advantageous as prices can be further increased with strong expectations of low consumption levels and increased financial inflows. This trend is suspected to be influenced by factors which constitute total costs of consumption. In particular, the total cost of

[32] However, empirical evidence is mixed on consumer's level of responsiveness to average, marginal and total costs of use (Ruijs et al., 2008)

consumption is composed of fixed and variable components, with the latter pertaining to actual consumption and the remainder attributable to sewage charges. Therefore, it is hypothesized that the fixed proportion of the total monthly costs influences the above observed price versus quantity relationship. Figure-B11[33], shown immediately below, illustrates the time series averaged share of sewage charges as a proportion of residential monthly costs of consuming 25 cubic meters. This variable is also employed in statistical estimation of municipal residential water demand within large municipalities.



Under non-volumetric pricing, proportion of fixed charges in both domestic regions has steadily risen and is observed to constitute 40% of monthly total costs. However, proportion of fixed charges is generally greater under volumetric pricing. It is also notable that the proportions of fixed monthly costs are relatively higher in Western Canada.

Under non-volumetric pricing increasing fixed costs of water consumption are observed, and are in-line with, an earlier observation of a negative relationship between total consumption costs and levels of per-capita use. Hence it is plausible that in both domestic regions an increase in residential consumption costs is attributable to a greater proportion of fixed costs. However, in this category of pricing, all consumption costs are by definition fixed and exact contribution of such variables toward changes in per-capita consumption is further investigated using statistical estimation. Sewage charges under volumetric pricing are either steady or decreasing in Central and Western regions respectively. Therefore, costs of water use are concluded to be increasing due to upward changes in costs rather than imposition of fixed charges. However,

[33] Right-hand graph in Figure-B11 is based on Table-B13 presented within Appendix-B
Right-hand graph in Figure-B11 is based on Table-B14 presented within Appendix-B

just as in the case of non-volumetric pricing, proportion of fixed costs is also included in estimation of water demand based on per-capita residential consumption.

Overall, this subsection illustrated a link between metering density, presence of pricing methods, per-capita residential use, total costs of consumption and constitution of total costs. It is observed that large municipalities in four most populated domestic regions are taking the financially efficient route to improving their financial operations and inducing conservative consumption through price increases. This observation is in relation to the high level of investment required to increase metering density and expand the volumetric customer base. Cumulatively, this is illustrated by decreasing trends in the share of metered residential clients, increasing monthly total consumption costs and decreasing/non-increasing per-capita residential consumption in non-volumetric/volumetric pricing methods.

4. STATISTICAL MODELING AND ESTIMATION OF DOMESTIC RESIDENTIAL WATER DEMAND

4.1. VARIABLES – GATHERING AND SELECTION

In an attempt to model and estimate domestic residential water demand, under volumetric and non-volumetric pricing methods, this section utilizes time series water pricing data concentrated on large municipalities within four largest Canadian provinces. Estimation employs variables gathered from the Municipal Water Pricing Database, Canadian Census, Adjusted Historical Canadian Climate Database and CANSIM database. Due to construction of the Canadian Census, the utilized dataset is constrained to three sample years capturing the 1991-2001 timeframe. Table-C1, shown immediately below, briefly presents all utilized variables in estimation of water demand[34].

Table-C1: Estimated Water Demand Equation Variables

Variable	Description
USE	Logarithm of residential per-capita consumption in liters per day
PRICE	Logarithm of inflation adjusted[35] residential monthly total consumption cost of 25 cubic meters of water
SEWAGE	Inflation adjusted sewage proportion of residential monthly total consumption cost of 25 cubic meters of water
INC	Logarithm of inflation adjusted average household income
SIZE	Logarithm of average number of household residents
GARDEN	Logarithm of proportion of dwellings not classified as apartment/building units

[34] Table-C1 and Table-C2 within Appendix-C present pairs wise correlation values, across three sample years, categorized by non-volumetric and volumetric data types respectively

[35] All inflation adjustment was completed using the Consumer Price Index (CPI) with 2002 as base year

PRECIP	Logarithm of annual total precipitation in millimeters
REGION	Dummy=0 if region is "Western Canada" Dummy=1 if region is "Central Canada"

The model is estimated with USE as the dependent variable, represented by daily per-capita residential water use within large municipalities of Western and Central domestic regions. The variable is a ratio of municipal residential water use, initially derived from aggregate municipal consumption, and municipal population served with water services. Although the measure focuses on a representative consumer, demand estimation is formulated at a household level[36]. Distribution of residential per-capita water consumption data, in its logarithmically transformed form, is approximately normal[37]. It is notable that this paper utilizes residential consumption data which is a composite of various uses categorized as either necessities or non-necessities. Consequently, in relation to all explanatory variables, elasticity estimates are influenced by unobserved distributions of such consumption categories (Hillenbrand and Schleich, 2008).

Three explanatory variables were selected to address variation of per-capita water consumption attributed to financially related factors. The PRICE variable describes inflation adjusted (2002 base year) derived monthly municipal residential total costs of consuming 25 cubic meters (see Figure-B10). A derived cost includes all applicable charges incurred during consumption of a fixed volume of water and a monetized representation of consuming specifically 25 cubic meters was chosen based on per-capita daily water use and average number of household residents. Further, in explaining variation of residential per-capita daily water use, total costs are preferred over marginal or average costs of consumption due to this measure's greater relevancy to a representative residential consumer[38] (Shin, 1985). In reference to surveyed literature, estimation is expected to yield negative and inelastic price estimates. Although this paper's demand estimation differentiates between two main pricing methods, in reference to surveyed literature, estimation is expected to yield negative and inelastic price estimates. A complete discussion pertaining to regression results is presented within the following subsection.

