# Cooperation between First Nations and Municipalities: Do Water-Sharing Arrangements Improve Drinking Water Quality?

**B. James Deaton** *Professor and McCain Family Chair, Department of Food, Agricultural and Resource Economics, University of Guelph, Ontario, Canada; bdeaton@uoguelph.ca*

**Bethany Lipka** *Project Coordinator and Research Associate, Department of Food, Agricultural and Resource Economics, University of Guelph, Ontario, Canada;blipka@uoguelph.ca*

**ABSTRACT** *Many communities engage in water-sharing arrangements (WSAs) with nearby communities. Using data characterizing drinking water systems in the Canadian province of Ontario, we assess the following question: Do WSAs influence drinking water quality outcomes for recipient water systems? We find that WSAs are associated with improved drinking water quality outcomes for First Nations recipient systems. We do not associate WSAs with improved outcomes for municipal recipient systems. These differing effects may be due to provincial state capacity, which is available to all municipalities, irrespective of WSA status, and the subset of First Nations systems in a WSA.* (JEL R11, R58)



## 1. Introduction

Local governments throughout the world face the ongoing challenge of ensuring safe drinking water in their communities. UNESCO (2021) reports that one in nine people worldwide access water from unsafe and unimproved sources. In North America, municipalities provide high-quality drinking water through public drinking water systems. In the United States, more than 148,000 public water systems supply 90% of Americans with drinking water (EPA 2021). As of 2016, 90% of U.S. water systems met the U.S. Environmental Protection Agency (EPA) contaminant standards (Beauvais 2016). That said, even in North America, drinking water quality varies systematically across regions. For example, in the United States, small (typically rural) water systems have relatively higher per capita violations than larger systems (EPA 2011). For these reasons, water is an important issue of public concern; 60% of Americans list drinking water pollution and river and lake pollution as a "great concern," exceeding concern for air pollution, climate change, and other environmental problems (Keiser and Shapiro 2019).

In Canada, the persistence of unsafe drinking water conditions in First Nations[1] communities is one of the most pronounced problems confronting Canadian public policy.[2] First Nations communities on reserves do not have access to drinking water that is equivalent in quality to drinking water provided in municipalities.[3] Approximately one in eight First

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[1] The Canadian constitution recognizes three groups of Indigenous peoples: First Nations, Métis, and Inuit (CIRNAC 2017). There are more than 630 First Nations communities across Canada, representing more than 50 nations and 50 Indigenous languages.

[2] In 2015, Prime Minister Justin Trudeau made a campaign promise to end boil-water advisories in First Nations communities within five years, if elected (CBC News 2015). While some progress has been made toward this goal (the details of which can be found at https://www.sac-isc.gc.ca/eng/1506514143353/1533317130660), Indigenous Services Minister Marc Miller confirmed in December 2020 that the five-year target would not be met (Stefanovich 2020).

[3] Reserves are defined by the Indian Act of 1985 as "tract[s] of land, the legal title to which is vested in Her Majesty, that has been set apart by Her Majesty for the use and benefit of a [First Nations] Band." A band is defined as a "body of Indians . . . for whose use and benefit in common, lands, the legal title to which is vested in Her Majesty, have been set apart." An elected "band council" is the basic governing unit of First Nations under the act. Importantly, many First Nations operate under self-governance agreements and have created their own governance systems outside of the constraints of the act; many others have separate and complex traditional modes of governance in addition to the

Nations communities in Canada are under a boil-water advisory at any given time, and the rate of waterborne infections for these communities is 26 times higher than the Canadian average (Baijius and Patrick 2019). These quality issues have far-reaching health implications. O'Gorman (2021) finds that access to indoor water supply is associated with an 80% reduction in the odds of reporting depression for people living on First Nations reserves in Canada. Water quality concerns in Indigenous communities are not unique to Canada. Wallsten and Kosec (2008, 193) provide a systematic empirical assessment of quality violations in U.S. drinking water systems and find that "water systems owned by Native American tribes tend to experience the most frequent contaminant violations."

Unlike previous literature, we directly assess the performance of municipal and First Nations drinking water systems. In this article, we evaluate the effect of water-sharing arrangements (WSAs) on drinking water quality outcomes. A WSA is an institutional arrangement whereby a water system in one jurisdiction (the donor) supplies drinking water to a system in another jurisdiction (the recipient).[4] Hereafter, we refer to the effect of WSAs on the recipient system's drinking water quality as the WSA effect. Deaton and Lipka (2021) find that 32% of Ontario communities—municipalities and First Nations—had at least one of their drinking water systems supplied in whole or in part through some form of WSA during the study period of 2009–2010.[5] However, the majority of these WSAs occurred between municipalities, with only 10% of First Nations communities in Ontario having a water system supplied through a WSA.

Given the prevalence of WSAs, assessing the WSA effect is relevant for understanding the gains of exchange that undergird many drinking water systems in Ontario, North America, and globally. Among the benefits associated with WSAs are the economies of scale in drinking water treatment that arise from aggregating water infrastructure and operations (Kim and Clark 1988; Boisvert and Schmit 1997; Garcia and Thomas 2001; Sauer 2005; Abbot and Cohen 2009). There is evidence that these economies of scale are especially pronounced for smaller utilities (Kim and Clarke 1988; Abbott and Cohen 2009), meaning communities with small water systems are likely to benefit the most from WSAs. WSAs also increase the capacity for communities to share in a wide range of quality-improving capital investments (e.g., more efficient, larger treatment systems and technologies) and quality-improving operations investments (e.g., monitoring technologies, improved business operations) (Kim 1985; Kim and Clarke 1988; Abbott and Cohen 2009).

Lipka and Deaton (2015) find that WSAs improve drinking water quality outcomes for recipient First Nations communities across Canada and that a number of independently supplied First Nations communities (some with poor drinking water conditions) are close to potential municipal WSA donors. Allaire, Wu and Lall (2018) examine U.S. national trends in drinking water quality violations and find that water systems that purchase treated water have a lower propensity for violations. Interestingly, and relevant to our later discussion on state capacity, the authors suggest that this lower propensity for violations is due to "wholesale water providers hav[ing] greater *capacity* to achieve regulatory compliance" (Allaire, Wu, and Lall 2018, 2081; emphasis added). They do not develop these issues in the context of Native American communities. That said, given Wallsten and Kosec's (2008) finding, the relationship between state capacity and drinking water violations appears to be an important area for future research in the United States.

band council system. The Indian Act of 1985 is available at https://laws-lois.justice.gc.ca/eng/acts/i-5/.

[4] WSAs can vary across different contexts, with respect to duration, pricing, infrastructure responsibilities, and so on. The Federation of Canadian Municipalities provides a water and wastewater service agreement template that provides a detailed look at the general structure of these agreements between First Nations and municipalities and terms and conditions that are common to most arrangements. See https://fcm.ca/en/resources/fnmcp/service-agreement-templates.

[5] In some cases, a municipality or First Nations community may be supplied by a single water system. But in many cases, communities are supplied by multiple distinct water systems as defined by the province or the First Nation.

In our study of WSAs in Ontario in 2009–2010,[6] we find that municipalities frequently shared water with each other and less frequently shared water with neighboring First Nations communities. During our study period, 41% of municipalities were receiving water through a WSA, compared with only 10% of First Nations communities (Deaton and Lipka 2021). With only one exception,[7] all water suppliers—or "donor systems"—in these WSA arrangements were municipal water systems that fell under provincial governance and regulation. Unlike Deaton and Lipka (2015), a unique aspect of the data collected for this study is that it characterizes water services in both municipal and First Nations communities in the province of Ontario. This allows for the first empirical assessment of the effect of WSAs on quality outcomes for both municipal and First Nations water systems in the same province. The importance of this interprovincial comparison, and the associated institutional issues, are developed below.

The institutions governing drinking water in First Nations communities and Ontario municipalities are distinctly different, and these institutional differences are an important feature of our analysis. Specifically, in our data set we observe (1) municipal water systems supplied through WSAs, (2) First Nations water systems supplied through WSAs, and (3) independently supplied municipal and First Nations water systems. WSAs between municipalities are classified as intrajurisdictional. Ontario municipalities are all "creatures" of the province, local governing units networked together via provincial legislation through shared forms of governance. Specifically, Ontario municipalities are networked through provincial water quality standards and enforcement in critical ways that generate benefits for drinking water. In contrast, WSAs between municipalities and First Nations can be classified as interjurisdictional. A key characteristic distinguishing First Nations from Ontario municipalities is their status of nationhood. Each First Nations community has a unique relationship with the federal government.[8] Hence, First Nations are not networked via provincial legislation in the same way as municipalities. First Nations exist independent of the province and independent of one another and are individually governed under the constraints of the Indian Act of 1985.[9] Because they operate in an entirely different institutional environment from municipalities, when a First Nations community is on the receiving end of a WSA, that WSA is best understood as an interjurisdictional exchange.

We use differences between municipalities and First Nations, with respect to the institutions governing water systems, to differentiate state capacity in the provision of drinking water. Our conceptualization of these differences

[6] As discussed later, a unique study during this time period provides the first and only access to detailed information on First Nations drinking water systems.

[7] The one exception to this is the WSA between Chippewas of the Thames First Nation and Munsee Delaware First Nation, where the former supplied the latter with treated water. This agreement is no longer in effect. This observation was removed from our regression analysis to keep consistent with our theoretical approach, which is focused on municipalities supplying First Nations. However, it is important to note that it is possible (but not common) for First Nations to be suppliers in WSA arrangements. Including this case does not influence our empirical or qualitative findings.

