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Full Length Research Paper

Towards equity in water pricing in small water systems: An Alberta case study

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Small water systems have water technology that has a higher cost structure than those of large cities. Consequently they cannot enjoy "comparable" consumption patterns. It is shown that full cost pricing is not compatible with achieving equity for small system residents and marginal cost pricing would not cover the capital costs. Therefore, provinces could seek legal recourse for higher federal transfers, based on section 36(2) of the Canadian Constitution Act, which mandates "comparable" public services irrespective of residence. It is argued that such a case is justiciable. This legal remedy would interest the global water policy community.

Key words: Alberta, water pricing, small water systems, affordability, income.

INTRODUCTION

Canadian small water communities face a number of disadvantages, such as higher units costs of water production based on older conventional treatment technologies, potentially contaminated rural source waters, a lower income population and a single source of local government income, namely, property taxes. In addition, small water communities continue to face the possibilities of waterborne disease outbreaks. Dore (2015a) shows that the majority of recent waterborne disease outbreaks occur in small water systems, which are of course in rural areas. The reasons for these outbreaks are varied: they range from source of water contamination due to animal fecal material to equipment failures due to old treatment trains and inadequate maintenance. The constraints to the delivery of clean water in small systems have been adequately reviewed in the Montana Colloquium (Ford et al., 2005) on small water systems. Many of these failures could be prevented if there was adequate funding, either through funds raised from water consumers or by appropriate funding from higher jurisdictions.

Following changes in government policies in Canada in the 1990s, it has become accepted that small communities themselves should be responsible for all costs associated with the provision of drinking water, although the drinking water is almost always provided by a public agency as *a* public service. Other public services, such as health and education, in Canada are

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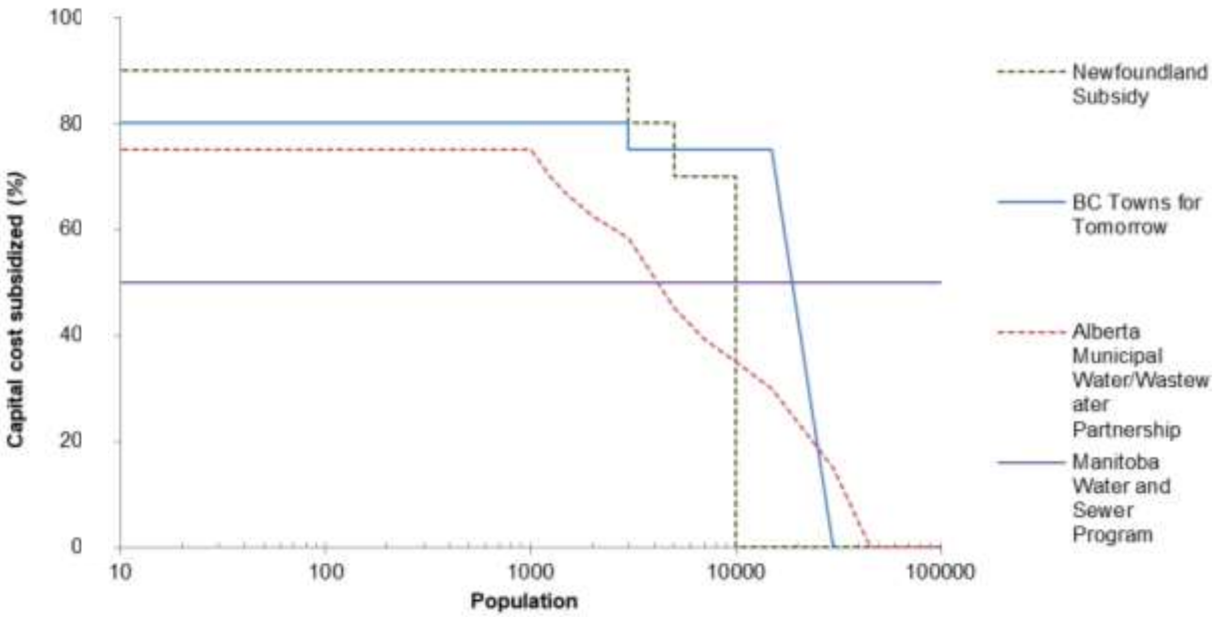

Figure 1. Capital grants for water treatment plants in Alberta, British Columbia, Manitoba and Newfoundland.

funded nationally or provided at the provincial level through appropriate level of federal transfers. But as the provision of water is a public service, it is suggested that there might be a better way of organizing the funding and supporting the supply of drinking water, especially for smaller communities. For such alternative, one may consult the Canadian Constitution for some support. A key objective of Canadian Constitution states:

Parliament and the government of Canada are committed to the principle of making equalization payments to ensure that provincial governments have sufficient revenues to provide reasonably comparable levels of public services at reasonably comparable levels of taxation" (Subsection 36(2) of the Constitution Act, 1982).

