*Cooperation Between First Nations and Municipalities: Do Water Sharing Arrangements Improve Drinking Water Quality?**

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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 Nation 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 Nation systems in a WSA.

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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 (DWS). In the U.S., there are over 148,000 public water systems supplying 90% of Americans with drinking water (EPA, 2021). As of 2016, ninety percent of U.S. water systems met 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 U.S. small – typically rural – water systems have relatively higher per-capita violations than larger systems (EPA, 2011). For the above 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 Nation[1] communities is one of the most pronounced problems confronting Canadian public policy[2]. First Nations people living on reserves[3] do not have access to drinking water that is equivalent in quality to drinking water provided in municipalities. Approximately one-in-eight First Nation communities in Canada are under a boil water advisory at any given time, and the rate of water-borne infections for First Nation 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 individuals living on First Nation reserves in Canada. Water quality concerns in Indigenous communities are not unique to Canada. Wallsten and Kosec (2008) 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…" (p. 193).

Unlike previous literature cited above, we directly assess the performance of municipal and First Nation drinking water systems. In this paper, we evaluate the effect of water sharing arrangements (WSAs) on drinking water quality outcomes. WSAs describe an institutional arrangement whereby a water system in one jurisdiction (the donor) supplies drinking water to a water 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[5] supplied in whole or in part through some form of WSA during their study period of 2009-10. However, the majority of these WSAs occurred between municipalities, with only 10% of First Nation communities in Ontario having a water system supplied through a WSA.

Given the prevalence of WSAs, assessing the WSA effect is relevant to understanding the gains of exchange that undergird many drinking water systems in Ontario, throughout North America, and globally. Among the benefits associated with WSAs are the economies of scale in drinking water treatment that arise from the aggregation of water infrastructure and operations (Boisvert and Schmit 1997; Kim and Clark 1988; 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., larger more efficient treatment systems and technologies) and quality improving operations investments (e.g., monitoring technologies, improved business operations, etc.) (Kim 1985; Kim and Clarke 1988; Abbott and Cohen 2009).

Lipka and Deaton (2015) found that WSAs improve drinking water quality outcomes for recipient First Nation communities across Canada. They also found that a number of independently supplied First Nation communities (some with poor drinking water conditions) are in close proximity 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 are shown to 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 "[w]holesale water providers hav[ing] greater *capacity* to achieve regulatory compliance" (pg. 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 cited above, the relationship between state capacity and drinking water violations appears to be an important area for future research in the United States.

In our study of WSAs in the Canadian province of Ontario in the years 2009-2010[6], we find that municipalities frequently shared water with each other, and less frequently shared water with neighbouring First Nation communities. During our study period, 41% of municipalities were receiving water through a WSA, compared to only 10% of First Nation 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 paper is that it characterizes water services in both municipal and First Nation communities within the province of Ontario. This allows for a first ever empirical assessment of the impact of WSAs on quality outcomes for both municipal and First Nation water systems residing within the same province. The importance of this inter-provincial comparison, and the associated institutional issues, are developed below and throughout the paper.

The institutions governing drinking water in First Nation communities and in 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 Nation water systems supplied through WSAs; and (3) independently supplied municipal and First Nation water systems. WSAs between municipalities are classified as 'intra-jurisdictional'. Ontario municipalities are all 'creatures' of the province, local governing units networked together via provincial legislation through shared forms of governance. More specifically, as we detail in the next

section, Ontario municipalities are networked through provincial water quality standards and enforcement in critical ways that generate benefits with respect to drinking water. In contrast, WSAs between municipalities and First Nations can be classified as 'inter-jurisdictional'. A key characteristic distinguishing First Nations from Ontario municipalities is their status of nationhood. Each First Nation has a unique nation to nation relationship with the federal government.[8] Hence, First Nations are not networked together via provincial legislation in the manner that municipalities are. First Nations exist independent of the province, and independent of each other, individually governed under the constraints of the federal *Indian Act* (1985). Because they operate in an entirely different institutional environment from municipalities, when a First Nation is on the receiving end of a WSA, that WSA is best understood as an 'inter-jurisdictional' 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. These institutional details are developed in Section 2. Our conceptualization of these differences 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 historic 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 and depending on the specific infrastructure being examined (i.e., roads, water, etc.). Put simply, 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 similar, in general terms, to the discussion provided by Acemoglu et al. (2015). Our measure of state capacity, however, is primarily institutional and differs from Acemoglu et al. (2015) who measure state capacity by the number of agencies or employees in a

municipality.[9] 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?* And, *does the WSA effect depend on whether the recipient system is a First Nation water system, or a municipal water system?* As we explain in the sections that follow, we hypothesize that WSAs do in fact 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 or not they are engaged in a WSA.