[8] In North America, the Royal Proclamation of 1763 (Brigham 1911) established a unique relationship between Indigenous peoples and the Crown, and this was carried forward to the federal government of Canada after confederation in 1867. In the United States, a similar relationship between the federal government and Indigenous peoples was established by the workings of the Supreme Court in a series of cases referred to as the Marshall trilogy: *Johnson v. McIntosh*, 21 U.S. (7 Wheat.) 543 (1823), available at https://www.loc.gov/item/usrep021543/; *Cherokee Nation v. the State of Georgia*, 30 U.S. (5 Pet.) 1 (1831), available at https://www.loc.gov/item/usrep030001/; and *Worcester v. the State of Georgia*, 31 U.S. (6 Pet.) 515 (1832), available at https://www.loc.gov/item/usrep031515/. In theory, these cases limited U.S. states from interfering in governance matters in Indigenous territories. While these cases have set a meaningful precedent, we would be remiss if we did not mention that the Supreme Court rulings failed to keep U.S. states from violating federal law, particularly in the time period shortly after *Worcester v. Georgia*. One of the most famous violations led to the forced displacement of many Indigenous peoples from their well-defined territories in Georgia. The retelling of this history is beyond the scope of this article; that said, we emphasize the need for ongoing efforts to understand the consequences of these institutional differences and why they emerged.

[9] Indian Act (1985, R.S.C., c. I-5).

as state capacity draws on previous research, including Mann (1984) and Acemoglu, Garcia-Jimeno, and Robinson (2015). Mann (1984) conceptualizes states as being differentiated by institutions (e.g., rules and regulations) that apply to a demarcated area. One historical and present function of the state is infrastructure provision. The capacity of the state to provide infrastructure varies by the constellation of institutions that differentiate state provision. Importantly, these institutions may vary between states, depending on the specific infrastructure being examined (i.e., roads, water). That is, from our perspective, institutions define the state capacity (or social technology) that organizes labor and capital in the provision of infrastructure. Our conception of state capacity builds on Mann's (1984) examination of infrastructural power and is generally similar to the discussion provided by Acemoglu, Garcia-Jimeno, and Robinson (2015). Our measure of state capacity, however, is primarily institutional and differs from Acemoglu, Garcia-Jimeno, and Robinson (2015), who measure state capacity by the number of agencies or employees in a municipality.[10] In our analysis, we differentiate state capacity by state itself (i.e., First Nations and municipalities), based on explicit institutional differences relevant to drinking water provision.

Our key research questions are: Do WSAs influence drinking water quality outcomes for the recipient system? Does the WSA effect depend on whether the recipient system is a First Nations water system or a municipal water system? We hypothesize that WSAs do have an influence on drinking water quality outcomes. We expect this effect to be pronounced for First Nations because WSAs allow First Nations to tap into the state capacity of the province with respect to water quality monitoring and enforcement. In contrast, we expect the WSA effect to be muted for municipalities, as they already have access to this provincial state capacity irrespective of whether they are engaged in a WSA.

The full suite of institutional issues that differentiate First Nations and municipalities are far beyond the scope of this (or likely any) applied study. Deaton and Lipka (2021) provide an overview of some of these issues and identify additional literature on the subject. Our approach is to develop a clear example of these institutional differences in the context of drinking water quality standards and enforcement. We also discuss factors that may explain why WSAs are more prevalent between municipalities than between municipalities and First Nations. Our empirical results suggest that the WSA effect significantly improves drinking water quality outcomes for First Nations water systems but does not meaningfully enhance drinking water quality outcomes for municipal water systems.

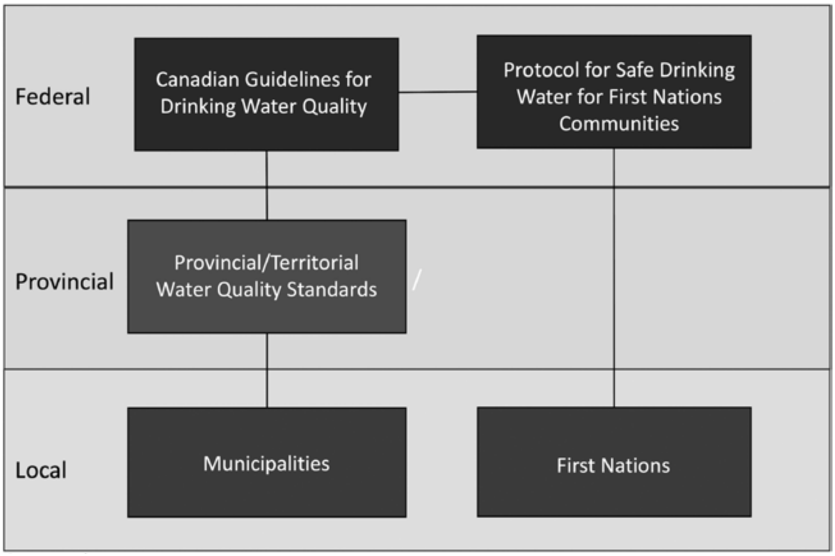
## 2. First Nations and Municipalities: Drinking Water Quality Standards and Enforcement

We provide some key background information regarding institutional and legislative differences in drinking water quality standards and enforcement for First Nations communities and municipalities in the Canadian province of Ontario. Although a full analysis of these differences is beyond the scope of this article, we focus on highlighting fundamental differences and their implications. Of central importance is the highly decentralized nature of water governance in Canada, being one of only two OECD countries that does not comply with the WHO recommendation to have a legally enforceable federal drinking water quality standard (Dunn, Bakker, and Harris 2014).[11] Instead, Canadian provinces

[10]This has several advantages, especially in terms of capturing variation across municipalities. But the expectation that higher levels of these measures are associated with preferable outcomes ignores the importance of institutional differences, which, in our assessment, meaningfully differentiate states. For example, institutions—conceptually—determine whether the number of state agencies are associated with improved outcomes or effectively deter beneficial outcomes. An anti-commons situation (Heller 1998; Buchanan and Yoon 2000) is a well-known example whereby the number of government agencies lead to deleterious outcomes due to the institutions undergirding resource use.

[11]Australia is the only other OECD country to have no legal federal water quality standard (Dunn, Bakker and Harris, 2014).

**Figure 1**
Governance of Drinking Water Safety in Municipalities and First Nations






and territories have established, and are responsible for enforcing, drinking water quality standards based on federal guidelines for Canadian drinking water quality (GCDWQ) (Health Canada 2020). In Ontario, these standards and enforcement institutions are established through the provincial Safe Drinking Water Act (2006) and accompanying regulations. Given that First Nations are governed federally and not provincially, there are critical differences in how drinking water quality is governed in First Nations communities and Ontario municipalities.

Figure 1 illustrates these differences and shows that the relationship between the province and municipalities is hierarchical. Ontario municipalities, established as local governing units of the province via the Municipal Act (2006), are networked by law through shared provincial water quality standards and enforcement.[12] In contrast, First Nations are in a nation-to-nation relationship with the federal government; they have no formal or hierarchical relationship with the province and are not subject to provincial laws. Instead, each First Nations community has a unique and distinct relationship with the federal government under the constraints of the 1985 Indian Act. While the act does refer to water, it does not explicitly define federal or First Nations responsibilities regarding drinking water (Alcantara, Longboat, and Vanhooren, 2020).[13] The federal GCDWQ, which provide the basis for provincial water quality standards, do not provide specific considerations for First Nations water concerns. The GCDWQ do provide the basis for the protocol for safe drinking water in First Nations communities (INAC 2010), which outlines guidelines for construction, maintenance, and monitoring of First Nations water infrastructure. However, this protocol is not legally enforceable in the same way that provincial water quality standards are enforceable.[14]

[12] Municipal Act (2001, S.O., 2001, c. 25), available at https://www.ontario.ca/laws/statute/01m25 (accessed June 22, 2020).

[13] The Indian Act discusses water in the context of authorization of capital expenditures for water infrastructure, with respect to government powers to pass by-laws for construction and maintenance of watercourses, and construction and regulation of on-reserve water supplies (Alcantara, Longboat and Vanhooren 2020).

[14] In 2013, the Safe Drinking Water for First Nations Act (S.C. 2013, c. 21) was passed, creating a framework that would allow for establishing more enforceable standards for drinking water quality on First Nations reserves (available at https://laws-lois.justice.gc.ca/eng/acts/S-1.04/index.html).

In Ontario, the Ministry of the Environment, Conservation and Parks (MOECP)[15] serves as the third-party enforcer of provincial water quality standards under the Safe Drinking Water Act (2002)[16] and, with Public Health Ontario (PHO), provides municipalities with resources for monitoring, enforcing, and remediating poor water quality outcomes. These resources include a rigorous annual inspection program, with a provincially developed inspection methodology that is reviewed every three years (MOECP 2022). Water sampling requirements are also set at the provincial level and vary by size and scale of system (PHO 2022).[17] Municipalities are required by law to report adverse sampling results to the MOECP and the local medical officer of health so that, if necessary, local health units can assist with any outbreaks (MOECP 2021). The Safe Drinking Water Act (2002) also provides guidelines for administrative penalties in the form of fines to be enforced for compliance failures.