The key statement is the provision of public services at “comparable levels” of quality and cost regardless of where the citizen lives within Canada. For this reason, the federal government provides “equalization payments” to the provinces, based on well-established criteria. In turn, the provinces provide funding to municipalities and other lower level jurisdictions (“regional municipalities”, townships, hamlets, etc.); for example, the province of Ontario makes “equalization payments” to its lower level jurisdictions, although by law, Ontario requires that water utilities in Ontario must charge “full cost pricing”, as the limited funding for water utilities it provides would not cover all the costs of water infrastructure.

All provinces recognize the “diminished capacity” of small communities to cover the full capital costs for water infrastructure and so offer varying levels of funding for capital costs as shown in the Figure 1.

The fact that all Canadian provinces offer some help with the capital costs indicates an underlying concern for some measure of equity for smaller communities, a recognition that some effort must be made for comparable levels of service in the case of clean and potable water. The objective of this paper is to examine the implications of taking equity into account by assessing measures of ability to pay for drinking water in relation to the capital and operating costs of providing drinking water in small communities. We can assume that water utilities cannot provide free water and are constrained to charge for water in the range of either full cost pricing (that is, cover all costs including a charge for the cost of capital), breakeven pricing (price where total revenue just equals total costs), or at the very least marginal cost pricing, that is, cover the variable costs of labor, materials and energy only. Indeed, there is another variant of marginal cost pricing, called “cash needs pricing,” in which communities charge prices that cover debt servicing cost as well as the operating and maintenance costs, but do not include debt repayment costs.

It should be noted that neoclassical general equilibrium theory is entirely linear and that its results depend on two required assumptions (a) no economies of scale and (b) no public goods. But economies of scale are a nonlinear phenomenon, which cannot be incorporated into neoclassical economics. This leads to serious difficulty in the received theory, because economies of scale lead to the emergence of monopoly. Economics rationalize this factor by calling it a “natural monopoly” in public utilities, which then require regulation, outside the realm of market operation. Second, water is a partly a public good and partly a private good. Both aspects lead to a public policy quandary: how to price water for the public? This paper introduces "equity and fairness" in the pricing of water, especially for people with low incomes.

Characteristics of small water systems

This aspect is based on findings on the characteristics of small water systems reported in Dore (2015b). These findings are based on a panel data analysis of a database provided by Environment Canada (2011), called "Municipal Water Pricing data and Municipal Water Use Data, 2001-2006." A brief summary of those characteristics is presented below.

First, for small systems as a whole, demand was price inelastic, confirming that water is a necessity and not a normal or "luxury" good. The statistical models showed that while price and metering are both statistically significant in affecting water consumption, the elasticities were very small.

Second, small systems appear to be different from large systems because neither pricing nor metering affects water consumption very much. For some very small communities, it would undoubtedly be the case that the additional costs of metering and administration would be higher than the cost savings due to reduced consumption. It should also be noted that in very small communities, the "utility" (usually one person) does more than just treat and supply water; the public servant of the "utility" might also mend road potholes, take care of street lighting, and collect household waste. In such circumstances, it does not make sense to view treated water as a separable public service. A fixed charge for water and a charge for other services could be included in the property tax. That would be an equitable approach, as the water cost would be borne mainly by the larger property owners.

Third, Dore (2015a) disaggregates the impacts of economies of scale into 5 population sizes: (a) 0 -1,999; (b) 2,000 - 5,999; (c) 6,000 - 15,999; (d) 16,000 - 49,999; (e) more than 50,000. Using cluster analysis, Dore (2015b) was able to demonstrate the presence of economies of scale even at the level of treatment components in small water plants. The greatest marginal decreases in costs due to economies of scale which occur in the population range of 2,000 to 5,999. For populations less than 2,000, average unit costs of production tend to be high when using conventional water treatment trains.

Fourth, Canadian water consumption is high by international standards and there is a case for introducing a strategy of water conservation. Pricing of water and metering are important components of such a strategy, but by themselves they are not enough. What is needed is a large community outreach program to educate households on the need to conserve water; the Regional Municipality of Victoria does that and has managed to reduce per capita water consumption to 300 L per person per day (Capital Region District BC, 2013). Other methods include the free distribution of low-flow shower heads, low-flow toilets, and rainwater harvesting in rain barrels for outdoor use in the summer. A seasonal rationing program of the sort introduced by the Regional Municipality of Victoria might also be worth considering, although it is likely to be unpopular at first. This form of limited rationing has an educational and informational content that is not conveyed by pricing alone.

Fifth, in Bowen Island in British Columbia, the utility operates with a two-part water tariff: a low water price in the winter months and much higher price in the summer, as the summer leads to a large increase in the island population due to owners of summer cottages.

Dore (2015a, b) contains an extensive literature review that shows that small water systems (as well as large systems) show strong evidence of economies of scale. Finally, the most heavily used water treatment technologies are reviewed in Dore (2015a); these technologies are chlorination, high rate clarification and filtration, ultra violet treatment, micro filtration-ultra filtration, ozonation, activated carbon treatment, reverse osmosis treatment, nanofiltration, and distillation. The empirical evidence shows that all of these treatment technologies show significant economies of scale; for further literature review and additional references see Dore (2015a).