[36] This particular approach to demand estimation is common across reviewed literature

[37] Refer to Table-C4 and Table-C6 for normality tests of dependant variables in corresponding model setups

[38] Utilization of marginal prices is advantageous in analysis of volumetric price constructs such as IBR and DBR, rather than a general volumetric category (Agthe and Billings, 1980). In addition, given the utilized dataset and pertaining to volumetric estimation, a large number of observations would be sacrificed if marginal rather total costs of consumption were to be employed.

Previously, it was shown that a portion of total consumption costs is attributable to a flat sewage service charge, in the case of both pricing methods (Figure-B11). The SEWAGE variable describes the proportion of municipality specific monthly costs, of consuming 25 cubic meters. The purpose of this variable is to address the effect of altering the composition of monthly total consumption costs, while maintaining such costs fixed. Although this variable is included in estimation, no equivalent reference exists within the surveyed literature, and hence, no specific expectation is made prior to estimation.

Another financially linked variable is INC, describing inflation adjusted average municipal household income. This variable is calculated as a ratio of gross average municipal income and number of households within the municipality. Similarly to PRICE, this measure is expressed at a household level rather than in a corresponding per-capita form, as water consumption is generally observed as a household rather than an individual resident's consumption decision[39]. To address the observed non-constant income elasticity (Hillenbrand and Schleich, 2008) and better explain differences in variation of consumption categorized by two general pricing methods across the four largest Canadian provinces, estimation of water demand also includes a squared term of logarithmically transformed household income data. However, although water is generally observed as a normal good (Domene and Sauri, 2006), via differentiation in pricing methods this paper presents a more involved set of results pertaining to a relationship between average municipal household income and per-capita residential water consumption.

A review of recent literature also highlighted household composition and socio-demographics among factors influencing water demand (Gatersleben et al., 2002). In consequence, the variable SIZE is included in the model to explain variation of residential per-capita consumption attributed to a municipal average of household residents. This variable is a ratio of municipal population and total number of households within the municipality, and is observed to have a negative relationship with residential water consumption (Loh and Coghlan, 2003). Data pertaining to household size is also included in the model to explain variation in water use resulting from recently observed changes in the real estate market. From a time series perspective, in all combinations of domestic regions and pricing methods, SIZE is observed to be oscillating but overall decreasing, thus indicating an increasing number of single member

[39] Based on model setups in majority of surveyed literature

households. Further, this variable is highly positively correlated with a municipal proportion of owned households, a variable which is increasing throughout the time series.

In addition to data describing household size, to better explain residential per-capita consumption, the model also utilizes data pertaining to dwelling characteristics describing the prevalent type of real estate within each municipality. Specifically, the variable GARDEN describes municipal proportion of individual dwellings most likely to be associated with a residential pool or significant green-space, attributes which positively influence per-capita residential water use. Recent literature relates increased presence of such properties, associated with urban expansion, and increasing residential per-capita water consumption specifically in large urban centers (Domene and Sauri, 2006). The GARDEN variable is compiled using a ratio of municipal non-apartment type dwellings and the total number of dwellings within the municipality. Regarding the utilized dataset, the proportion of such real estate properties is observed to be oscillating but overall increasing throughout the time series, in both domestic regions and pricing methods. Overall, this variable is expected to positively contribute toward per-capita residential consumption in large municipalities within the four largest domestic provinces.

To address variation of per-capita consumption attributed to climate data, the PRECIP variable was included to describe total annual precipitation within both domestic regions, expressed in millimeters per annum. Recall from an earlier section that the utilized climate data has undergone statistical manipulation to reflect variation resultant from various changes in measurement. However, utilization of specific types of climatic data in estimation of water demand is mixed, as evident within the surveyed literature, with strong preference directed at data pertaining to “rain days” (Wong, 1972). In addition, precipitation mainly reduces “external” residential consumption through reduced need for irrigation, versus “internal” or in-home water use, which is a strong contributing factor specifically during the summer months. Nevertheless, this data is utilized and in addition to relating climatic fluctuation and residential water use. PRECIP is also interpreted as a regional indicator due to a strong disparity in precipitation trends between Western and Central Canada. Overall, annual precipitation data is expected to negatively and weakly contribute toward per-capita residential water use.

Finally, the model also includes a dummy variable REGION in consideration to a strong difference in per-capita consumption between both domestic regions (Figure-B9). This variable is assigned a unitary value, if and only if, the municipality is located within the Central Canadian region. This estimate is expected to be a negative value, in consideration to the strong differences in consumption between the two domestic regions.

4.2. STATISTICAL MODEL – SPECIFICATION AND RESULTS

This subsection outlines formulation and estimation results of a model describing domestic residential water demand in large municipalities under volumetric and non-volumetric pricing. Estimation is completed using a semi log-log OLS model, a common formulation across reviewed literature, separately for each pricing method and individual sample year (Hillenbrand and Schleich, 2008)[40]. The model's equation is shown immediately below[41]:

$$\mathit{USE} = \beta_0 + \beta_1 * \mathit{PRICE} + \beta_2 * \mathrm{SEWAGE} + \beta_3 * \mathit{INC} + \beta_4 * \mathit{INC\_2} + \beta_5 * \mathit{SIZE} + \beta_6 * \mathit{GARDEN} + \beta_7 * \mathit{PRECIP} + \beta_8 * \mathrm{REGION} + \varepsilon \qquad (1)$$

Varying attempts have been made in order to effectively complete estimation of water demand under both pricing methods. In particular, due to possible endogeneity between price and quantity, Two Stage Least Squares Instrumental Variables method was utilized with an additional variable describing population served with water services. However, results have proved to be both insignificant and incomparable to those in relevant literature. Another attempt is based on clustering precipitation data through robust estimation and is utilized due to high frequency of non-unique precipitation values in individual combinations of sample years and market types[42]. This method of estimation was chosen for presentation and discussion, over non-robust OLS and 2SLS-IV estimation attempts.