Importantly, First Nations are excluded from this provincial enforcement and do not have a similar centralized enforcement structure in place under the federal government or any other third-party institution. The *Protocol for Centralized Drinking Water Systems in First Nations Communities* states that the federal government will "provide advice" to First Nations, but First Nations are "responsible for the design, construction, operation, maintenance and monitoring of their drinking water systems" (INAC 2010, 2). First Nations bands provide training to water system operators, and operators implement sampling and testing procedures. Whereas municipalities benefit from the economies of scale provided by provincially established standards and inspection and sampling protocols, individual First Nations must take on the bulk of the costs of monitoring and enforcing water quality in their communities. Their protocol does specify that First Nations should aim to meet established federal guidelines or provincial standards for water quality, whichever are "most stringent"; in Ontario, the provincial standards are more stringent (Dunn, Bakker, and Harris 2014). However, because adopting the provincial standards is not legally enforced, First Nations that choose to adopt them do so voluntarily (Alcantara, Longboat, and Vanhooren 2020). While their protocol contains some quality assurance recommendations—specifically related to asset inspections—these are also not legally enforced. Hence, each First Nations community is primarily responsible for its own community-level monitoring regimes.

First Nations and municipalities differ considerably in how they finance the provision of drinking water. Municipalities rely on property taxes, nontax revenue (e.g., parking fines, by-law fines), and provincial transfers through the Ontario Municipal Partnership Fund (AMO 2022a, 2022b). In contrast, First Nations primarily rely on federal transfers and limited own-source revenues (FNB 2020). Some provinces, including Ontario, have made funding available to First Nations through programs aimed at economic development initiatives (FCM 2022; MIA 2022).[18] However, these provincial transfers, generally awarded on a programmatic basis, make up a very small portion of total government transfers to First Nations (an estimated 12% federally in 2020) (FNB 2020). Research indicates that First Nations communities are

However, this act was strongly opposed by many First Nations stakeholders, as these new standards would put First Nations in a position of having to achieve similar quality standards as municipal governments without having the necessary third-party support (i.e., the act did not specify the creation of accompanying institutions similar to the Ministry of the Environment, Conservation and Parks that would provide coordinated resources to help communities achieve the new standards). As a result of this opposition, no enforceable drinking water quality standard for First Nations has been developed at the time of writing.

[15] Formerly (during our study period of 2009–2010) named the Ministry of the Environment (MOE).

[16] Safe Drinking Water Act (2002, S.O. 2022, c.32), available at https://www.ontario.ca/laws/statute/02s32.

[17] Regulations for large and small water systems are laid out in O. Reg. 170/03: Drinking Water Systems (under the Safe Drinking Water Act), available at https://www.ontario.ca/laws/regulation/030170 and O. Reg. 319/08: Small Drinking Water Systems (under the Health Protection and Promotion Act [1990, R.S.O., 1990, c. H.7]), available at https://www.ontario.ca/laws/statute/90h07.

[18] For example, the government of Ontario has the Indigenous Economic Development Fund, Indigenous Community Capital Grants Program, and New Relationship Fund. More information about these programs can be found at https://www.ontario.ca/page/funding-indigenous-economic-development.

underfunded with respect to their needs by the Canadian federal government (Auditor General of Canada 2011; White, Murphy and Spence 2012; Black and McBean 2017a, 2017b; Alcantara, Longboat, and Vanhooren 2020).

In addition to issues directly related to drinking water (i.e., standards, monitoring, enforcement, and funding), First Nations and municipalities differ by other institutions that influence water quality more generally. For example, the Ontario Clean Water Act of 2006 established a regulatory framework for source water protection planning.[19] The majority of First Nations fall outside the established protection areas, and those that do not must pass a band resolution or by-law promising compliance to the provincial process to participate in source water protection planning. Many First Nations see this as a violation of inherent and treaty rights (Collins et al. 2017).

Cumulatively, the differences in how drinking water quality is governed in First Nations communities and Ontario municipalities create key disparities in practice. For example, the lack of sampling procedures for First Nations has historically resulted in a lower prevalence of water sampling in these communities. For the 2008–2009 fiscal year, the year preceding our study period, Health Canada reported that water in First Nations communities was tested less often than recommended under the Canadian guidelines for drinking water quality; specifically, only 40% of community sites conducted bacteriological sampling at the recommended frequency (Auditor General of Canada 2011). During our study period of 2009–2010, approximately 46% of First Nations water systems in Ontario could be classified as “high risk” (Neegan Burnside 2011), while the average water system inspection rating (an assigned grade out of 100%) for municipal systems in Ontario was approximately 97.8% (Stager 2011).

## The Emergence of WSAs

First Nations and municipalities may enter into WSAs, although they are far more prevalent among municipalities (Deaton and Lipka 2021). There are many factors that may prevent a First Nations community from engaging in a WSA, some more directly measurable than others. In terms of measurable factors, Deaton and Lipka (2021) find northernness, proximity to potential suppliers, and regional wealth to be significant factors influencing the likelihood of WSA participation.

Geographic feasibility of WSAs does not necessarily translate to desirability from the community perspective. When these exchanges are feasible, First Nations and municipalities face important considerations. First Nations may consider a WSA as limiting their autonomy and efforts to be self-governing. The trade-off between self-governance and integration in more centralized forms of governance undergirds a historical tension that expands beyond water services.

Past research on the relationship between centralized control of Indigenous lands and resources and economic development is extensive in Canada and the United States (Trosper 1978; Carlson 1981; Anderson and Lueck 1992; Alcantara 2007; Anderson and Parker 2009, 2017; Aragón 2015; Aragón and Kessler 2020; Frye and Parker 2021). For example, in the United States, Frye and Parker (2021) find positive income growth effects associated with tribal self-governance. In contrast, Anderson and Parker (2017) find that homogenization of systems of contract enforcement resulting from centralized state jurisdiction over law and order on reservations in the United States was positively correlated with income growth. At the same time, the authors acknowledge the historical role that federal control over land and resources has played in stunting development on reservations and argue in favor of a federalist arrangement that would allow tribes to choose when it is optimal to yield jurisdiction and when to retain it.

Huo, Charbonneau, and Alcantara (2022) explore barriers to WSAs in Canada and cite three common First Nations concerns: (1) financial capacity to implement and monitor agreements successfully; (2) legal, institutional, and cultural differences between First Nations and municipalities with respect to the understanding and use of water; and (3) concerns about water sovereignty as it relates

[19] Clean Water Act (2006, S.O. 2006, c. 22), available at https://www.ontario.ca/laws/statute/06c22.

to Indigenous self-determination and nation-building. Another important factor to note is that the government of Canada has a fiduciary and constitutional responsibility to First Nations, including providing drinking water (Baijius and Patrick 2019). While participating in a WSA may be viewed as a potentially cost-effective water provision solution for some First Nations communities, participating in a WSA may also be viewed as the downloading of this water provision responsibility from the federal level to the provincial/local level.

## 3. Empirical Approach

Our empirical approach aims to test three key hypotheses. First, if the state capacity of the province enhances the capacity of each municipality to ensure safe drinking water, then we expect municipal water systems to have fewer drinking water advisories (DWAs) then First Nations water systems. Second, we expect First Nations water systems supplied through WSAs to have a lower prevalence of DWAs as they take advantage of the state capacity afforded by the province to their municipal donor. Third, because municipalities already leverage the state capacity of the province with respect to drinking water quality, we expect that WSAs supplying municipal water systems will not be associated with improved drinking water quality. That is, all municipalities are already assumed to equally benefit from provincial state capacity with respect to water supply and quality irrespective of WSA participation. Hence, the WSA effect for municipal recipient water systems is expected to be smaller than the WSA effect for First Nations recipient water systems, since the latter benefit from expanded state capacity through their municipal donor.

To clarify our approach, we begin with a simple conceptual model. We develop that model in a way that mirrors the presentation of our empirical results. A simple model characterizes the performance of a water system as follows:

$$p_{i,j} = f(s_{i,j}, x_i, z_{i,j}), \qquad [1]$$

where performance of a water system $j$ in community $i$ is a function of community and drinking water system–level covariates $s_{i,j}$, $x_i$, and $z_{i,j}$. $s_{i,j}$ represents the state capacity applied to a system. We conceptualize state capacity differing for First Nations depending on whether the system is supplied independently or by a municipal neighbor via a WSA. If a WSA allows a First Nations water system to tap into the state capacity of the province, then state capacity is expected to be greater for First Nations water systems that are engaged in a WSA, compared with those that are independently supplied. (In the previous section, we developed arguments consistent with this expectation.) Of course, a host of other factors may influence system performance, including community characteristics, $x_i$ (e.g., population, location, regional income), and water system characteristics, $z_{i,j}$ (e.g., source water supply and system size). A general regression relationship can be specified as follows:

$$p_{i,j} = \lambda s_{i,j} + \theta x_i + \sigma z_{i,j} + u_{i,j}. \qquad [2]$$

Given the foregoing discussion, our basic approach is to use a categorical variable (i.e., $WSA_{i,j}$ = 1; 0 otherwise) to differentiate the state capacity influencing the performance of a drinking water system. This substitution results in equation [3]:

$$DWA_{i,j} = \lambda WSA_{i,j} + \theta x_i + \sigma z_{i,j} + u_{i,j}. \qquad [3]$$