However, it is obvious that when the production scale is small, the unit costs are higher and that is a problem faced by all small systems, no matter which water treatment technology they use. The strong economies of scale mean that, based on estimates given in Dore (2015b), populations under 6,000 are likely to be at a disadvantage and so are candidates for equity considerations in meeting the costs of drinking water. It is shown that for population sizes of less than 10,000 there is a case for greater financial assistance, if the constitutional provision of reasonably comparable services is taken seriously.

METHODOLOGY

Using a log-log regression model, the capital and operating costs of a sample of Alberta communities are estimated. The data on capital and operating costs were collected by Janzen (2017) using survey techniques; the costs are in constant 2015 Canadian dollars. The survey yielded usable capital and operating costs from 25 small systems in which 11 used surface water and 14 used groundwater. Two separate models are estimated statistically: one for capital costs and one for operating costs, with surface water and groundwater distinguished by a dummy variable for surface water.

The cost coefficients were also estimated using the (nonlinear) Maximum Likelihood Estimation (MLE) technique; the results were exactly the same as the log-log regression model; this is of course not surprising, as it is known that MLE results converge to Ordinary Least Squares estimates, as the sample size increases. The log-log model generates better statistical diagnostics and so it is the results of the log-log model that are reported here.

Table 1. Estimated regression equations.

Dependent variable	Constant	Dummy variable (surface water=1)	Independent variable (Log of volume in m^3)	R^2
			Capital costs equation	
Capital cost/m^3	27.5	2.49	-2.38	
t-Statistic	(8.86)	(3.53)	(-8.28)	0.80
p-Value	0.0000	0.0018	0.0000	
			Operation and maintenance costs equation	
Operations and maintenance cost/m^3	7.54	0.81	-0.64	
t-Statistic	(8.75)	(4.09)	(-7.92)	0.80
p-Value	0.0000	0.0005	0.0000	

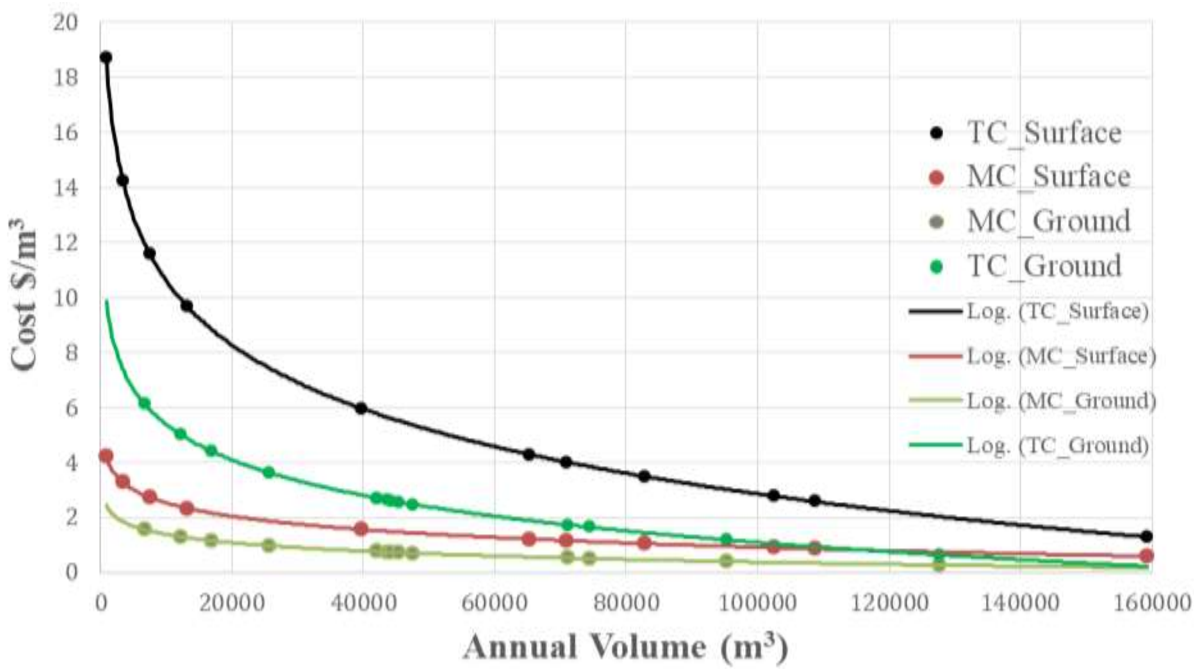

Figure 2. Total and marginal costs for surface and ground water. TC: Total cost; MC: marginal cost.

RESULTS AND DISCUSSION

The estimated log-log regression results are summaraized in Table 1. The normality of residuals is confirmed both for capital costs and for operating costs. In addition, it was found that there is no heteroscedasticity. The very low p-values of the estimated coefficients (reproduced in Table 1) demonstrate the reliability of this regression model (Statistical Appendix with full diagnostics for details). Figure 2 shows strong economies of scale in this sample up to about 80,000 m^3 for surface water treatment plants, mainly in the capital costs component.