Although robust estimation results are generally superior in comparison to other attempts, not all combinations of sample years and pricing methods resulted with significant results. Therefore, in cases of both pricing methods, estimation of the 1991 and 2001 sample years are chosen for immediate presentation based on model and individual estimate significance,

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[40] The model is labeled as a semi log-log due to the absence of a logarithmic transformation of a variable describing the percentage of sewage charges in derived total costs of consuming 25 cubic meters of water. SEWAGE, was left free of any transformation due to a large percentage of valid zero entries.

[41] Italicized variables are those which have been logarithmically transformed

[42] An earlier subsection describes alignment of climate and pricing data based on distance minimization with 75 kilometers set as a maximum distance. Hence, a number of weather stations are assigned to more than a single municipality, and in consideration to the close proximity of such municipalities, water consumers therein are assumed similar in their consumption preferences.

explanatory power, a series of model related tests (dependant variable and error's normality, specification and multicollinearity) and comparability with that of surveyed literature[43]. Table-C2 presents these estimation results for non-volumetric and volumetric water markets[44].

Table-C2: Non-Volumetric and Volumetric Pricing OLS Estimation Results				
	Non-Volumetric		Volumetric	
Variables/Years	1991	2001	1991	2001
PRICE	-0.20** (0.07)	-0.31*** (0.07)	-0.36*** (0.08)	-0.17** (0.07)
SEWAGE	0.01*** (0.00)	0.00 (0.00)	0.00 (0.00)	0.00** (0.00)
INC	27.38** (12.50)	47.71** (20.08)	-37.11** (15.31)	-24.99** (9.00)
INC_2	-1.31** (0.04)	-2.17** (0.91)	1.72** (0.69)	1.10** (0.40)
SIZE	3.32*** (0.00)	-2.19* (1.05)	-1.43*** (0.42)	0.07 (0.31)
GARDEN	-1.16*** (0.00)	0.57 (0.34)	0.55** (0.20)	0.90*** (0.24)
PRECIP	-0.30** (0.02)	0.00 (0.08)	0.10 (0.07)	0.02 (0.03)
REGION	-0.09 (0.33)	-0.13* (0.06)	-0.18** (0.06)	-0.25*** (0.04)
INTERCEPT	-132.89* (0.07)	-255.74* (110.14)	205.30** (84.43)	144.31** (50.77)
Observations	40	30	65	34
R-Squared	0.61	0.71	0.48	0.72

4.3. ESTIMATED WATER DEMAND – A DISCUSSION

The PRICE variable is estimated with high statistical significance throughout all combinations of sample years and pricing methods. A negative inelastic relationship is observed between total monthly cost of consuming 25 cubic meters and residential daily per-capita water consumption throughout the 1991-2001 timeframe under both pricing methods. It is notable that all PRICE variable estimates fall in the range of those presented in a literature review by Dalhuisen et al. (2003) and correspond with above graphical presentation of price and quantity (Figure-B9 and Figure-B10). It is hypothesized that the inelastic price estimates are related to a low share of residential water consumption costs within the total average household budget. However, considering Canada's relatively high level of per-capita residential water use and comparable estimates of water demand determinants, estimated price elasticity estimates are not strong indicators of conservation. Specifically, such low estimates cannot be attributed to a state of

[43] Table-C2 presents most significant results and Appendix-C contains results of all robust estimation attempts
[44] '*' indicates a significance at α=0.1, '**' indicates significance at α=0.05 and '***' indicates significance at α=0.01

maximal per-capita water conservation (Hillenbrand and Schleich, 2008), implying challenges in further implementation of costly volumetric pricing methods in attainment of use reductions. However, on the other hand and in consideration to Canada's low residential use costs, relative to other OECD member countries, inelastic price estimates are also favorable as further price increases and revenues gains can be accomplished with similar effects on consumption. Hence, observed inelastic price estimates are not in line with desired reductions of household use, especially through implementation of costly pricing schemes, but are a supporting factor in improvement of an individual utility's financial well being.

Although the SEWAGE variable, describing the portion of monthly residential total costs of consumption associated with a fixed sewage service charge, is statistically significant in estimation attempts of one of the sample years under each pricing method and it is estimated as not having an effect on the percentage change in per-capita consumption. Hence, under both pricing methods, residential per-capita consumption is not influenced by consumers' knowledge regarding composition of total costs. It is hypothesized that the difference in per-capita use between volumetric and non-volumetric pricing methods (Figure-B9) is related to levels of total costs (Figure-B10) and presence of metering in a particular household. Although contribution of the former factor is diminished by inelastic price estimates, the latter pertains to availability of information across representative consumers and is observed to be influential in their consequent consumption decisions (Nauges and Thomas, 2000). Therefore, in relation to pricing decisions, the average consumer is less concerned with the composition of their total water bill, rather than, whether or not their consumption is being monitored and how such monitoring translates to total monthly charges at an average level of consumption.

Estimates pertaining to average household income are statistically significant in all combinations of sample years and pricing methods. The relationship between income and residential per-capita consumption was modeled with inclusion of a squared term to account for income differences across and within Western and Central Canadian regions. In the case of non-volumetric methods, residential per-capita consumption is estimated to decrease with higher average household income levels. The opposite is observed as a result of estimation using volumetric pricing data. Elasticity estimates, resulting from combined effect of both estimated terms, are calculated using mean values of inflation adjusted average municipal household income and are shown, immediately below, in Table-C3.

Table-C3: Income Elasticity Estimates			
Pricing Method	Year	Mean INC	Elasticity
Non-Volumetric	1991	47,983	-0.86
	2001	59,014	0.03
Volumetric	1991	54,942	0.43
	2001	69,881	-0.45

Although income elasticity estimates fluctuate in sign, throughout time and dependant on pricing methods, estimates are inelastic in all cases of estimation attempts. Under both pricing methods, quadratic signs shift direction of residential per-capita consumption at highly extreme household income levels. Estimated income elasticity estimates are highly comparable to that of surveyed literature, such that, estimates across the OECD group of countries are generally inelastic and are in a comparable range (see Dalhuisen et al., 2003; Arbues et al., 2003; Klein et al., 2007; Worthington and Hoffman, 2008). One certain possibility of the inelastic estimates is the low share of income committed toward water costs across all instances of pricing methods[45]. This observation is in favor of continued increases of user fees to address projected water utility deficits required in maintenance and future improvement of municipal water infrastructures. Furthermore, increasing household income also implies future increases in use of luxury goods (amenities, appliances), ultimately resulting in higher residential consumption.