We discuss our identification concerns more fully shortly, but equation [3] allows us to clarify our main hypotheses regarding the WSA effect. For First Nations water systems, we expect a WSA to improve quality performance. We attribute this effect to the enhanced state capacity available to the municipal system supplying the treated water. If we allow $p_{i,j}$ to measure poor performance (e.g., the issuance of a drinking water advisory, DWA = 1|0, to the system), as we do in the remainder of the article, then we hypothesize $\lambda_{FN} < 0$. Put differently, WSAs are expected to reduce the likelihood of poor performance for First Nations water systems. Our hypothesis for municipal systems, however, is less clear. As discussed, municipalities all already access—or are all already networked into—the state capacity of the province. Hence, WSA participation is not expected to have a substantive effect on DWAs for intramunicipality WSAs. Therefore, we would expect the magnitude of $\lambda_{mun}$ to be small. We begin by estimating equation [3] using separate probit models for First Nations and municipal water systems.[20] Next, and appreciative of the caveats discussed in the following section, the data are pooled to estimate the regression:

$$DWA_{i,j} = \alpha\ FN + \beta WSA_{i,j} + \tau(FN^{*}WSA) + \theta x_i + \sigma z_{i,j} + u_{i,j}. \quad [4]$$

In the pooled regression, we expect $\alpha$ to be positive, $\beta$ to be insignificant, and $\tau$ to be negative. Again, we hypothesize the marginal effect on the interaction term, $FN \times WSA$, to be negative based on the idea that when a First Nations community enters into a WSA, they effectively tap into the enhanced state capacity for water quality provision provided to municipalities by the province.

## Identification Challenge and Sensitivity Analyses

An identification challenge to the models is that WSAs may be endogenously determined. Indeed, one threat to identification is that communities that participate in WSAs may have greater state capacity themselves. For example, First Nations that engage in WSAs may have greater state capacity, and this could explain their participation and subsequent water system performance. In this case, the estimated $\hat{\beta}_{FN}$ may conflate the state capacity of the First Nations with the state capacity afforded by the province through WSA participation. Because we do not have a measure of each individual community's state capacity, and our study captures system performance at one point in time, this presents a meaningful identification challenge.

To address this challenge, we assess the sensitivity of our probit estimates to a bivariate probit regression. Using the bivariate probit, we simultaneously estimate the effect of WSAs on water system performance and factors influencing the likelihood that a system in a given community will be supplied through a WSA. We provide a general specification here (see Greene 2008):

$$p_{i,j} = \lambda WSA_{i,j} + \theta x_i' + \sigma z_{i,j}' + u_{i,j},$$
$$p_{i,j} = 1[DWA^{*} > 0], \quad [5]$$

$$WSA_{i,j}^{*} = \gamma x_i'' + \mu z_{i,j}'' + v_{i,j},$$
$$WSA_{i,j} = 1[WSA^{*} > 0]. \quad [6]$$

The error terms, $u$ and $v$, are assumed to follow a bivariate normal distribution. As with the probit regressions, we estimate bivariate probit models for First Nations and municipal water systems separately. We compare our estimates of $\beta_{FN}$ and $\beta_{mun}$ to those from the probit model estimation of equation [3]. There is some overlap in $z'$ and $z''$ covariates and in $x'$ and $x''$ covariates. These variables and sources are discussed in greater detail in the data section. (For a complete list of variables included in our analysis, see Appendix Table A1.)

Participation in a WSA depends on mutual interactions between First Nations and municipalities. Hence, there are supply and demand considerations regarding drinking water, as well as a host of political, socioeconomic, and historic considerations (discussed in Section 2). A more fully developed discussion of the emergence of WSAs is developed in Deaton and Lipka (2021). A key finding from their empirical analysis (conducted at the community level) is that the relative remoteness of a community significantly influences the likelihood of WSA participation. With this in mind, we run an additional sensitivity test, limiting our original probit regression samples to only those drinking water systems located in communities that we assess to be within a feasible distance to a potential water-sharing partner. We define this feasible distance in the data section.

While the bivariate probit approach addresses issues associated with selectivity bias, we remain concerned that there are other omitted variables that may influence state

[20] In the data section, we provide information on the data sources for the regressions. Key differences in the sources of municipal and First Nations water system and water quality data led us to estimate separate regressions for First Nations and municipal water systems.

capacity and be correlated with both WSAs and DWAs. For this reason, we include a third and final sensitivity test examining how our key results for the First Nations subset of the data respond to the inclusion of a variable that identifies First Nations who are signatory to the Framework Agreement (FA) on First Nations Land Management (1996). In summary, following the 1996 FA initiated by First Nations, the federal government enacted the First Nations Land Management Act (FNLMA) in 1999.[21] The FNLMA allows First Nations who become signatory to the FA to opt out of certain provisions of the 1985 Indian Act and develop their own land code. Signatories to the FNLMA may demonstrate a greater state capacity, as they signal the ability and desire to develop and enforce land codes at the community level. We identify First Nations in Ontario who have become signatory to the FA to date. Including this variable in our analysis allows us to examine the extent to which WSAs and DWAs are associated with FNLMA adoption. We are particularly interested in whether including this variable influences our key results with respect to the effect of WSAs on drinking water quality for First Nations.

There are a few key limitations to our empirical approach that are important to note. Few First Nations have multiple water system observations, and there are no cases in our regression analysis of First Nations having a mix of independent and WSA supplied drinking water systems.[22] Hence, community-level fixed effects cannot be used to address omitted variable issues. Further, as discussed, we recognize the added value that observations over time would bring to our identification efforts, allowing us to observe water system performance before and after WSAs. As we explain next, to our knowledge such a data set cannot be feasibly collected in Ontario with presently available data. Finally, we cannot fully account for the many context-specific cultural, historic, and socioeconomic situations that might vary across the communities we observe.

Given these concerns, this study is best viewed as an initial step in addressing a very important and relatively unexamined issue in North America and throughout the world. Future research can examine these issues in settings where better data are available. For example, the EPA makes detailed longitudinal water system and quality data available through the Safe Drinking Water Information System Federal Reporting Services (EPA 2022).[23] Moreover, a focus on institutional differences across countries will better illuminate the extent to which state capacity explains variation in drinking water quality outcomes. In this regard, ongoing efforts to better identify the causal relationship between state capacity and infrastructure outcomes remain an important consideration.

## 4. Data

Our regression analysis is applied to a data set characterizing 710 water systems in the province of Ontario—145 First Nations water systems and 565 municipal water systems—as well as their surrounding communities. Appendix Figure A1 provides a map of centroid longitude and latitude coordinates of host communities for each of the water systems included in our analysis. Our cross-sectional data are from 2009 and 2010. In the remainder of this section, we provided a brief overview of key variables included in the analysis.[24] We place particular emphasis on our discussion of the collection of water system data, specifically our key variable of interest, DWAs.

[21] See Doidge, Deaton, and Woods (2013) for a detailed history of the FNLMA (S.C. 1999, c. 24), available at https://laws.justice.gc.ca/eng/acts/F-11.8/page-1.html.

[22] At the time of the Neegan Burnside (2011) survey, there was only one First Nations reserve that had more than one water system, where water sharing was taking place in one system and not the other: the Mohawks of the Bay of Quinte Band, Tyendinaga Mohawk Territory. This community had two water systems, one supplied by the neighboring town of Deseronto, and one supplied independently. This band was dropped from the regression analysis due to missing census data. Interestingly, during the Neegan Burnside (2011) study period, Mohawks of the Bay of Quinte's independent water system was under a DWA, and the system supplied through the WSA was not.

[23] This extensive data set can be queried at https://sdwis.epa.gov/ords/sfdw_pub/f?p=108:200.

[24] Appendix Table A1 details each variable included in our analyses and provides source information.

## DWAs

There are significant data gaps in Canada with respect to DWAs. Despite the improvement of water quality in First Nations communities being a stated priority of the Canadian federal government, there is no public central repository of DWA data federally or provincially that would allow us to compare the prevalence of DWAs in First Nations communities and municipalities during our study period of 2009–2010.[25] Because First Nations and municipalities fall under different jurisdictions with respect to water provision, different data sources had to be used to document DWAs for First Nations and municipal water systems. Importantly, this variable (DWA) was identically defined for both First Nations and municipal systems: it identifies water systems that had active DWAs at some point during our study period. DWAs include boil-water advisories, do not consume advisories, and do not use advisories. They are issued based on the results of water quality testing to warn consumers that the water may be unsafe or is known to be unsafe (ISC 2021a).

DWA data for First Nations water systems were taken from the survey by Neegan Burnside (2011), which took place between 2009 and 2010. It is the only detailed Canada-wide inspection of First Nations water systems to ever take place,[26] and for this reason our study period is limited to the two-year period covered by this report. Neegan Burnside (2011) indicates whether a DWA was in effect for each First Nations water system at the time it was surveyed. No similar survey exists that allows us to identify municipal DWAs during the same period. The Ontario *Chief Drinking Water Inspector's Report* (Stager 2011) from 2009 to 2010 indicates municipal water system compliance with provincial standards and water system inspection ratings, but it does not provide DWA data. Our municipal DWA data were provided by the organization Water Today,[27] an independent ad-based media group with a key focus on DWAs. Municipal DWA data for the study period 2009–2010 were collected by Water Today through media reports, health units, and Freedom of Information requests.