Assume daily consumption of 32 m^3 per person and 2.5 persons in a household. This amounts to a monthly household consumption of 24.3 m^3. The quantity of 80,000 m^3/per year corresponds to a population of about 700 people or 275 households at a breakeven price of $4.00 per cubic meter, where a breakeven price means total revenue equals total costs (Before proceeding, recall the definition of marginal costs: these are the additional variable costs of labor, materials and energy costs for producing one more cubic meter of water). It is clear that if the average utility charged just for marginal costs, then a price of $2.00 per cubic meters would be affordable for communities with a population of up to about 1,030. Both of these quantities turn out to be interesting from an equity perspective as shown later in this paper.

First note that the unified regression, with a dummy variable for surface water, provides a very good fit. The

Table 2. Water expenditures by income groups in Canada.

Water and sewerage spending as % of total household income	Total household income range
4.30	Under $20,000
1.40	$20,000-40,000
0.90	$40,000-60,000
0.70	$60,000-80,000
0.60	$80,000-100,000
0.40	Over $100,000

Source: Statistics Canada (2011).

empirical estimates show that the capital costs for communities with surface water are $2.50 per cubic meter higher than those for groundwater communities, and that the operating and maintenance (or variable) costs are higher by 81cents per cubic meter for surface water communities. Second, a 1% increase in the volume of treated water will decrease the capital costs by $0.0238. Third, a 1% increase in the volume of water decreases operating and maintenance costs by $0.006. Thus, the main economies of scale are in capital costs, which are shown in Figure 2. The total costs (that is, capital plus operating costs) for surface water are on average $3.31 per cubic meter higher than groundwater.

Equity and affordability in water pricing

Rodriguez (2004) has eloquently raised the issue of equity and “access for poor, peri-urban populations.” Equity and affordability can be approached in two ways: a fiscal approach and a water tariff approach. Some researchers in Canada, considered equity in a water pricing to be not a major issue as access to water for lower incomes can be accommodated through fiscal and other measures (Renzetti, 2005, 2007, 2009). This is standard neoclassical approach which regards “equity” and “efficiency” to be separable and that once “efficiency” is guaranteed, any equitable redistribution can be carried out, as indicated by the so-called “Second Theorem of Welfare Economics,” the backbone of neoclassical economic policy. However, this “theorem” is now viewed as vacuous as it is incentive incompatible and most desirable allocations are not feasible.

Renzetti (2007) and others (Water Expert Panel, 2005; Renzetti and Kushner, 2004) are also strong advocates of “full cost pricing of water,” which is what accountants recommend (Recall: full cost in the accounting sense covers the cost of capital depreciation, interest costs and all other costs that a firm would normally incur, without any subsidy from any other source). As argued in Dore (2015a), full cost accounting has no theoretical justification in economics, as water is produced by a natural monopoly, which is almost always publicly owned. When privately owned, the natural monopoly must be subject to regulation, so that it is forced to adopt a marginal cost-pricing rule; this is a standard principle of public economics.

The fiscal approach is outside the scope of this paper, as it requires taxes and/or transfers directly to qualifying individuals. The water tariff approach is followed by a number of US bodies and jurisdictions. The water tariff is considered in relation to the Median Household Income (MHI) as an affordability criterion and an equity threshold. For example, in California, access to water is taken to be a human right and bylaws mandate that the water tariff should not exceed 1.5% of MHI. The US Environmental Protection Agency (2012) recommends that the threshold be 2 to 2.5% of MHI, but this includes a charge for both water and wastewater combined. The United Nations Development Program (UNDP) recommends this threshold to be 3% (Donelly and Christian-Smith, 2013).

According to Statistics Canada, people in lower income brackets spend a larger portion of their income on water and sewer services as shown in Table 2.

Of course there is no universally agreed upon measure for a threshold of affordability, just as there are no “objectively” determined income tax brackets. However, the MHI is an acceptable benchmark, as it is being used in some jurisdictions. In the present case study, both 1 and 2% of MHI were used as an equity threshold for southern Alberta communities. Consequently, Figure 3 is just Figure 2 with the two equity thresholds added.

The two equity thresholds are based on the following calculation. While the MHI for Alberta as a whole is $85,449 (in 2015 Canadian dollars), the lowest MHI for the communities in southern Alberta was found to be $60,000. The average household in the city of Calgary uses 24.3 m^3/month. Then 1% of MHI per cubic meter is: ($60 000 per year × 0.01) / (24.3 m^3/month × 12 months) = $2.06 per cubic meter. It follows that 2% of MHI will be twice that amount; that is, it will be $4.12 per cubic meter. In Figure 3, the two equity thresholds are introduced to the estimated regression model (From Figure 2, it is clear that equity is not an issue for groundwater systems, as the unit costs are lower).