Estimation results of municipal average household size fluctuate throughout estimation attempts but an elastic relationship is observed throughout. Under non-volumetric pricing, the estimate shifts from positive to negative, indicating increased level of conservation awareness within larger households in later sample years. The shift may be attributed to a combination of sharp and continuous increases in monthly total costs of residential consumption (Figure-B10). In the case of volumetric pricing, with only the 1991 sample year estimation as statistically significant, reduced level of per-capita consumption within larger households is observed. Therefore, results derived using volumetric data are fully in-line with expectations based on recent literature, such that the relationship between municipal household size and per-capita consumption is negative (Loh and Coghlan, 2003). In general, the relationship is explained by increasingly shared use of household appliances (dish and clothes washers) and enjoyment of

[45] In case of non-volumetric pricing, income shares allocated to water use are 0.39% and 0.56% during 1991 and 2001 respectively. Similarly, in the case of volumetric pricing, 0.32% and 0.39% are the observed income shares. All observed values are significantly lower than those observed in a study of the German residential water market (Hillenbrand and Schleich, 2008).

green space (lawns and gardens). Therefore, an increase of single resident households, observed during real-estate market expansions, is highly disadvantageous toward inducement of conservative levels in per-capita water consumption[46].

The variable GARDEN, describing a municipal proportion of properties likely to include amenities associated with higher use is estimated to influence per-capita residential consumption conditionally on pricing method. In the case of non-volumetric data, an unexpected negative elastic relationship is observed. It is hypothesized that non-volumetric consumers with a lower average household income level and a similar proportion of dwelling ownership, relative to consumers represented by volumetric data, are limiting their residential water consumption in connection to luxury goods. Specifically to volumetric data, positive inelastic estimates are observed as expected, and these results are in connection with relationships between household income, monthly total consumption costs and per-capita levels of consumption. Although differing dwelling characteristics indeed reveal differences in consumption preferences, in the case of volumetric data, inelasticity of results may be the result of the non-seasonal data utilized in this analysis[47]. Overall, excluding possible effects of other variables such as income and household ownership, it is observed that possible inclusion of amenities is positively related to residential use in the case of non-seasonal data.

Inclusion of variables selected for representation of climatic and geographical differences have resulted in mostly statistically insignificant estimates. PRECIP, a variable describing precipitation within a particular municipality, is included within the model to also address variation in consumption not immediately related with subsistence (“external” consumption). Estimates are insignificant across all attempts with the exclusion of the 1991 sample year under non-volumetric pricing, such that an inelastic reduction in residential per-capita water use is observed. In consideration to the utilized data lacking seasonal adjustment and variation due to precipitation most effectively represented by the number of rain-days, the negative estimate within a relatively lower-income group in a year coinciding with a strong economic downturn is

[46] Increases of single member households and consequent increases in per-capita consumption are also observed in other economically developed regions of the world and are attributed to rapid urban expansion (Domene and Sauri, 2008). Unfortunately, the trend is indeed observed within the utilized sample through continued increases in the proportion of owned households and decreasing average household size.

[47] Given prevailing weather patterns specific to large urban concentrations across Canada, gardening and private pools are mainly utilized at most 6-7 months out of the 12 month calendar year.

notable. Overall and in the strongest case, total annual precipitation is a minimally significant determinant of residential water consumption.

Estimates of the model's only dummy variable REGION, representing the domestic location of a particular municipality, confirms earlier observations of notably lower consumption in Central Canada under both types of pricing methods (Figure-B9). Specifically, negative inelastic estimates are calculated with significance under both pricing methods in most recent sample year, as well as in the 1991 sample year under volumetric pricing only. The estimation confirms earlier observations of differing consumption patterns between the two domestic regions, when a collection of other demand determinants are accounted for within the model.

The final variable of interest, the model's intercept, does not qualify as a demand determinant but nevertheless reveals a significant difference between two pricing methods. Specifically, without any regard for sample years and all other variables, initial consumption under volumetric pricing is noticeably higher. It is hypothesized to that the two pricing methods pertain to different consumption groups based on income levels and dwelling characteristics.

5. CONCLUSION

The purpose of this study was to quantitatively investigate time series residential water consumption and pricing trends, and attempt to model water demand using financial, socioeconomic and climatic determinants. The utilized data was constrained to residential volumetric and non-volumetric consumption and pricing observed within large domestic municipalities in four most populous provinces, categorized as located within Western or Central Canada. Choice of the utilized data, describing consumption and pricing, was completed based on a thorough investigation of the initially gathered time-series datasets (Figure-B1 to Figure-B4, and Figure-B6).

The study has identified aggregate consumption exhibiting a positive relationship with population and per-capita use having a negative relationship with presence of volumetric pricing methods (Figure-B5 to Figure-B10). Further, it was also established that time dependant proportion of residential use share is increasing (Figure-B4) and implementation of volumetric pricing is decreasing (Figure-B7). In addition, in favor of resource conservation and increasingly efficient user costs, residential per-capita consumption is decreasing and is relatively stable under non-volumetric and volumetric pricing respectively (Figure-B9), as total consumption costs are rapidly increasing under all pricing methods (Figure-B10). It is concluded that inducement of conservative residential use is indeed being achieved through higher use rates under all pricing methods, rather than via a costly expansion of a volumetric pricing client base. Sewage charges, represented as a fixed proportion of consumption costs, are also observed to fluctuate in order to attain desired pricing levels and induce effectiveness of volumetric pricing methods, through increasing and decreasing share of fixed consumption costs under non-volumetric and volumetric pricing respectively.