While they are the best and only sources of DWA data available for First Nations and municipalities in Ontario during our study period, both Neegan Burnside (2011) and Water Today have limitations that are important to note. Neegan Burnside's (2011) survey methodology makes it possible that some DWAs were missed during data collection. Their report indicates whether a DWA was in effect for each First Nations water system when the system was visited (with site visits taking place in September and October 2009, and May–September 2010). It is possible that a surveyor, in capturing the state of water quality at the time of the site visit only, may have missed an advisory that was put in place before or after the survey; in that case, it would not be noted in the data. In contrast, Water Today provided us with a list of municipal DWAs that were publicly reported between 2009 and 2010, which should reduce the potential for missed advisories. However, Water

[25] Attempts to contact various federal and provincial government ministries to inquire about the availability of these data were not successful. Over the course of our data collection efforts, we contacted the MOECP; Environment and Climate Change Canada; and PHO. None were able to provide us with a comprehensive list of DWAs that were in effect in Ontario during our study period. In fact, PHO, which we contacted last, referred us back to the MOECP, which we had contacted first. Any public data on DWAs made available by government agencies that we were able to locate were segregated (i.e., different sources for First Nations communities and municipalities) and did not include the historic data we required (2009–2010). Indigenous Services Canada (ISC 2021b) provides a list of current long-term DWAs in First Nations communities on their website; however, this list only allows us to access DWAs currently in effect and does not include historic data. The government of Canada has published data on DWAs in effect across Canada from 2010 to 2019, collected through the Canadian Network for Public Health Intelligence Drinking Water Advisory Application (ECCC 2020). However, these data are collected from participating provincial and territorial regulatory agencies, and thus excludes First Nations; it also excludes some nonparticipating non–First Nations jurisdictions. Although these data do partially overlap with our study period (2010), they are only reported on aggregate, not at the system level.

[26] In Ontario, 120 of 121 First Nations communities with water and wastewater assets opted to participate in this survey (Neegan Burnside 2011). For the purpose of the survey, a First Nations water system was classified as a system receiving funding from the federal government (Indigenous and Northern Affairs Canada at the time, Indigenous Services Canada today), servicing five or more residences or public facilities.

[27] Available at https://www.watertoday.ca.

Today's municipal DWA data were collected case by case via secondary sources and may be incomplete due to human error or missing information.

## Water System and Community Characteristics

First Nations water system data are taken from the Neegan Burnside (2011) report. In addition to DWA data and other quality indicators, this report provides detailed water system characteristics for each First Nations water system surveyed. As no similar survey exists for municipal water systems in Ontario during our study period, municipal water system data had to be collected on a case-by-case basis by contacting individual municipalities and requesting information. First, a comprehensive list of Ontario municipal water systems was taken from the 2009–2010 Chief Drinking Water Inspector's Report for Ontario (Stager 2011). The municipal owners of these systems were then contacted, and we requested water system documentation that would allow us to identify key system characteristics, such as ownership, source water (i.e., groundwater, surface water), supply information (i.e., independent supply or WSA), and general scale information (i.e., large or small system).[28] In cases where no relevant system documents were available, a municipal contact was used to confirm the water system details we required.[29]

Each water system in the data set was paired with community characteristics that were collected from the 2006 Canadian Census community profiles and boundary files (Statistics Canada 2019a, 2019b) and FedNor (2017).[30] Census characteristics from community profiles include community area and population density (census subdivision level) and regional median income (census division level) (Statistics Canada 2019b). Community remoteness is captured by two dummy variables identifying (1) water systems located in communities that are a distance of 5 km or less from the closest neighbor with water infrastructure (measured from boundary to centroid), and (2) water systems located in communities that are greater than 5 km but less than or equal to 10 km from the closest neighbor with water infrastructure. These distances were calculated using GIS software and 2006 census subdivision boundary files (Statistics Canada 2019a).[31] Water systems were identified as being located in "northern" or "southern" Ontario communities according to FedNor's (2017) classification of northern Ontario census divisions.

As discussed, as a sensitivity test to address the potential endogenous determination of the WSA variable, we run each probit model using a bivariate probit regression that simultaneously estimates the likelihood of WSAs and DWAs. In the bivariate probit regressions, there are community and water system characteristics included in equations [5] and [6]. Both models include community northernness, population density, and median regional income. These community characteristics are expected to influence the likelihood of WSA participation and the likelihood of a DWA. Deaton and Lipka (2021) include these characteristics in their assessment of factors influencing community decisions to participate in WSAs. More remote northern communities with dispersed populations in low-income regions are expected to have more frequent water quality concerns. Both models include a variable identifying large residential water systems, as system size is also expected to influence both the likelihood of water

[28] The requested documents included quality management system operational plans, annual water system reports, and annual Ministry of the Environment inspection reports. There are two main types of residential drinking water systems in Ontario: (1) small residential servicing 6–100 residences, and (2) large residential serving 100+ residences (MOECP 2021).

[29] Many municipalities do not archive documents for longer than 6 years, making it difficult to obtain the requested documents in some cases. Additionally, some small municipalities lacked the capacity to search for documents for us. In cases where a municipality was unable to provide any of the requested documents for these reasons, we sought a knowledgeable contact who could confirm the information we required by phone or email. A municipal contact was used for approximately 2.8% of the water systems included in our regressions: 20 of 710.

[30] FedNor is the Canadian federal government's economic development agency for northern Ontario.

[31] This distance was calculated as the straight-line distance from the boundary of the community to the centroid of the neighbor in kilometers.

sharing and water quality. The equations also include a variable identifying water systems with exclusively secure groundwater supply. This type of variable is included in previous U.S. studies examining drinking water quality (Wallsten and Kosec 2008). Access to secure groundwater is also expected to influence the likelihood that a community will seek out potable water from a neighbor; that is, access to a secure groundwater source may improve local water quality and security, reducing the likelihood of WSA participation. One variable that is included in the WSA model (equation [6]) and not the DWA model (equation [5]) of the bivariate probit estimation is a measure of community size. We believe communities with larger areas may have greater access to potential water sources, and this measure may be inversely associated with participation in a WSA. This variable is excluded from equation [5], because we do not expect the area of a community to influence the performance of a specific drinking water system after controlling for other covariates.

For additional sensitivity, we create a dummy variable, FEAS, that identifies water systems located in communities that are within a feasible distance to a potential water-sharing partner. We use this variable to assess the sensitivity of our base probit regression results (probit estimations of equations [3] and [4]) to limiting our samples to only communities that have potential water-sharing partners within this feasible distance. As with the remoteness variable, this dummy variable was generated based on distances calculated using GIS software and 2006 census subdivision boundary files for each community in our data set (Statistics Canada 2019a). We define this feasible distance as the maximum distance between two communities where water sharing was taking place (measured as the straight-line distance from recipient boundary to supplier centroid). This maximum distance was approximately 21.8 km between Whitefish Lake First Nation and the city of Sudbury.

For a final sensitivity variable, we include a dummy variable, FNLMA, in our probit and biprobit model estimations for the First Nations subset of the data. This variable identifies water systems located in communities governed by First Nations that are signatory to the FA. As discussed, under the FNLMA, opting into this framework allows First Nations to opt out of certain sections of the 1985 Indian Act and develop their own land codes. The Lands Advisory Board of the First Nations Land Management Resource Centre provides a list of current FA signatories on their website (LAB 2022), which we use to identify Ontario signatories in our data set.

## 5. Empirical Results

Figure 2 provides comparisons of the prevalence of DWAs for water systems supplied through WSAs and those with independent supply. These comparisons are made for all water systems included in our regression analysis (top panel), municipal water systems included in our regression analysis (middle panel), and First Nations water systems included in our regression analysis (bottom panel). The top panel comparison shows that water systems supplied through WSAs have a much lower DWA prevalence: 6%, compared with a 17% prevalence for systems with no water sharing. The middle and bottom panels make it clear that this difference is driven by First Nations water systems. The middle panel shows that municipal water systems supplied through WSAs have an almost identical DWA prevalence as municipal water systems with no water sharing, at 6% and 5%, respectively. Comparably, the bottom panel shows that First Nations water systems supplied through WSAs have a much lower prevalence of DWAs: 11%, compared with a 50% prevalence for First Nations water systems with no water sharing. These summary data are consistent with our first hypothesis that municipal water systems would have fewer DWAs than First Nations water systems.

