
GLOBALIZATION AND WATER RESOURCES MANAGEMENT: THE CHANGING VALUE OF WATER

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ENVIRONMENTAL CONDITIONS AND THE COST OF WATER SUPPLY

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ABSTRACT: The purpose of this research is to develop an econometric model of water utility costs so that the effects of variations in the quantity and quality of raw water supplies may be examined. The state of the raw water input is represented by a sub-function in which the average water level, variability of water level and water quality are the characteristics. The estimation results provide several valuable insights. First, increases in raw water availability lead to cost decreases. Second, increases in variability of raw water availability lead to cost increases and have a relatively larger impact on costs than do changes in the mean level of raw water availability. Third, increases in the level of contaminants in raw water supplies lead to increases in the cost of treating and supplying a given quantity of output.

KEY TERMS: cost, water supply, water quality

INTRODUCTION

This paper investigates the factors that influence the cost of supplying water to municipal consumers. It specifies an empirical model of the technology of water supply and uses this model to investigate the significance of environmental factors for the cost of supplying potable water. In particular, the role of fluctuations in the quantity and quality of raw water supplies is examined. There are several reasons to be concerned about the relationship between the state of water supplies and the cost of providing potable water to firms and households. First, municipal water and sewage utilities face increasing stringent water quality guidelines and regulations in some provinces. Second, there is evidence that global climate change could have significant impacts on the state of raw water supplies in parts of Canada (Hofmann *et. al*, 1997). Third, these changes are occurring when many regional and local governments are facing growing fiscal restraints.

This paper addresses these issues by drawing together data sets on water utility operations and finances with records of fluctuations in the quantity and quality of the lakes and rivers supplying them. This effort yields a cross sectional data set of annual observations on municipal water utilities operating in Ontario, Canada during 1991. These data sets are then used to estimate a restricted water supply cost function in which characteristics of the raw water input act as arguments.

The estimation of water supply costs yields the following results. The water supply technology displays economies of scale. With respect to the role of the raw water input, decreases in the average availability of raw water supplies and increases in the variability of raw water supplies both increase the cost of supply (for a given level of output). In addition, increases in the level of contaminants in raw water supplies also lead to increases in the cost of supplying a given level of output. These results have not been recorded in the econometric literature to date.

These results suggest that recent efforts to improve water quality in the Great Lakes may have had beneficial effects on water supply costs. Unfortunately, if climate change implies reduced water availability and increased variance in raw water supplies then water utilities can expect to experience increased costs.

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INSTITUTIONAL FRAMEWORK

In Canada, each province is responsible for regulating the behaviour of municipal water utilities under its jurisdiction. To the limited extent that provincial governments have concerned themselves with municipal water utilities, their primary interests have been related to imposing constraints on utilities' debt loads or specifying minimum water quality and pressure requirements (Tate, 1991). In Canada, the norm is to be a department within a municipal or regional government (this is the case for all of the agencies in the sample used in this study).

There are a variety of factors that determine a water utility's cost of supply such as its output level, the utility's technology, government regulations and the prices of inputs. Further, the characteristics of the raw water input can be expected to influence the cost of supply. For a given quality level, for example, the less raw water that there is available, the more the utility must spend (in the form of greater capacity, more pumping and more labour hired) to supply a given amount of output. It can also be expected that the more variable is the supply of raw water (again, holding quality fixed), the greater will be costs. The reason is that an increase in the standard deviation of raw water availability, for example, would lead the utility to establish a greater collection and storage capacity in order to insure that it is able meet output goals in lower-than-average supply periods. Finally, it can be expected that, as the quality of raw water supply worsens (holding fixed its quantity), water utility costs will rise as greater screening, filtering and treating of the water is required.

It might be argued that these features of a utility's raw water supply and their influence on costs should already be captured by the price that the utility pays for its raw water supply. This would be the case if the market for raw water were truly competitive and suffered from no market failures. For example, the retail price of electricity to industrial customers often depends, in part, on the contracted level of reliability. Higher levels of reliability mean higher prices. There is no such mechanism in municipal water pricing in Canada, since the majority of municipal water utilities do not pay for their raw water supplies. While each province has provided itself with the necessary legislative authority (Renzetti and Dupont, 1999), only British Columbia, Saskatchewan and Nova Scotia have set out fee schedules for the licences needed for direct abstractions of surface water. In contrast, an Ontario water utility that is withdrawing water directly from an aquifer, river or lake need not pay for that water (beyond its own pumping and treatment costs). Thus, there is no market mechanism to ensure that water utilities or other users of water are confronted with changes in prices that signal changes in the availability or quality of water supplies.