Next, we proceed to assess how many people, with low income close to our chosen thresholds, could afford to achieve water consumption standard that is roughly

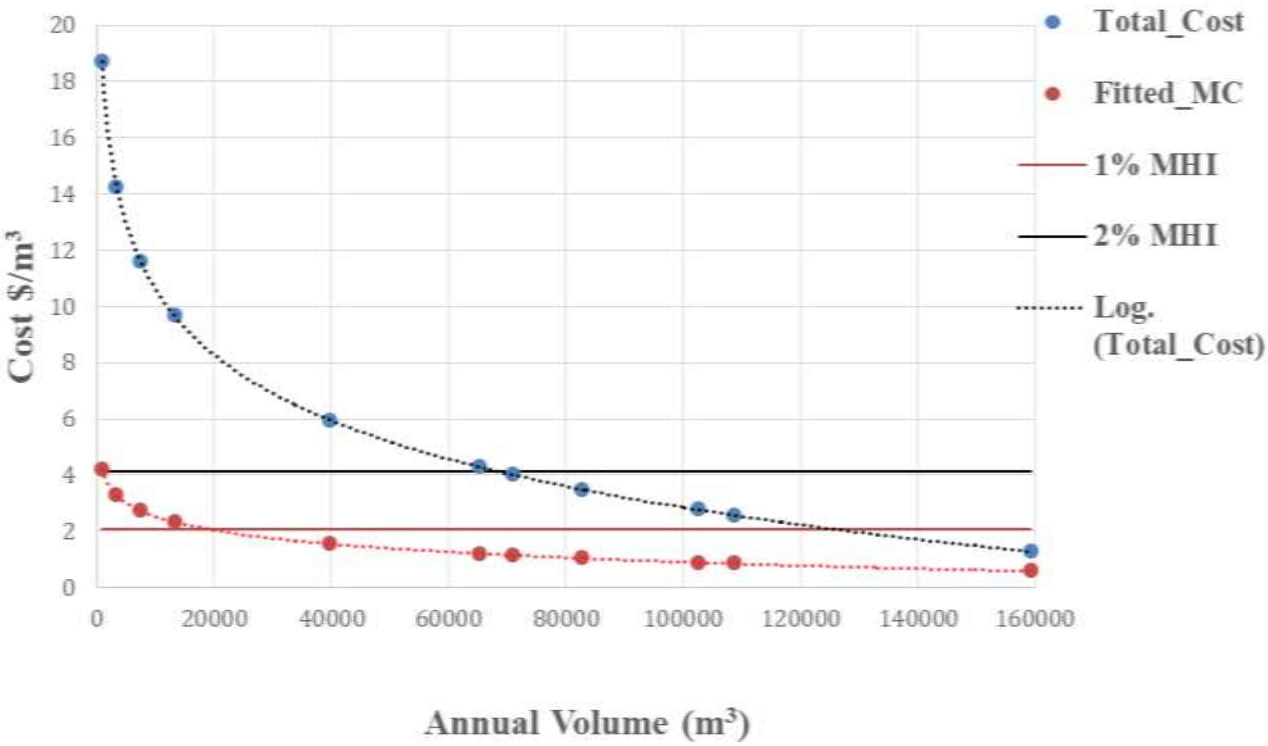

Figure 3. Surface water: Total costs and marginal costs. TC: Total cost; MC: marginal cost.

"comparable" to those of bigger cities like Calgary. Figure 3 shows that if the "average water utility" adopted marginal costs pricing, the people whose income is around the threshold of 1% MHI, the number of people who would be below the "affordable" threshold would be about 1030 or 412 households. However, if the utility adopted a price based on breakeven costs, then those with income of 1% of MHI would encounter hardships and be unable to meet their water bills. But people whose income was higher, and say their income was close to 2% of MHI, about 600 people (240 households) would fall below the affordability threshold.

By examining Figure 3, two obvious conclusions were drawn. In public economics, marginal cost pricing has a solid theoretical basis (Dore, 2015a). Thus, if marginal cost pricing were adopted as the pricing policy, then small communities of about 1028 people would find the policy unaffordable, based on the 1% of MHI as the threshold. If however, the average utility were committed to a breakeven price (that is, at price where total revenue equals total cost), then based on the 2% of MHI, a population of about 700 would find the price unaffordable. If the present study's target population were small communities of one thousand or less, then marginal cost pricing would enhance equity and give such small communities access and meet an equity goal.

Could small communities achieve their equity goals for water through recourse to the law in Canada? In other words, could they rely on the Canadian Constitution to achieve greater equity for small communities? That possibility is examined next.

Striving for equity: Towards a constitutional remedy

It has been argued that there is a constitutional provision whereby residents of high-cost small water systems should in principle be able to enjoy comparable water quality and quantity, based on Subsection 36(2) of the Constitution Act, 1982. However, as far as we are aware, this section has never been tested in the courts. In the past, the provinces have objected to federal intrusion in provincial jurisdictions. There have been at least two important test cases. In BC vs. Canada (1991) referenced as Canada Assistance Plan, the federal government, which was trying to reduce the federal budget deficit, decided to cut expenditures and limit the growth of payments made to financially stronger provinces under the Canada Assistance Plan. The BC government, with many other provinces as interveners, challenged the federal actions and sought to limit federal powers. The Appeal Court of BC ruled in favor of BC and the provinces that were interveners. But later, the Supreme Court agreed with the Appeal Court of BC that the case was justiciable; nevertheless it ruled in favor of the federal government and the provinces lost the case.