Table 1 provides summary data for all the variables included in our regression analyses, including sensitivity analyses. These summary data are presented for all water systems, municipal water systems, and First Nations water systems. As expected, there are key differences in important variables when comparing municipal and First Nations community characteristics. For example, the mean population density measure (in persons per square

**Figure 2**

Proportion of Water Systems with Drinking Water Advisories Reported in 2009–2010: Regression Sample Showing All Systems, Municipal Systems, and First Nations Systems

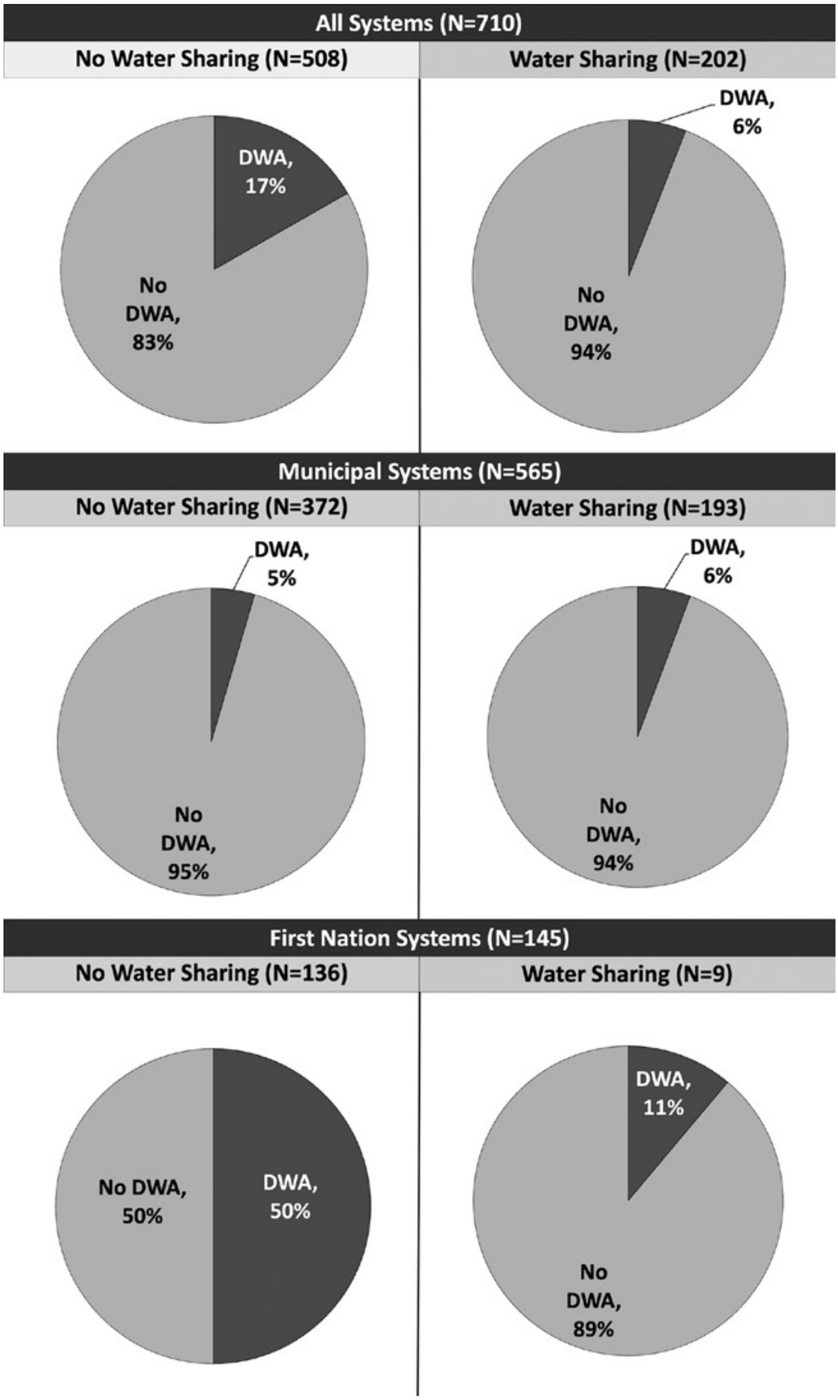


**Table 1**

Regression Summary Statistics: All Systems, Municipal Systems, and First Nations Systems

| | All Systems ($N$=710) | | | Municipal Systems ($N$=565) | | | First Nations Systems ($N$=145) | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Mean (SD) | Min. | Max. | Mean (SD) | Min. | Max. | Mean (SD) | Min. | Max. |
| Drinking water advisory in effect during study period (*DWA*) | 0.137 (0.344) | 0 | 1 | 0.050 (0.217) | 0 | 1 | 0.476 (0.501) | 0 | 1 |
| System is supplied through a water-sharing arrangement (*WSA*) | 0.285 (0.451) | 0 | 1 | 0.342 (0.475) | 0 | 1 | 0.062 (0.242) | 0 | 1 |
| Host community is located in northern Ontario (*NORTH*) | 0.311 (0.463) | 0 | 1 | 0.168 (0.374) | 0 | 1 | 0.869 (0.339) | 0 | 1 |
| Host community is ≤5 km from closest neighbor with water infrastructure (*dumdis1*) | 0.563 (0.496) | 0 | 1 | 0.641 (0.480) | 0 | 1 | 0.262 (0.441) | 0 | 1 |
| Host community is >5 km and ≤10 km from closest neighbor with water infrastructure (*dumdis2*) | 0.277 (0.448) | 0 | 1 | 0.281 (0.450) | 0 | 1 | 0.262 (0.441) | 0 | 1 |
| Natural log of host community population density (100s/km$^2$) (*lnPOPDEN*) | –0.999 (1.623) | –5.809 | 3.682 | –0.746 (1.605) | –5.809 | 3.682 | –1.984 (1.285) | –5.521 | 1.415 |
| Area of host community (km$^2$) (*AREA*) | 530.75 (763.16) | 0.093 | 3,200.56 | 653.43 (810.46) | 2.109 | 3,200.56 | 52.73 (76.48) | 0.093 | 412.97 |
| Natural log of regional (census division) median income (CA$1,000s) (*lnINC*) | 3.264 (0.099) | 2.990 | 3.568 | 3.283 (0.094) | 2.990 | 3.568 | 3.192 (0.083) | 2.990 | 3.466 |
| System is supplied exclusively by groundwater sources (*GW*) | 0.415 (0.493) | 0 | 1 | 0.453 (0.498) | 0 | 1 | 0.269 (0.445) | 0 | 1 |
| System is classified as "large residential" (100+ connections) (*LARGE*) | 0.686 (0.464) | 0 | 1 | 0.775 (0.418) | 0 | 1 | 0.338 (0.475) | 0 | 1 |
| Host community is within feasible distance to potential water-sharing partner (*FEAS*) | 0.910 (0.287) | 0 | 1 | 0.975 (0.156) | 0 | 1 | 0.655 (0.477) | 0 | 1 |
| Host community is a First Nations First Nations Land Management Act signatory (*FNLMA*) | — | — | — | — | — | — | 0.400 (0.492) | 0 | 1 |

**Table 2**
Probit Regression Results, Average Marginal Effects Reported: Municipal and First Nations Subsets (Equation [3]) and Full Sample with Interaction Effect (Equation [4])

| Variable | First Nations Water Systems (*N*=145) | Municipal Water Systems (*N*=565) | Full Sample with Interaction Effect (*N*=710) |
|---|---|---|---|
| System is supplied through a water-sharing arrangement (*WSA*) | –0.438*** | 0.034 | –0.075** |
| | (0.086) | (0.027) | (0.030) |
| System is located in a First Nations community (*FN*) | — | — | 0.218*** |
| | | | (0.054) |
| System is located in a First Nations community and supplied through a water-sharing arrangement (*FN* × *WSA*) | — | — | –0.331***[a] |
| | | | (0.086) |
| Host community is located in northern Ontario (*NORTH*) | 0.090 | 0.056* | 0.069* |
| | (0.136) | (0.031) | (0.038) |
| Host community is ≤5 km from closest neighbor with water infrastructure (*dumdis1*) | –0.139 | –0.018 | –0.051 |
| | (0.129) | (0.029) | (0.036) |
| Host community is >5 km and ≤10 km from closest neighbor with water infrastructure (*dumdis2*) | –0.080 | –0.019 | –0.034 |
| | (0.121) | (0.026) | (0.034) |
| Natural log of host community population density (100s/km$^2$) (*lnPOPDEN*) | –0.022 | 0.003 | –0.002 |
| | (0.037) | (0.006) | (0.009) |
| Natural log of regional (census division) median income (CA$1,000s) (*lnINC*) | 1.580*** | –0.184 | 0.138 |
| | (0.601) | (0.118) | (0.170) |
| System is supplied exclusively by groundwater sources (*GW*) | –0.334*** | –0.069*** | –0.127*** |
| | (0.094) | (0.026) | (0.029) |
| System is classified as "large residential" (100+ connections) (*LARGE*) | –0.040 | 0.034* | 0.012 |
| | (0.100) | (0.019) | (0.027) |
| Pseudo *R*-squared | 0.1398 | 0.1538 | 0.3338 |

*Note:* Standard errors are in parentheses and are clustered by census subdivision (i.e., community housing the water system). The dependent variable equals 1 if the drinking water advisory was in effect at some point during the study period (2009–2010), 0 otherwise.
[a] Stata does not generate marginal effects for interaction terms (in our case, i.WSA##i.FN) using the standard "margins" command. The marginal effect for this interaction term was calculated separately using the following command: margins WSA, dydx(FN) pwcompare(effects). This marginal effect compares First Nations water systems supplied through water-sharing arrangements to First Nations water systems that are independently supplied.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

kilometer) for the municipalities hosting water systems in our regressions is 209, and for First Nations communities hosting water systems it is 34. In addition, 87% of First Nations water systems in our regressions are located in northern Ontario communities, compared with only 17% of municipal water systems.