Attempted demand estimation yielded highly credible results regarding the choice of relevant determinants (Table-C1), particular to the domestic scenario of recent residential municipal consumption, and contribution of included variables on the households' choice regarding water use (Table-C2). This was accomplished through price method specific robust estimation using 1991-2001 sample year data. In reference to a review of recent and relevant literature, expected inelastic negative price and inelastic income estimates were observed. In the former case, the observation is upheld based on the fact that water consumption constitutes less that 1% of an average households' income. Regarding the latter, as the estimates across combinations of sample years and pricing methods are inelastic, residential water cannot be confirmed as either a normal or an inferior good. It is also notable, in reference to the variable describing the proportion of costs attributed to sewage service charges, that the composition of a household's water bill is not immediately relevant regardless of pricing method. Overall, regarding purely economic variables, residential household consumption is most responsive to changes in total costs rather than to changes in the composition of charges or differences in income. However, in the case of the intercept, it is notable that initial consumption under volumetric pricing (households of relatively higher income) is always greater relative to non-volumetric data. The latter observation is hypothesized to be attributed to the initial difference in the type of consumers based on economic status, as categorized by pricing methods rather than time dependant fluctuation in income figures. For example, a household residing on a property with a higher likelihood of luxury amenities will certainly require a higher quantity of water, as exemplified by the model's estimation results of the GARDEN variable specific to volumetric pricing.

Inclusion of an explanatory variable describing climatic differentiation failed to yield significant estimates. Lack of seasonal data and annual, rather than daily, precipitation measurements are the root causes. Although yielding statistically significant estimates, the variable describing household size does not provide an indicative explanation of its contribution to variation in residential consumption, due to this variable's relationship with other explanatory variables in connection to recent real-estate market expansion.

The above combined set of observations derived from quantitative investigation and estimation of residential water demand, point to a mixed scenario in connection with inducement of water conservation and general improvement in the financial state of an average water utility. In the area of conservation, present and future price increases as well as presence of metering are cumulatively showing improvements relative to past trends of consumption. Increased revenues are also being derived from price increases which have an inelastic effect on changing residential consumption. However, it is also noted that a representative household/user cares little for their expenditure on water as an input and corresponding level consumption as exemplified through low price and income elasticity estimates, initiation of market transactions resulting in a negative relationship between per-capita use and household size, disregard for the composition of a water bill and a positive relationship or consumption with an individually intrusive measurement tactic such as volumetric pricing. Therefore, with an observed decline in the continued expansion of metering and corresponding volumetric pricing, the most obvious initiative in attaining conservation and improved financial management is the continued increase in monthly user costs, most evident under non-volumetric pricing. In light of the above research, it is advocated that price increases continue to a point of an observed shift in price and income elasticity values corresponding with maximal conservation and observed changes in preferences pertaining to household input expenditure, respectively.

Retrospectively, regarding estimation of domestic municipal residential water demand, data describing volumetric consumption strictly within Central Canada, yield a more concise set of estimation results. Similarly is the case specific to non-volumetric data describing residential use in Western Canada. Therefore, additional data selection, seasonal adjustment and inclusion of daily binary, rather than annual, precipitation data are all desirable modifications to the above analysis with the aim of better estimation results.

6. APPENDIX-B: MUNICIPAL WATER USE AND PRICING SUMMARY TABLES

Table-B1: Water Use Dataset Time Series Average Water Use and Service Levels in Large Municipalities (Percentages)			
Province	Aggregate Use	Residential Use	Pop. Served
Ontario	29.87	28.1	36.48
Quebec	24.83	21.86	18.92
British Columbia	10.62	12.99	10.79
Alberta	6.2	6.1	7.99
Newfoundland	.85	1.06	.65
PEI	.085	.044	.089
Nova Scotia	1.29	1.28	1.49
New Brunswick	1.87	.83	.74
Manitoba	1.86	1.83	2.85
Saskatchewan	1.58	1.35	1.93
Total	79.06	75.44	81.93
Western and Central Canada	71.53	69.03	74.17

Table-B2: Water Use Dataset Time Series Aggregate Use in Large Municipalities (Millions of Cubic Meters)							
Province/Years	1991	1994	1996	1999	2001	2004	2006
Ontario	3.89	3.91	4.35	4.45	4.81	4.61	4.62
Quebec	3.5	3.4	3.36	3.47	3.7	4.21	3.8
British Columbia	1.35	1.38	1.5	1.63	1.62	1.68	1.73
Alberta	.88	.81	.81	.91	1	.95	1
Newfoundland	.121	.142	.144	.147	.151	.084	.083
PEI	NA	NA	.015	.016	.018	.019	.019
Nova Scotia	.17	.16	.2	.2	.2	.2	.19
New Brunswick	.26	.27	.29	.32	.33	.36	.086
Manitoba	.32	.32	.27	.27	.23	.24	.24
Saskatchewan	.26	.21	.22	.22	.24	.25	.23
Total	10.77	10.62	11.15	11.63	12.31	12.61	12.00

Table-B3: Water Use Dataset Time Series Average Water Use Shares in Large Municipalities (Percentages)			
Province	Residential Use	Commercial Use	Other Use
Ontario	50.00	37.27	11.14
Quebec	46.83	26.58	25.44
British Columbia	65.06	27.44	6.86
Alberta	52.32	37.06	10.02
Newfoundland	65.84	25.63	7.94
PEI	27.37	58.7	13.94
Nova Scotia	52.92	29.22	17.87
New Brunswick	23.49	64.69	11.82
Manitoba	52.37	34.13	13.5
Saskatchewan	45.4	40.26	14.35
Western and Central Canada	48.6	32.55	17.45
Total	50.74	33	15.18