PREVIOUS RESEARCH

Much of the econometric municipal water supply literature is directed at either obtaining econometric estimates of the degree of scale economies (Boisvert and Schmit, 1997) or is concerned with testing for differences in efficiency between publicly and privately owned firms (Feigenbaum and Teeple, 1983; Teeple and Glyer, 1987). There are few econometric studies that explicitly consider the role of fluctuations in raw water quantity or quality on the cost of water supply. Feigenbaum and Teeple (1983) estimate a cost function for water delivery systems in which output is represented by a bundle of attributes. One attribute is an index of water treatment and this is found to have a positive and significant impact on costs. Teeple and Glyer (1987) also examine water supply costs using a sample of Californian water utilities that use both self-supplied and purchased raw water. Self-supplied water and purchased water are found to be substitutes.

More recently, Dearth, McCarl and Tolman (1998) examine the impact of diminished water quality due to soil erosion on water treatment cost. The authors regress average chemical treatment cost against total quantity of water treated, a measure of turbidity (adjusted for pH levels), a dummy that indicates whether water quality guidelines were exceeded and a measure of rainfall. The estimated regression indicates that lowered water quality raises chemical treatment costs. In particular, the elasticities of chemical cost with respect to turbidity and rainfall are 0.27 and 1.74, respectively.

A separate line of research is directed at assessing the impact of climate change on Canada's water resources. Farid, Jackson and Clark (1997) provide a summary of many of the available studies on this topic and conclude that "Great Lakes' water levels will decrease due to increased evapotranspiration because of higher temperatures and decreased runoff. Runoff to the Great Lakes will decrease by 23 to 51 percent. Overall the Great Lakes will drop by a half metre to one metre." (p.74). Furthermore, a recent Environment Canada report concludes that, "the average level of the Great Lakes could decline to record lows by the latter part of the 21st century" (Environment Canada, 1997, p. 3). Hofmann *et. al.*, (1997) conduct a major review of the effects of climate change on Canada's water resources. They indicate that climate change may lead to significant impacts on Canadian municipal water utilities: "Under climate change scenarios, water consumption will likely increase while stream flows may be

reduced; there may be water demand-supply mismatches” (p.4). However, these impacts are poorly understood as “few studies have been completed concerning municipal water” (p. 7). Finally, the authors predict that municipal water utilities may have to expand their reservoirs, intake pipelines and other components of their infrastructure to cope with reduced water levels and increased variability of water supplies.

ESTIMATION MODEL

The estimation model is based on the assumption that municipal water utilities seek to minimize the cost of supplying a given quantity of output (Q). In their choices regarding inputs labour (L), energy (E) and capital (K) and raw water (W), utilities are constrained by prevailing input prices (p_L , p_E , p_K) and their technology as represented by the production function, $Q = f(L, E, K; W)$. The variable W represents the state of the raw water input as supplied by the environment and its construction is discussed below. Utilities are assumed to have no control over the value of W available to them and, as a result, W acts as a fixed input for the utility.

These assumptions imply that the utilities' technology may be represented by a restricted cost function:

$$C = C(p_L, p_E, p_K, Q, W(W_{MN}, W_{SD}, W_{QL}))$$

Cost is measured as each utility's annual expenditures on labour, energy and capital. Output (Q) is measured by the sum of annual recorded deliveries to residential, industrial, commercial and institutional customers. The price of labour (p_L) is represented by the average weekly wage of utility employees; the price of energy (p_E) is represented by the price of electricity; the price of capital (p_K) is represented by the average interest rate on debentures issued by the utility during 1991.