In the second case, called Quebec vs. Canada (2005), referenced as Employment Insurance Act, the provinces maintained that the provisions of the Federal Employment Insurance Act were unconstitutional, as the federal government had intruded into provincial jurisdiction. The provinces won at the Quebec Court of Appeal, but lost at the Supreme Court, which ruled that the Employment Insurance Act was legal. Thus, only the federal spending power has been challenged; the adequacy of meeting “comparable” standards for public services like water has not been challenged; we would suggest that such a claim would be judiciable: the provinces could claim that from 1995 onwards, when the federal government started to reduce its deficits by cutting transfers to the provinces; the latter did not have adequate revenues to provide support to water utilities to maintain and improve water infrastructure. Beginning in 2008, the Federal Gas Tax Fund, provides funding directly to municipalities to support improvements to local infrastructure. In its 2008 budget, the federal government announced that this fund would become permanent beyond 2014, contributing $2 billion annually. However, there is still a large gap and a long way to go in re-building water infrastructure. For many years after 1995 municipalities had to live with deferred maintenance and deteriorating water infrastructure. Due to lack of funding, the water treatment facilities were never modernized; they remained stuck with old, high-cost obsolete treatment technology.

Of course, all ongoing federations face stresses and strains, mainly on the division of federally collected tax revenues. The Canadian federation is no exception; researchers (Boadway and Watts, 2004) have identified and analyzed these strains as ‘vertical’ and ‘horizontal’ imbalances in fiscal federalism. The vertical imbalance refers to unequal command over resources such as taxing powers between the federal and provincial/territorial levels. The horizontal imbalances refer to the unequal fiscal capacities between the provinces and varying level of control to determine and implement provincial social policy. But at least in health and education there is a nation-wide attempt to provide roughly equal quality and standard of public services. Expanding it to include drinking water as a national public service that must also be of roughly equal quality right across the nation would help reduce one source of horizontal imbalance in the Canadian federation. The horizontal imbalances are further increased when some provinces, such as Newfoundland and Labrador, do more for small water communities than other provinces.

Conclusions

This paper is an exploration of what might be considered an “equitable” price for water for small communities. It has been argued that if water is a public service, then in accordance with the Canadian Constitution, smaller communities that face a higher cost of production as compared to residents of larger cities that typically enjoy economies of scale in the total cost of production per cubic meter should be offered some offsetting or compensating benefit (in the form much higher capital cost subsidy), so that they too can enjoy water at roughly comparable cost and quality.

Using an econometric model, based on existing technology, the total costs of production of a sample of 25 communities in southern Alberta were rigorously estimated. Then two thresholds of affordability were introduced: 1 and 2% of median household income. It was found that if the threshold of 1% of median household income is used, then a population of just under a thousand in small communities would encounter difficulties in being able to have access to water at an affordable price based on marginal cost. On the other hand, if there were a commitment that the public authority must breakeven, then the 2% of median household income would make water unaffordable to communities of populations less than 700, based on average water consumption rates. Naturally, the actual numbers generated (that is, populations of 1000 and 700) depend on the costs and income measures used.

Finally, it was argued that perhaps the federal government is not living up to the demands of the Canadian Constitution in providing adequate levels of transfers to the provinces especially after 1995, when the federal government brought down its deficits by downloading the problem to the provinces, who in turn downloaded the problem to the municipalities. A constitutional remedy is proposed. Such a remedy would be of interest to the global water policy community.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests

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This research was financed by research grants held by Professor Achari at the University of Calgary. This paper is dedicated to the memory of Professor Cooper Langford (1934-2018), who was originally one of the co-authors; unfortunately he did not see the final version of this paper.

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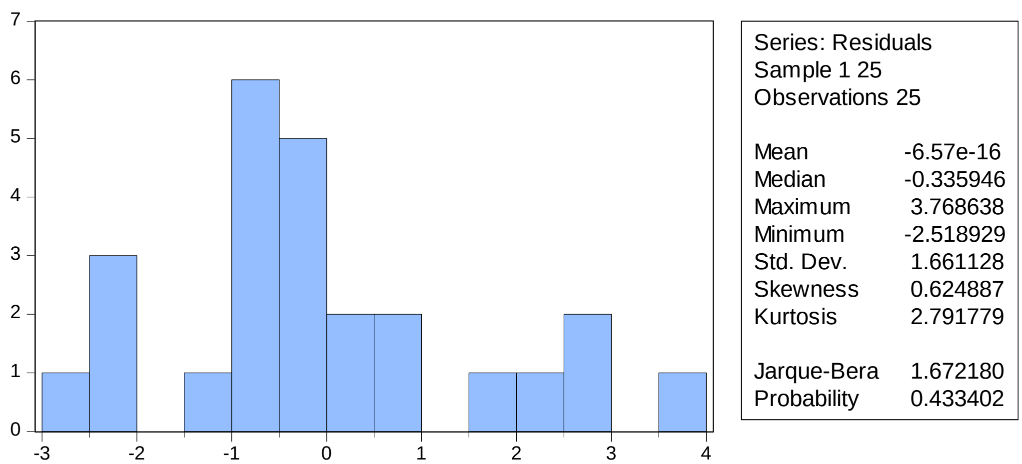
STATISTICAL APPENDIX

Details of the estimated regression model are provided in this appendix. We also carried out Maximum Likelihood Estimates (MLE); but these results were identical with the robust linear regression model with a dummy variable to distinguish systems with surface water as the source from groundwater.