Table-B4: Water Use Dataset Time Series Residential Use Share in Large Municipalities (Percentages)							
Province/Years	1991	1994	1996	1999	2001	2004	2006
Ontario	43.27	47.08	46.61	51.65	52.41	53.29	53.91
Quebec	44.02	46.13	44.68	46.25	48.76	48.22	49.06
British Columbia	60.66	65.97	68.20	62.75	64.48	66.49	66.41
Alberta	44.40	44.02	49.55	55.62	52.62	55.93	61.64
Newfoundland	50.90	68.15	65.41	66.08	71.36	69.75	69.92
PEI	NA	NA	28.00	27.00	30.00	26.00	26.00
Nova Scotia	46.42	43.95	45.87	44.76	62.51	62.50	62.72
New Brunswick	34.21	19.58	23.32	21.96	19.60	20.45	37.65
Manitoba	43.15	54.28	55.03	48.69	55.08	53.66	59.13
Saskatchewan	42.57	45.37	46.87	45.90	40.94	58.24	37.79

Table-B5: Water Use Dataset Time Series Residential Use in Large Municipalities (Liters Daily Per-Capita)							
Province/Years	1991	1994	1996	1999	2001	2004	2006
Ontario	235.21	247.43	258.93	283.31	276.80	246.05	254.53
Quebec	393.47	399.30	362.58	387.88	379.39	406.57	379.68
British Columbia	409.04	414.59	407.64	395.04	391.48	392.73	416.60
Alberta	241.29	216.13	236.23	280.93	271.42	254.67	278.49
Newfoundland	424.32	632.78	603.75	629.09	753.32	378.83	385.65
PEI	NA	NA	153.00	155.98	197.25	163.61	156.45
Nova Scotia	267.99	262.66	252.31	249.01	341.01	319.18	310.89
New Brunswick	533.28	310.49	370.28	408.83	386.27	422.15	186.57
Manitoba	213.06	265.43	226.14	198.11	201.07	190.45	213.51
Saskatchewan	261.61	219.01	206.83	219.69	221.87	318.98	196.65

Table-B6: Water Pricing Dataset Time Series Average Water Use and Service Levels in Large Municipalities (Percentages)				
Province/Measure	Aggregate Use	Residential Use	Pop. Served	Pop Metered
Ontario	34.12	29.64	37.95	52.92
Quebec	12.85	13.17	10.94	4.03
British Columbia	12.20	14.25	11.59	3.97
Alberta	5.89	5.30	7.09	10.18
Newfoundland	1.11	1.27	0.72	0.00
PEI	0.07	0.07	0.07	0.01
Nova Scotia	1.09	0.92	1.13	1.77
New Brunswick	1.65	0.93	0.78	0.63
Manitoba	2.62	2.41	3.61	5.77
Saskatchewan	2.10	1.68	2.46	3.93
Western & Central Canada	65.04	62.36	67.57	71.10
Canada	73.69	69.63	76.33	83.20

Table-B7: Water Pricing Dataset Population Metered Share Time Series in Large Municipalities (Percentages)					
Province/Years	1991	1994	1996	1999	2001
Ontario	84.28	85.78	86.88	85.73	95.93
Quebec	21.54	19.05	22.46	21.78	37.29
British Columbia	19.38	22.50	23.51	22.04	23.56
Alberta	88.21	86.30	86.41	86.07	99.80
Newfoundland	0.00	0.00	0.00	0.00	2.14
PEI	NA	NA	0.00	0.00	100.00
Nova Scotia	91.28	100.00	100.00	100.00	77.01
New Brunswick	31.08	43.29	41.01	65.45	97.20
Manitoba	100.00	100.00	100.00	100.00	100.00
Saskatchewan	100.00	100.00	100.00	100.00	100.00

Table-B8: Water Pricing Dataset Time Series Average Pricing Shares in Large Municipalities (Percentages)				
Province/Pricing Type	FLAT	CUC	IBR	DBR
Ontario	15.09	61.44	12.58	10.90
Quebec	78.98	17.81	3.21	NA
British Columbia	79.27	12.94	4.89	2.90
Alberta	NA	61.63	17.86	20.38
Newfoundland	99.79	0.21	NA	0.21
PEI	88.88	11.12	NA	NA
Nova Scotia	3.55	NA	NA	96.45
New Brunswick	62.57	14.53	NA	22.90
Manitoba	NA	NA	NA	100.00
Saskatchewan	NA	34.92	NA	65.08

Table-B9: Water Pricing Dataset Time Series Non-Volumetric Residential Use in Large Municipalities (Daily Per-Capita Liters)					
Province/Years	1991	1994	1996	1999	2001
Ontario	239.18	306.55	331.17	293.39	273.45
Quebec	476.90	411.33	360.99	385.63	390.73
British Columbia	427.43	424.89	400.49	392.55	395.98
Alberta	NA	NA	NA	NA	NA
Newfoundland	424.32	632.78	603.75	629.09	655.61
PEI	NA	NA	153.00	155.98	NA
Nova Scotia	393.60	NA	NA	NA	425.51
New Brunswick	606.17	306.33	381.85	571.14	278.13
Manitoba	NA	NA	NA	NA	NA
Saskatchewan	NA	NA	NA	NA	NA
Western Canada (British Columbia & Alberta)	427.43	424.89	400.49	392.55	395.98
Central Canada (Ontario & Quebec)	384.49	376.06	350.58	354.02	328.77

Table-B10: Water Pricing Dataset Time Series Volumetric Residential Use in Large Municipalities (Daily Per-Capita Liters)					
Province/Years	1991	1994	1996	1999	2001
Ontario	243.72	234.13	244.81	278.90	260.01
Quebec	378.06	406.91	334.06	345.57	435.01
British Columbia	408.17	379.25	419.54	370.99	418.06
Alberta	229.32	213.58	235.01	266.38	274.34
Newfoundland	NA	NA	NA	NA	798.37
PEI	NA	NA	NA	NA	197.26
Nova Scotia	269.03	305.35	250.32	246.55	NA
New Brunswick	284.27	332.22	306.98	305.86	369.22
Manitoba	213.06	265.43	226.14	198.11	201.07
Saskatchewan	261.61	219.01	206.83	219.69	221.87
Western Canada (British Columbia & Alberta)	273.71	260.57	294.14	291.53	302.67
Central Canada (Ontario & Quebec)	252.96	245.44	251.72	283.94	270.03