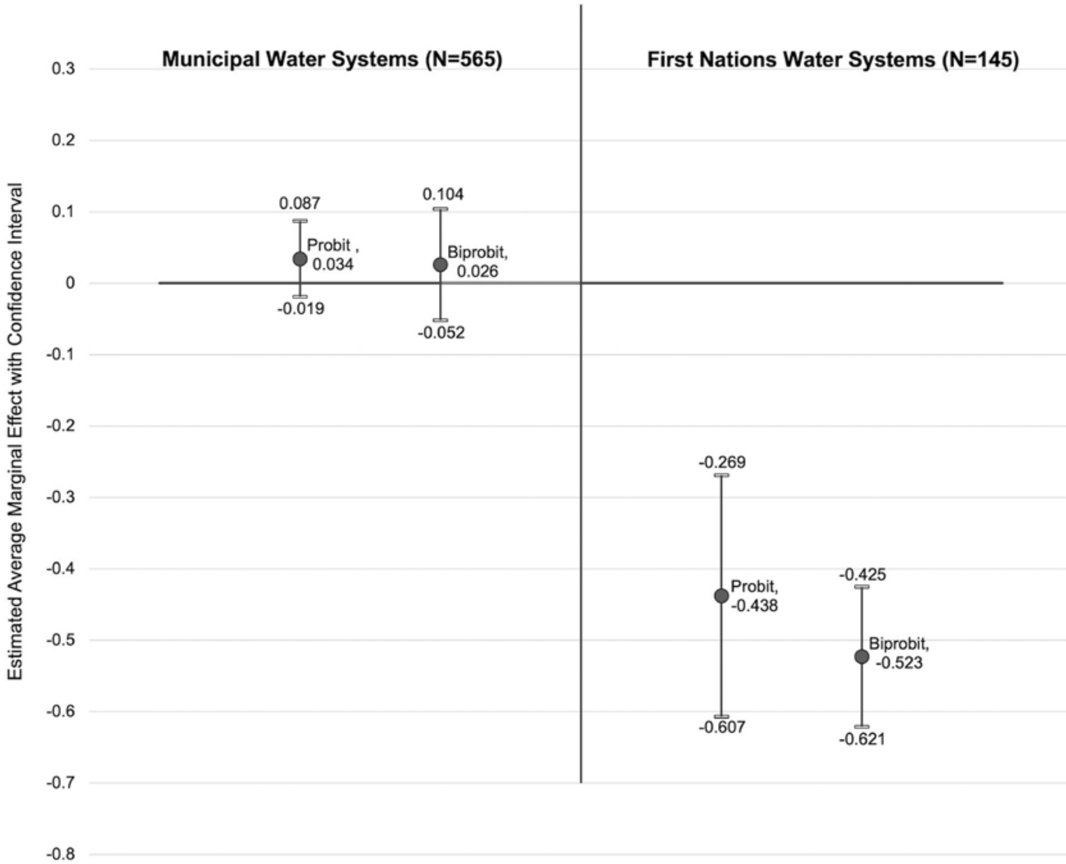
We estimate equation [3] in two separate probit models for municipal and First Nations water systems in our data set. We estimate equation [4] on the full sample. Table 2 provides a comparison of the average marginal effect estimates for the results of these three key base probit regressions.

Supplementary to this table are two figures highlighting our key findings for the WSA effect. Figure 3 highlights the key results from our probit estimations of equation [3]; it provides a visual of the average marginal effect point estimates for the key variable, *WSA*, for municipal and First Nations water systems with 95% confidence intervals. Figure 4 displays predictive margins for the DWA outcome estimated in equation [4], for WSA = 0 and WSA = 1 for municipal and First Nations water systems (generated from our interaction effect, *FN* × *WSA*). As these figures help demonstrate, a WSA is associated with a significant decline in the likelihood of a DWA for First Nations water systems. However, the WSA effect is not significant—statistically or economically—for municipal water systems.

Comparing results for equation [3], presented in Table 2: WSAs are associated with a 44 percentage point decrease in the likelihood of a DWA for First Nations water systems. This result is significant at the 1% level. Comparably, the marginal effect on the WSA variable in the municipal probit is much lower, at 0.034, and not statistically significant. In our probit estimation of equation [4], we find (as expected, and consistent with

**Figure 3**

Average Marginal Effect of Water-Sharing Arrangements: Probit and Biprobit Model Estimations on Municipal and First Nations Data Subsets

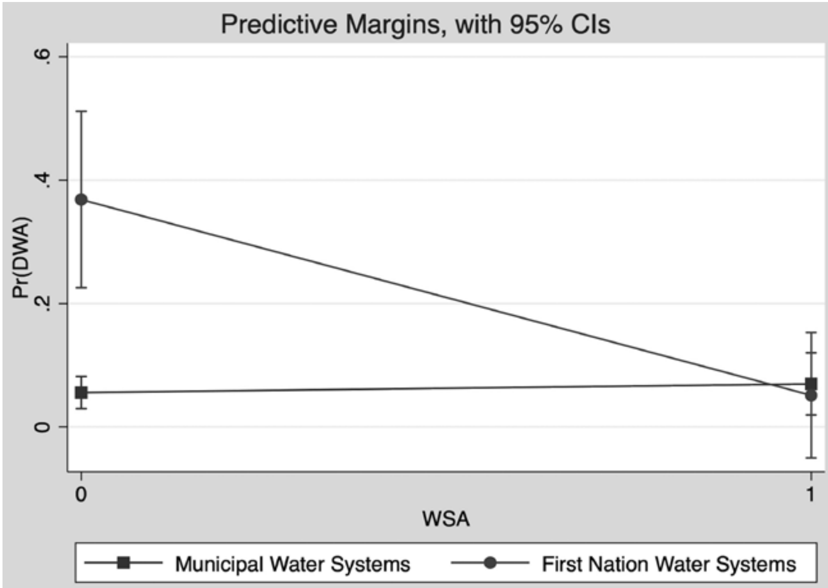



our first hypothesis) that First Nations water systems are more likely to experience DWAs. The marginal effect on FN can be interpreted to indicate that First Nations water systems are 22% more likely to experience DWAs, and this finding is significant at the 1% level. The marginal effect on WSA can be interpreted to indicate that participation in a WSA reduces the likelihood of DWA for all water systems in our sample overall by approximately 8%. This result is significant at the 5% level. The marginal effect on the interaction variable, *FN* × *WSA*, indicates that First Nations water systems supplied through WSAs are approximately 33 percentage points less likely to be under a DWA compared to independently supplied First Nations water systems. Overall, these results are consistent with our expectation that the WSA effect would be large for First Nations water systems but muted for municipal water systems.

In all three base probit regressions, secure groundwater sources are associated with reduced DWAs. This result is significant at the 1% level across all three models. Importantly, the magnitude of this result is much greater for First Nations water systems. First Nations water systems supplied exclusively by secure groundwater sources are approximately 33 percentage points less likely to experience a DWA. For First Nations water systems only, regional income was found to be a significant factor influencing DWAs. This variable was positive and statistically significant at the 1% level, and the marginal effect estimate can be interpreted to indicate that a CA$1,000

**Figure 4**

Predictive Margins for Water-Sharing Arrangements: Municipal and First Nations Water Systems






increase in regional (census division) median income is associated with an approximately 1.6 percentage point increase in the likelihood of a DWA. This finding indicates that water systems hosted by First Nations communities in wealthier regions were more likely to experience DWAs. In assessing this effect, it is important to keep in mind that this income variable is a regional and is used because income data for many First Nations communities are not available through the census.[32] We did not expect that this result would be positive; the negative sign in the municipal regression is more consistent with our a priori expectations (thought that result is not statistically significant).

For the municipal subset of the data, there were some additional findings regarding geographic location and water system scale; these findings were much less robust than those described above. A water system in a northern Ontario municipality was approximately 6 percentage points more likely to be under a DWA, and this result was statistically significant at the 10% level. In the full sample estimation of equation [4], this result was also significant at the 10% level with a marginal effect of 0.069. However, this result was likely driven by municipal observations, as the First Nations probit estimation of equation [3] produced a positive but insignificant marginal effect for this variable. Large municipal water systems were also found to be approximately 3% more likely to have a DWA in effect, and this result was significant at the 10% level.

## Sensitivity Analyses

We assess the sensitivity of our key finding—that WSAs reduce the likelihood of DWAs for First Nations—to the following: (1) bivariate probit estimations of our three key model specifications (outlined in equations [5] and [6]), (2) the limitation of our probit regression samples to communities within a feasible distance to a potential water-sharing partner, and (3) the inclusion of a variable capturing signatories to the FA (First Nations

[32]The correlation between this regional median income variable and community-level median income for the subset of First Nations water systems in our regression analysis with available community-level income data (only 46.8%, due to missing census data), is 0.05. In contrast, the correlation between this regional median income variable and municipal median income (available for 99.8% of municipal water systems, all but one) is 0.63.