OLS capital cost equation with dummy (=1 for surface water)

Dependent Variable: TOTAL_CAPITAL_UNIT_COST_				
Method: Least Squares				
Date: 05/23/17; Time: 17:18				
Sample: 1 25				
Included observations: 25				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	27.25292	3.075641	8.860894	0.0000
LOG(ANNUAL_VOLUME)	-2.383479	0.287799	-8.281753	0.0000
SURFACE	2.495530	0.705259	3.538457	0.0018
R-squared	0.804368	Mean dependent var		3.510737
Adjusted R-squared	0.786583	S.D. dependent var		3.755628
S.E. of regression	1.734991	Akaike info criterion		4.052049
Sum squared resid	66.22429	Schwarz criterion		4.198314
Log likelihood	-47.65061	Hannan-Quinn criter.		4.092616
F-statistic	45.22789	Durbin-Watson stat		2.447686
Prob(F-statistic)	0.000000			-



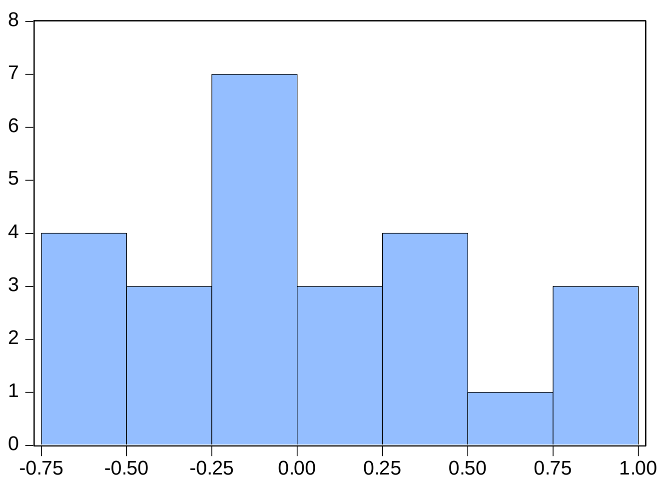
Normality test of residuals: Normality confirmed.

Test for Heteroscedasticity. No heteroscedasticity

Test	Heteroscedasticity Test: Breusch-Pagan-Godfrey		
F-statistic	2.885915	Prob. F(2,22)	0.0771
Obs*R-squared	5.195760	Prob. Chi-Square(2)	0.0744
Scaled explained SS	3.604698	Prob. Chi-Square(2)	0.1649

OLS Operations and Maintenance Costs Equation with Dummy (=1 for surface water)

Dependent Variable: LOG(O_M_UNIT_COST_IN_2013_DOLLARS)				
Method: Least Squares				
Date: 05/23/17 Time: 19:01				
Sample: 1 25				
Included observations: 25				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	7.543157	0.861722	8.753587	0.0000
LOG(ANNUAL_VOLUME)	-0.639385	0.080634	-7.929423	0.0000
SURFACE	0.809161	0.197597	4.095008	0.0005
R-squared	0.803255	Mean dependent var		1.235629
Adjusted R-squared	0.785369	S.D. dependent var		1.049260
S.E. of regression	0.486104	Akaike info criterion		1.507377
Sum squared resid	5.198528	Schwarz criterion		1.653642
Log likelihood	-15.84221	Hannan-Quinn criter.		1.547944
F-statistic	44.91000	Durbin-Watson stat		1.388696
Prob(F-statistic)	0.000000			-



Series: Residuals	
Sample 1 25	
Observations 25	
Mean	-4.62e-16
Median	-0.150293
Maximum	0.917384
Minimum	-0.701932
Std. Dev.	0.465409
Skewness	0.578010
Kurtosis	2.404698
Jarque-Bera	1.761214
Probability	0.414531

Normality test of residuals: Normality confirmed.

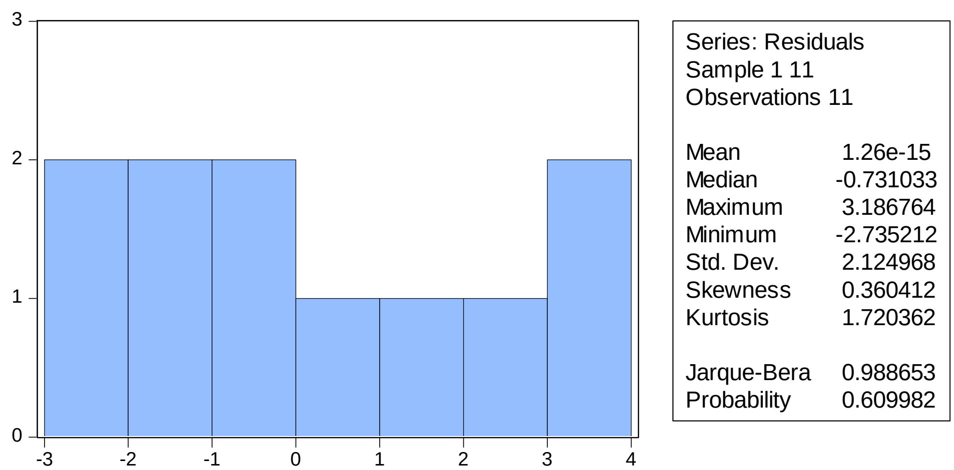
Test for heteroscedasticity: No heteroscedasticity.

Heteroscedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	0.536503	Prob. F(2,22)	0.5922
Obs*R-squared	1.162621	Prob. Chi-Square(2)	0.5592
Scaled explained SS	0.632348	Prob. Chi-Square(2)	0.7289

OLS Output for surface water capital cost equation.

Dependent Variable: TOTAL_CAPITAL_UNIT_COST				
Method: Least Squares				
Date: 05/21/17 Time: 14:19				
Sample: 1 11				
Included observations: 11				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	32.69337	4.391689	7.444371	0.0000
LOG(ANNUAL_VOLUME)	-2.671111	0.423770	-6.303209	0.0001
R-squared	0.815311	Mean dependent var		5.340909
Adjusted R-squared	0.794789	S.D. dependent var		4.944602
S.E. of regression	2.239913	Akaike info criterion		4.613717
Sum squared resid	45.15490	Schwarz criterion		4.686062
Log likelihood	-23.37544	Hannan-Quinn criter.		4.568114
F-statistic	39.73044	Durbin-Watson stat		2.967435
Prob(F-statistic)	0.000140			-

Result: $y = -2.67\ln(x) + 32.69$



Normality Test: Normality confirmed.

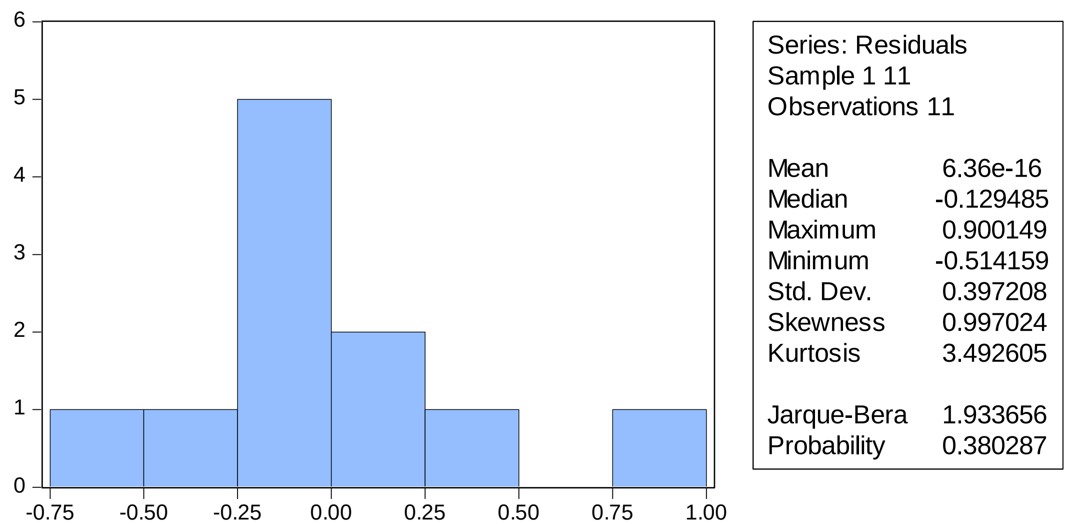
Test for Heteroscedasticity: No heteroscadasticity.

Heteroscedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	0.935047	Prob. F(1,9)	0.3588
Obs*R-squared	1.035277	Prob. Chi-Square(1)	0.3089
Scaled explained SS	0.249618	Prob. Chi-Square(1)	0.6173

OLS Output for surface water operations and maintence equation.

Dependent Variable: LOG(OM_UNIT_COST_IN2013_DO)				
Method: Least Squares				
Date: 05/21/17 Time: 14:31				
Sample: 1 11				
Included observations: 11				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.974753	0.820914	10.93264	0.0000
LOG(ANNUAL_VOLUME)	-0.700194	0.079213	-8.839389	0.0000
R-squared	0.896712	Mean dependent var		1.804690
Adjusted R-squared	0.885235	S.D. dependent var		1.235928
S.E. of regression	0.418694	Akaike info criterion		1.259615
Sum squared resid	1.577745	Schwarz criterion		1.331960
Log likelihood	-4.927883	Hannan-Quinn criter.		1.214012
F-statistic	78.13480	Durbin-Watson stat		3.138849
Prob(F-statistic)	0.000010			

Result: y = 7899.86x^ -0.7



Normality test: Normality comfirmed.

Test for Heteroscedasticity; No heteroscedasticity.

Heteroscedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	1.503726	Prob. F(1,9)	0.2512
Obs*R-squared	1.574773	Prob. Chi-Square(1)	0.2095
Scaled explained SS	1.313836	Prob. Chi-Square(1)	0.2517

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