Table-B11: Water Pricing Dataset - Residential Non-Volumetric Total Monthly Cost of 25 Cubic Meters in Large Municipalities (Dollars)					
Province/Years	1991	1994	1996	1999	2001
Ontario	23.71	26.61	26.32	28.89	32.82
Quebec	13.75	13.49	15.80	16.46	15.53
British Columbia	13.72	19.36	23.40	29.61	32.32
Alberta	NA	NA	NA	NA	NA
Newfoundland	NA	NA	NA	NA	NA
PEI	NA	NA	NA	NA	NA
Nova Scotia	NA	NA	NA	NA	NA
New Brunswick	NA	NA	NA	NA	NA
Manitoba	NA	NA	NA	NA	NA
Saskatchewan	NA	NA	NA	NA	NA
Western Canada (British Columbia)	13.72	19.36	23.40	29.61	32.32
Central Canada (Ontario & Quebec)	16.01	16.11	17.90	18.85	22.01

Table-B12: Water Pricing Dataset - Residential Volumetric Total Monthly Cost of 25 Cubic Meters in Large Municipalities (Dollars)					
Province/Years	1991	1994	1996	1999	2001
Ontario	25.59	28.35	30.15	31.26	37.91
Quebec	14.17	14.56	14.63	14.61	18.01
British Columbia	14.21	22.10	22.53	21.64	25.76
Alberta	35.23	39.81	43.41	43.38	44.86
Newfoundland	NA	NA	NA	NA	NA
PEI	NA	NA	NA	NA	NA
Nova Scotia	NA	NA	NA	NA	NA
New Brunswick	NA	NA	NA	NA	NA
Manitoba	NA	NA	NA	NA	NA
Saskatchewan	NA	NA	NA	NA	NA
Western Canada (British Columbia & Alberta)	26.04	30.95	32.51	32.51	35.31
Central Canada (Ontario & Quebec)	23.96	26.42	27.65	28.77	36.81

Table-B13: Water Pricing Dataset Time Series - Residential Non-Volumetric Sewage Charge Shares at 25 Cubic Meters (Percentages)					
Province/Years	1991	1994	1996	1999	2001
Ontario	37.84	41.22	37.61	42.89	50.12
Quebec	12.65	16.65	25.69	27.15	23.11
British Columbia	31.79	40.56	41.59	45.90	42.26
Alberta	NA	NA	NA	NA	NA
Newfoundland	NA	NA	NA	NA	NA
PEI	NA	NA	NA	NA	NA
Nova Scotia	NA	NA	NA	NA	NA
New Brunswick	NA	NA	NA	NA	NA
Manitoba	NA	NA	NA	NA	NA
Saskatchewan	NA	NA	NA	NA	NA
Western Canada (British Columbia & Alberta)	31.79	40.56	41.59	45.90	42.26
Central Canada (Ontario & Quebec)	21.13	24.77	29.19	31.79	38.21

Table-B14: Water Pricing Dataset Time Series - Residential Volumetric Sewage Charge Shares at 25 Cubic Meters (Percentages)					
Province/Years	1991	1994	1996	1999	2001
Ontario	42.59	47.08	44.65	46.85	41.38
Quebec	6.60	16.23	17.04	20.48	41.44
British Columbia	24.00	49.27	47.98	37.22	31.97
Alberta	44.09	47.84	44.22	47.95	39.26
Newfoundland	NA	NA	NA	NA	NA
PEI	NA	NA	NA	NA	NA
Nova Scotia	NA	NA	NA	NA	NA
New Brunswick	NA	NA	NA	NA	NA
Manitoba	NA	NA	NA	NA	NA
Saskatchewan	NA	NA	NA	NA	NA
Western Canada (British Columbia & Alberta)	39.29	48.35	45.58	44.38	36.60
Central Canada (Ontario & Quebec)	39.55	44.69	42.30	44.85	41.38

7. APPENDIX-C: DOMESTIC RESIDENTIAL WATER DEMAND ESTIMATION[48]

Table-C1: Time Series Average Variable Pair-Wise Correlation Under Non-Volumetric Pricing (N=140)							
Variables/Variables	USE	PRICE	SEWAGE	INCOME	SIZE	GARDEN	PRECIP
PRICE	-0.15	1.00					
SEWAGE	-0.06	0.52	1.00				
INCOME	-0.06	0.26	0.27	1.00			
SIZE	-0.10	0.04	0.11	0.65	1.00		
GARDEN	-0.06	0.27	0.21	0.49	0.78	1.00	
PRECIP	-0.04	0.08	0.17	0.16	0.13	0.04	1.00
REGION	-0.22	-0.15	-0.24	-0.28	-0.11	-0.14	-0.47

Table-C2: Time Series Average Variable Pair-Wise Correlation Under Volumetric Pricing (N=179)							
Variables/Variables	USE	PRICE	SEWAGE	INCOME	SIZE	GARDEN	PRECIP
PRICE	-0.22	1.00					
SEWAGE	-0.20	0.49	1.00				
INCOME	-0.10	0.19	0.28	1.00			
SIZE	-0.17	0.03	0.24	0.70	1.00		
GARDEN	-0.13	0.28	0.36	0.56	0.66	1.00	
PRECIP	-0.02	-0.29	-0.09	-0.15	0.01	-0.17	1.00
REGION	-0.35	-0.11	0.06	0.10	0.10	-0.04	0.09