**Table 3**
Sensitivity Analyses, Average Marginal Effects Reported: Summary of Key Findings Compared with Base Probit Models

| | | Marginal Effect on Water-Sharing Arrangements | Marginal Effect on First Nations Water-Sharing Arrangements[a] |
|---|---|---|---|
| First Nations water systems | Base probit model (*N*=145) | −0.438*** (0.086) | — |
| | Sensitivity 1: bivariate probit estimation (*N*=145) | −0.523*** (0.050) | — |
| | Sensitivity 2: feasible distance Sample (*N*=95) | −0.382*** (0.074) | — |
| | Sensitivity 3: addition of FNLMA variable (*N*=145)[b] | −0.439*** (0.093) | — |
| Municipal water systems | Base probit model (*N*=565) | 0.034 (0.027) | — |
| | Sensitivity 1: bivariate probit estimation (*N*=565) | 0.026 (0.040) | — |
| | Sensitivity 2: feasible distance sample (*N*=551) | 0.031 (0.025) | — |
| Full sample with interaction effect | Base probit model (*N*=710) | −0.075** (0.030) | −0.331*** (0.086) |
| | Sensitivity 1: bivariate probit estimation (*N*=710) | −0.101** (0.050) | −0.348*** (0.091) |
| | Sensitivity 2: feasible distance sample (*N*=646) | −0.042* (0.024) | −0.335*** (0.097) |

*Note:* Standard errors are in parentheses and are clustered by census subdivision (i.e., community housing the water system). The dependent variable equals 1 if the drinking water advisory was in effect at some point during the study period (2009–2010), 0 otherwise.
[a] Stata does not generate marginal effects for interaction terms (in our case, i.WSA##i.FN) using the standard "margins" command. The marginal effect for this interaction term was calculated separately using the following command: margins WSA, dydx(FN) pwcompare(effects). This marginal effect compares First Nations water systems supplied through water-sharing arrangements to First Nations water systems that are independently supplied.
[b] Marginal effect from probit model specification reported; result remains consistent when the model is run as a bivariate probit. Full probit and bivariate probit results are provided in Appendix Table A2.3.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Land Management Resource Centre 1996) in the First Nations probit and bivariate probit estimations of equation [3]. Table 3 presents results for each of these sensitivity analyses with respect to our key findings, in contrast with base model results. As this table demonstrates, our key findings remain statistically and economically significant across all model specifications. Across all regressions we find that First Nations water systems supplied through WSAs are significantly less likely to be under a DWA.

As outlined in Section 3, in an effort to control for the potential endogeneity of our WSA variable, our bivariate probit estimation approach included the DWA outcome models discussed above (equation [5]) estimated simultaneously with a second model predicting the likelihood of a WSA (equation [6]). Appendix Table A2 presents full results for these bivariate probit regressions. Figure 3 provides a visual comparison of the marginal effects on the WSA variable in the probit and bivariate probit estimations of our DWA outcome model for the municipal and First Nations subsets of our data with 95% confidence intervals. As this figure demonstrates, the impact of WSA on DWA likelihood is close to zero in both the probit and bivariate probit estimations on the municipal subset of the data (an estimated marginal effect of approximately 0.03 in both sets of results). In contrast, the estimated marginal effect on WSA in the probit and bivariate probit estimations run on the First Nations subset of the data are both negative and statistically significant at the 1% level. These marginal effects can be interpreted as indicating that being supplied through a WSA reduces the likelihood of a DWA for First Nations water systems by between 44 (probit) and 52 (biprobit) percentage points, depending on the model specification.

Equation [4] was also run as a bivariate probit simultaneous with the WSA outcome model. Results were similarly consistent, with probit and bivariate probit marginal effects on the interaction term ($FN \times WSA$) of −0.33 and −0.35, both significant at the 1% level. This indicates that First Nations water systems supplied through WSAs were between 33 and 35 percentage points less likely to be under a DWA compared with independently supplied First Nations water systems, depending on the model specification. The bivariable probit estimation of equation [4] also produced results for FN and WSA that were relatively consistent with the probit estimation: marginal effects of approximately 0.23 (at the 1% significance level) and approximately −0.10 (at the 5% significance level), respectively.

For all three bivariate probit estimations, a Wald test of $\rho$ (the correlation between the error terms of the two model equations) did not produce a significant result. Until recently, this finding may have led us to fail to reject the null hypothesis that $\rho = 0$ and conclude that WSA is exogenously determined in all models. In this case, the univariate probit estimation approach would be the preferred estimation method. However, as Filippini et al. (2018) point out, if one suspects that a recursive data-generating process exists, then a zero $\rho$ is not enough evidence to support exogeneity.[33] For this reason, we provide the bivariate probit results for comparison with the probit results. Again, and importantly, our estimation of the WSA effect is consistent for both approaches across all three models. The signs and significance of all other key findings across the models are consistent across both estimation approaches.

We test the robustness of our base probit regression results to the limitation of our samples to communities that are within a feasible distance to a potential water-sharing partner. Full results of these regressions are presented in Appendix Table A3. Again, our key finding remains unchanged: WSAs are still found to reduce the likelihood of DWAs for First Nations water systems in the First Nations probit and the full sample probit with the interaction effect, at a significance level of 1% in each regression. In the full sample probit, First Nations water systems were still found to be more likely to be under DWA, a marginal effect very similar in magnitude to the base probit regression (approximately 0.22), also at a significance level of 1%. Limiting the regression sample to only communities with feasible water-sharing partners on the full sample probit did reduce the strength of the result on the WSA variable—from a 1% significance level to a 10% significance level—and reduced the marginal effect by approximately half, from approximately 0.08 to approximately 0.04.

As a final sensitivity test, we run the probit and bivariate probit regressions again for the First Nations subset and include an additional variable: FNLMA. These results are overviewed in Table 3 and provided in full in Appendix Table A4. This variable identifies signatories to the FA (First Nations Land Management Resource Centre 1996), communities that may have a greater state capacity as indicated by their desire to opt out of certain sections of the 1985 Indian Act and develop their own land codes. Including this variable in our analysis did not change our key finding. WSAs are still found to reduce DWA likelihood by 44 (probit) to 52 (bivariate probit) percentage points, depending on the model specification. A Wald test of $\rho$ indicates that the bivariate probit results may be the most robust, however, results are consistent across both estimation approaches. In the probit and bivariate probit regressions, FNLMA was negative and significant at the 5% level. The respective marginal effects indicate that being signatory to the FNLMA reduces the likelihood of a DWA by approximately 27 percentage points (probit) to 24 percentage points (bivariate probit), depending on the model. Findings for regional income and groundwater supply remain consistent in both regressions as well.

[33] See Filippini et al. (2018) for a full discussion of this issue.

## 6. Conclusion

First Nations and municipalities in Canada are distinguished by key institutional differences that are pronounced and long standing. With respect to the monitoring and regulation of drinking water systems, municipalities are networked by the province per force of law. First Nations are not similarly networked with the province for a host of important reasons we discussed earlier. That said, some First Nations drinking water systems are supplied with treated water by neighboring municipal water systems. In these cases, we suggest that First Nations simultaneously access both treated water and the institutional capacity of the province.

We find that First Nations drinking water systems in Ontario are more likely than municipal water systems to experience a DWA. Our empirical results suggest that WSAs enhance drinking water quality for recipient First Nations water systems. We do not find that WSAs between municipalities meaningfully influence the prevalence of DWAs for the recipient municipal systems. We attribute this result to the fact that all municipal drinking water systems are already governed by provincial standards and regulations.

This study provides an important first step into an undertapped area of research. Theoretical, empirical, and case study research remains an important area of inquiry.[34] There are also opportunities to study these issues in the United States. Institutional differences between the United States and Canada may support expanded insight into the issue of water sharing and water quality. Moreover, there remains a need for case studies and an ongoing assessment of the state capacity arguments offered in this article. For example, on November 7, 2022, the Atlantic First Nations Water Authority (AFNWA) became the first Indigenous water utility in Canada. The AFNWA has an expanded scope of responsibility to coordinate water and wastewater system for those First Nations that choose to participate. Ongoing efforts to assess the extent and manner by which AFNWA influences drinking water quality outcomes may support greater insight into the variety of alternative institutional arrangements available to First Nations.[35]

From the perspective of policy, we hope our results will encourage leaders from First Nations, the federal government of Canada, the province of Ontario, and municipalities to explore the potential of increased transactions between communities, where mutually beneficial partnerships may exist. Though many First Nations in Ontario are too remotely located to consider a WSA, many have potential WSA partners in neighboring municipalities. During the time period we study, there were at least 36 First Nations drinking water systems under a DWA within what we determine to be a feasible distance to a potential municipal donor—approximately 23% of the total number of First Nations water systems in our data set.

Importantly, even where feasible, WSAs may not be desirable for all First Nations communities. There are many challenges, including concerns regarding autonomy and funding obligations that may not be easily generalized. Similarly, though less explored in this article, municipalities may have concerns regarding interjurisdictional exchanges. Hence, although our results indicate that these exchanges may enhance quality, we recognize the many complexities associated with these situations. However, in cases where First Nations are interested in exploring WSAs, a better understanding of the costs and barriers may encourage mutually beneficial exchanges.

To that end, future research can better assess the many transaction costs that complicate the potential for Coasian bargains between First Nations and nearby municipalities with respect to service provision. These costs are likely to be exacerbated by historical,

[34] To support ongoing and future inquiry into this area, we provide our data and a description of our metadata at https://doi.org/10.5683/SP3/BE5R96. A more direct link to the data set used to generate the empirical results is available at https://doi.org/10.5683/SP3/VMFJTA. We hope this public data set will support future research in this area and potentially allow researchers to provide improved and updated measures of many of the variables we provide.

[35] See the press release from November 7, 2022, at https://www.canada.ca/en/indigenous-services-canada/news/2022/11/atlantic-first-nations-water-authority-makes-history-as-first-indigenous-water-utility.html.

political, and social issues. For this reason, targeted case studies could play an important role in identifying key issues that need to be meaningfully addressed. Exploring the potential of improved relations between First Nations and municipalities, in a way that appreciates and respects the history, sovereignty, and aspirations of First Nations, is above all the hoped-for outcome of this research.

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