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Better safe than sorry? The cost of high standards for water system expansion

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ABSTRACT

This paper provides an economic assessment of the city of Guelph's (Ontario, Canada) water expansion plan for the period of 2013–2038. Using historical demand data we use a probabilistic approach to determine alternate expansion strategies. The empirical results identify the cost savings and reduction in idle capacity associated with alternative water system expansion strategies that maintain a negligible likelihood of a water capacity shortfall. We estimate cost savings of $24.5 to $35.7 million which is 64%–93% of the total costs the city currently plans to spend on water infrastructure. We identify the potential benefits of policy reforms that more effectively weigh the benefits and costs of high standards for water system expansion.

1. Introduction

Canadian municipalities provide water to over twenty-five million people [1]. When and how much to expand these water systems is an ongoing challenge for these municipalities. Both of these decisions have important economic implications. This paper provides a theoretical and case study approach to assess the reasons for, and, the economic consequences of, too much excess water capacity and ill-timed water expansions. Our findings have implications for municipalities throughout North America that are obligated to meet all levels of demand. In the absence of regulations that place a ceiling on the permitted level of idle capacity, municipalities may advance costly water supply plans that result in high levels of idle capacity. This finding is important in the context of natural monopolies, like municipal water suppliers, whose costs are not limited by competitive market pressures.

Presently, in Canada, municipal expansion decisions are driven by provincial regulations and guidelines that require municipalities to maintain a water supply system with the capacity to meet forecasted maximum demand. The timing of these expansions is determined by expectations regarding forecasted maximum demand. Importantly this level of capacity can be equal to, or greater than, the level recommended by the government regulator. While regulations set minimum requirements that guide water supply decisions, these regulations do not "cap" the level of water supply capacity that a municipality can develop. Yet, as we show, excess supply leads to a costly misallocation of resources.

Maximum demand is, by definition, greater than mean demand. This combined with the regulations that require a municipality to scale their water supply capacity to maximum demand means that, except for the maximum day of demand, there will always be idle or excess capacity in the system. This 'consumer-driven' idle capacity is directly related to the variability of demand; the further maximum demand is from mean demand the larger will be the level of idle capacity on average. The amount of idle capacity is exacerbated when municipalities inflate forecasts of maximum demand to levels that greatly exceed those that are likely to be realized. We refer to this as

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'policy-driven' idle capacity. Policy-driven idle capacity is guided by regulation but ultimately left to each municipal water provider to determine.

Idle capacity is problematic because the costs of fixed infrastructure assets must still be recovered from consumers even when the capacity is going unused by the community. The mismatch between the forecasted maximum demand used for municipal planning purposes, and the actual, realized, maximum demand has substantive economic consequences. Forecasts that are significantly higher than actual maximum demand will lead to premature capacity expansions for the system. The welfare losses imposed on communities from premature expansions have been developed in the literature by authors such as [2–5]. These authors point out that significant welfare losses may be present in communities that fail to appropriately price for peak demand. For example, if the price of water is too low, the associated peak demand may necessitate costly water system expansions, which, in turn, places upward pressure on the price of water. Hence, peak demand management (whether via appropriate prices or conservation incentives) has the ability to forestall water system expansions, which lowers costs and the price of water in the long run. This previous literature emphasized the role of consumer demand and municipal water pricing. In contrast, we demonstrate the costs that occur from a municipal policy approach that over-estimates maximum demand and thereby hastens water system expansion. To our knowledge, this is the first study of this kind.

We estimate the underlying probability distribution for water consumption in the city of Guelph, Ontario, Canada and use this information to determine the likelihood that a water expansion will be required during a given year. This distribution allows us to assess the city of Guelph's proposed expansion strategy and estimate the costs associated with early expansion or, alternatively put, the potential savings from delay. The contributions of this paper are threefold: (1) we characterize the existing rules and associated policies that influence the level of idle capacity; (2) we provide an empirical approach to estimate idle capacity and estimate the potential cost savings from alternate strategies; (3) we discuss and develop the larger implications of our findings in the context of regulations without upper boundaries and the potential costs to society.

This paper is organized as follows. Section 2 provides background information on issues related to maximum demand and water capacity expansion. In addition, following [5]; we illustrate the theoretical welfare loss associated with policy-driven idle capacity. Section 3 develops our empirical analysis of the monetary losses associated with policy-driven idle capacity using our case study: i.e., the city of Guelph, Ontario, Canada. We review the key guidelines that ensure a minimum level of excess capacity. However, we note that there appears to be no guideline placing an upper limit on the level of idle capacity. Indeed our empirical findings demonstrate high levels of idle capacity and the potential for significant cost savings from delaying infrastructure expansion.

We provide estimates of the magnitude of idle capacity that is due to consumer-driven behaviour versus that which is policy-driven through a lack of upper restrictions on contingency. Section 4 concludes with a summary of our contribution to the literature as well as recommendations for future research.

2. Background and theory

The relationship between maximum daily demand and daily water system capacity is a critical factor in determining the amount of water supply needed and the timing of investments needed to ensure this quantity. In this context, "meeting demand" requires the system to have a level of capacity sufficient to assure the highest expected quantity of water demand is fulfilled. For the purposes of this article, system capacity refers to the combination of available water from the source and the infrastructure needed to ensure the water is safe to drink. In the remainder of this section we provide background on the relationship between maximum demand and system capacity. We show, abstractly, how this relationship influences the level of idle capacity, the timing of infrastructure investments, and excess costs. We end this section by linking all of the aforementioned consequences – i.e., idle capacity, investment timing, and excess costs – to the decision of municipalities to add additional contingency into their plan. As we discuss below, high levels of contingency effectively increase estimates of future peak load demand and, subsequently, hasten the timing and level of municipal investment in water supply infrastructure.

To develop the intuition behind the importance of peak (maximum) demand, consider a community of one hundred people who all consume an average of one cubic metre per day. Now suppose that on one day the community increases its consumption to 200 m^3. Perhaps that day is associated with high temperatures or drought conditions. Whatever the cause, by regulation, the water capacity for this community must be scaled to provide at least 200 m^3/day. The difference between 200 m^3/day and 100 m^3/day is a stylized example of what we refer to as consumer-driven idle capacity. Consumer-driven idle capacity is the level of capacity in the water system that will go unused on the average day due to the difference between maximum and mean daily demand. This example also demonstrates how maximum demand in one year influences future expectations of water capacity needs despite its rare occurrence. At this point, it is worth reflecting on an important element of our background discussion thus far; if policy instruments could reduce maximum demand, less infrastructure would need to be built and maintained. The magnitude of the savings associated with eliminating any particular peak in demand will depend on the underlying distribution of demand.

Fig. 1 provides an opportunity to assess these general insights in the context of our case study city. Fig. 1 identifies daily demand through the course of the year 2011 in the city of Guelph. This year is selected as an example because of an easily identifiable and distinct peak which, subsequently, determines the level of consumer-driven idle capacity.

Maximum daily demand is represented by the highest peak in daily demand and is identified by the horizontal bar at the top of the diagram. The difference between maximum daily demand for this particular year and mean daily demand is substantial. Maximum day demand was 64,416 m^3; mean day demand was 45,478 m^3/day. Therefore, the level of idle capacity that was consumer-driven was 18,938 m^3/day.

Peak demand has implications for planning water system capacity. [6] provides a theoretical discussion of capacity expansion under the assumption that demand increases over time. The assumption of 'increasing demand' is appropriate for growing urban areas and is

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