Table-C3: Time Series Variable Statistics Under Non-Volumetric Pricing						
	1991 (N = 40)		1996 (N=58)		2001 (N=30)	
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
USE	434.98	94.56	381.77	106.12	401.73	92.43
PRICE	15.04	6.08	19.75	8.51	27.48	18.06
SEWAGE	17.08	21.06	25.74	23.47	34.45	28.14
INCOME	48,863.33	8,962.47	48,703.64	9,537.75	60,061.76	10,815.35
SIZE	2.67	0.27	2.61	0.28	2.63	0.31
GARDEN	70.99	14.04	69.80	16.03	75.40	14.19
PRECIP	1,181.23	447.55	1519.85	850.56	1,084.78	456.88

Table-C4: Time Series Variable Statistics Under Volumetric Pricing						
	1991 (N=65)		1996 (N=61)		2001 (N=34)	
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
USE	281.64	87.85	273.04	76.89	279.52	48.32
PRICE	25.21	9.07	30.81	10.05	40.45	15.61
SEWAGE	34.10	26.59	42.76	24.94	43.95	15.99
INCOME	56,086.01	12,139.29	55,367.56	11,043.91	71,338.42	15,978.61
SIZE	2.73	0.33	2.72	0.36	2.73	0.28
GARDEN	73.01	13.17	74.45	14.56	80.18	9.14
PRECIP	911.09	254.36	1129.38	265.79	910.57	439.54

[48] The data used in demand estimation was treated separately for each individual sample year. Creation of panel data and analysis was considered early in the research but was ultimately refrained from. The reasons for this are:

- Creation of a panel implies establishment of a link between annual municipal observations which is not trivial given an increase in the number of municipal amalgamations in the later sample years. Therefore, as the use of geographical coordinates is required (to join data represented by segregated municipalities), municipal differentiation in consumption, pricing and sewage cost shares would be decreased as well as the number of annual observations in earlier sample years. Hence the advantage of having a greater number of municipalities in earlier sample years, and consequent differentiation in use and pricing trends due to municipal restructuring, would be erased.
- Municipal specific time dependant effects attributed to non-constancy in commitments to varying pricing methods (observed in relationships between use, pricing and other regressors) would also be diminished as municipalities, in early sample years would be joined.

Table-C5: Non-Volumetric Pricing Robust OLS Estimation Results[49]									
	1991			1996			2001		
Variable	Coeff.	Std. Err.	Prob.	Coeff.	Std. Err.	Prob.	Coeff.	Std. Err.	Prob.
PRICE	-0.20	0.07	0.01	0.05	0.15	0.76	-0.31	0.07	0.00
SEWAGE	0.01	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.31
INCOME	27.38	12.50	0.04	-12.46	7.32	0.10	47.71	20.08	0.03
INCOME_2	-1.31	0.58	0.04	0.57	0.34	0.10	-2.17	0.91	0.03
SIZE	3.32	0.90	0.00	-0.08	0.50	0.88	-2.19	1.05	0.05
GARDEN	-1.16	0.27	0.00	0.02	0.20	0.91	0.57	0.34	0.12
PRECIP	-0.30	0.12	0.02	-0.21	0.12	0.09	0.00	0.08	0.99
REGION	-0.09	0.09	0.33	-0.33	0.12	0.01	-0.13	0.06	0.05
INTERCEPT	-132.89	68.16	0.07	75.40	39.99	0.07	-255.74	110.14	0.03

Table-C6: Non-Volumetric Pricing Model Statistics			
Statistics/Sample Years	1991	1996	2001
Observations	40	58	30
PRECIP clusters	20	28	19
R-Squared	0.61	.23	0.71
Model Significance (Prob > F)	0	.14	0
Normality of Dep. Var. (sktest)	0.37	0.09	0.45
Normality of Errors (sktest)	0.15	0.28	0.58
Specification (ovtest)	0.22	0.17	0.09
Multicollinearity (Greatest vif value)	8.56	6.65	12.63

Table-C7:Volumetric Pricing Robust OLS Estimation Results[50]									
	1991			1996			2001		
Variable	Coeff.	Std. Err.	Prob.	Coeff.	Std. Err.	Prob.	Coeff.	Std. Err.	Prob.
PRICE	-0.36	0.08	0.00	-0.19	0.09	0.05	-0.17	0.07	0.02
SEWAGE	0.00	0.00	0.67	0.00	0.00	0.23	0.00	0.00	0.02
INCOME	-37.11	15.31	0.02	-52.08	20.18	0.02	-24.99	9.00	0.01
INCOME_2	1.72	0.69	0.02	2.37	0.93	0.02	1.10	0.40	0.02
SIZE	-1.43	0.42	0.00	0.37	0.41	0.38	0.07	0.31	0.83
GARDEN	0.55	0.20	0.01	-0.26	0.17	0.14	0.90	0.24	0.00
PRECIP	0.10	0.07	0.20	-0.18	0.09	0.07	0.02	0.03	0.66
REGION	-0.18	0.06	0.01	-0.27	0.08	0.00	-0.25	0.04	0.00
INTERCEPT	205.30	84.43	0.02	294.80	110.00	0.01	144.31	50.77	0.01

Table-C8: Volumetric Pricing OLS Model Statistics			
Statistics/Sample Years	1991	1996	2001
Observations	65	61	34
PRECIP Clusters	30	31	16
R-Sqr.	0.48	0.44	0.72
Model's Significance (Prob > F)	0	0	0
Normality of Dep. Var. (sktest)	0.93	0.02	0.03
Normality of Errors (sktest)	0.12	0.36	0.54
Specification (ovtest)	0.93	0.53	0.28
Multicollinearity (Greatest vif value)	4.52	5.42	4.31

[49] Demand estimation using the 1996 sample year was omitted from analysis due to poor model and individual estimates' significance, especially in the case of non-volumetric data. In addition, exclusion of this sample year's results are due to their low comparability to estimates derived from other sample years in this dataset, and relevant surveyed research results obtained using highly similar model setups and datasets.

[50] Ibid

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