It is assumed that the state of the raw water, W, is a function of three distinct characteristics: mean water availability (W_{MN}), the variability of water availability (W_{SD}) and the level of contaminants present in the raw water (W_{QL}). Thus, we substitute these three variables in place of W in the cost function. The water utilities in the data set draw their raw water from either a lake or river. The W_{MN} variable is represented by the annual average of daily lake level or river flow rate observations, depending on whether the utility draws its raw water supply from a lake or river. The W_{SD} variable is measured by the standard deviation of daily lake level or river flow observations over the year 1991. The W_{QL} variable is an index composed of observations on six environmental contaminants: faecal coliform, lead, aluminium, benzene, PCB and trichlorobenzene. The details regarding the construction of the regression variables are available from the author.

There are 40 observations in the data set. Twenty-three of the utilities draw their raw water from a lake while seventeen draw their raw water from a river. None of the utilities use groundwater as a significant source of supply and all are self-supplied. That is, they do not purchase water from a regional wholesaler and, as a result, do not face an external price for raw water supplies. The restricted cost function is estimated using a translog functional form. A dummy variable is included to differentiate between water utilities using a lake ($D=1$) or river ($D=0$) for its raw water supply. The cost function and the labour and capital share equations are estimated jointly using an iterative Zellner SUR procedure with linear homogeneity and symmetry imposed.

Based on the preceding discussion, predictions regarding the signs of the cost elasticities with respect to the level of output and the characteristics of raw water supply can be set out. The expected signs are the following: (the availability of raw water supplies) $e_{MN} < 0$; (the standard deviation of raw water supplies) $e_{SD} > 0$; and (quality of raw water supplies) $e_{QL} > 0$. The reason for the last prediction stems from the way in which the water quality variable is constructed. It is an index of the level of contaminants in the raw water supply and, as such, an increase in its value indicates worsening water quality. Hence, there is predicted to be a positive relationship between W_{QL} and the cost of supply (for a given level of output).

RESULTS

The cost function's estimated coefficients are used to calculate the cost elasticities for this set of water utilities. The elasticities are the log derivative of cost with respect to each variable. These calculations are reported (at the mean of the data set) in Table 1. All of the elasticities related to the quantity and quality of raw water supply display the predicted signs and are statistically significant. (the symbol (*) indicates that the estimated elasticity is statistically significant at the 10% level and the symbol (**) indicates significance at the 5% level) The estimated

elasticity of cost with respect to the availability of raw water supplies (e_{MN}) indicates that decreases in the average availability of raw water raises costs by a relatively small margin (a 1% increase in average water availability leads to only a 0.07% decrease in costs). This may be because water utilities have already installed collection systems (such as deep intake pipes) that allow them to operate independently of lake and river depths. It is likely that this elasticity would have been larger if utilities that rely on groundwater sources had been included in the sample.

Table 1: Estimated Cost Elasticities

<u>ELASTICITY</u>	<u>ESTIMATE</u>	<u>STANDARD ERROR</u>
e_{MN}	-0.075*	0.042
e_{SD}	0.903**	0.263
e_{QL}	0.799**	0.215

In contrast, increases in the variability of raw water supplies raise costs and have a larger proportional impact than do changes in the average water availability. The estimated elasticity with respect to the variability of raw water supply (e_{SD}) indicates that a 1% change in the standard deviation of water supplies leads to almost a 1% increase in cost. The difference between the estimated values of e_{MN} and e_{SD} may be because increases in the variability in raw water supplies have more significant impacts on system design. For example, these may necessitate expanding the scale of a number of the components of the utility supply network such as reservoirs, pumps, storage tanks and treatment facilities. Finally, the cost elasticity of raw water quality (e_{QL}) is positive. This estimate indicates that increases in the level of contaminants that make up the water quality index increase the costs of supplying a given quantity of output.

CONCLUSIONS

This paper presents the findings of an investigation into the costs of municipal water supply. The data are a cross section of annual observations on the operations of Ontario municipal water utilities in 1991. Estimates of the cost elasticities associated with the environmental variables are obtained by estimating a water supply restricted cost function. The cost elasticities related to the quantity and quality of raw water supply conform to expectations. Increasing either the scarcity of raw water supplies or the variability of raw water supplies will increase the cost of supplying potable water to municipal customers although the latter has a larger proportional effect. In addition, worsening raw water quality leads to higher costs of supply. These findings suggest that, if climate change leads to lower lakes levels, reduced river flows and increased variability in raw water supplies, then water utilities will experience increased costs. Similarly, reduced water quality due to industrial effluents or agricultural run-off may impose significant costs on water utilities.

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