In Sections 2, 3 and 4 we develop our method. Section 2 provides background on key institutional differences between drinking water standards and enforcement in municipalities and First Nation communities. 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 then between municipalities and First Nations. In Section 3, we draw from the basic ideas developed by Acemoglu, Garcia-Jimeno and Robinson (2015) to develop our econometric approach. In Section 3.1, we explain the ways we try to address a potential identification challenge in our analysis. Section 4 provides an overview of our unique data set. Section 5 provides summary data for key variables and reports our regression results. Section 5.1 reports the results of sensitivity analyses we have run to address issues raised in Section 3.1. As expected, our empirical results suggest that the WSA effect significantly improves drinking water quality outcomes for First

Nation 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

In this section we provide some key background information regarding institutional and legislative differences in drinking water quality standards and enforcement for First Nation communities and municipalities in the Canadian province of Ontario. While a full analysis of these differences is beyond the scope of this paper, 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 World Health Organization's recommendation to have a legally enforceable federal drinking water quality standard (Dunn, Bakker and Harris, 2014).[10] Instead, Canadian provinces 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 the province of Ontario, these drinking water quality 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 Nation communities and Ontario municipalities.

Figure 1 helps to simply illustrate these differences. As the figure indicates, the relationship between the province of Ontario and Ontario 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. In contrast, First Nations are in a nation to nation relationship with the federal government, have no formal or hierarchical relationship with the province, and are not subject to provincial laws. Instead, each First Nation has a unique and distinct relationship with the federal government under the constraints of the *Indian Act* (1985), which

governs First Nations in Canada. While the *Indian Act (1985)* does make reference to water, it does not explicitly define federal or First Nations' responsibilities with respect to drinking water (Alcantara, Longboat and Vanhooren, 2020).[11] 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[12].

[[Insert Figure 1 here.]]

In the province of Ontario, the Ministry of the Environment, Conservation and Parks (MOECP)[13] serves as the third-party enforcer of provincial water quality standards under the *Safe Drinking Water Act (2002)*; and together with Public Health Ontario (PHO) provides municipalities with resources for monitoring, enforcement and remediation of 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[14] (PHO, 2022). Municipalities are required by law to report adverse sampling results to both 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* (INAC, 2010) 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 pp. 2). First Nation Bands are responsible for providing training to water system operators, and operators are responsible for implementing sampling and testing procedures. While municipalities benefit from the economies of scale provide by provincially established standards and inspection and sampling protocols, individual First Nations must take on the bulk of the costs of monitoring and enforcement of 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 the province of Ontario, the provincial standards are more stringent (Dunn et al., 2014). However, as adoption of the provincial standards is not legally enforced, First Nations that choose to adopt the standards do so voluntarily (Alcantara, Longboat and Vanhooren, 2020). And while their protocol contains some quality assurance recommendations – specifically related to asset inspections – these are also not legally enforced. Hence, each First Nation is primarily responsible for their 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, non-tax revenue (e.g., parking fines, bylaw fines, etc.) and provincial transfers through the Ontario Municipal Partnership Fund (AMO, 2022a, 2022b). In contrast, First Nations primarily rely on federal transfers as well as limited own source revenues (FMB, 2020). Some provinces, including the province of Ontario, have made funding available to First Nations through specific programs aimed at economic development initiatives (FCM, 2022; MIA, 2022).[15] However, these provincial transfers, generally awarded on a programmatic basis to successful applicants, make up a very small portion of total government transfers to First Nations (an estimated 12% federally in 2020) (FMB, 2020). A great deal of research argues that First Nation communities are under-funded with respect to needs by the Canadian federal government (Auditor General of Canada, 2011; White, Murphy and Spence, 2012; Black and McBean, 2017a, 2017b; Alcantara et al., 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 (2006)* established a regulatory framework for source water protection planning. 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 in order 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 Nation 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 First Nation communities. For the 2008-09 fiscal year, the year preceding our study period, Health Canada reported that water in First Nation communities was tested less often than recommended under the Canadian Guidelines for Drinking Water Quality (CGDWQ); and more specifically, only 40% of community sites conducted bacteriological sampling at the recommended frequency (Auditor General, 2011). During our study period of 2009-10, approximately 46% of First Nation 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

Both First Nations and municipalities may enter into WSAs, though they are far more prevalent amongst municipalities (Deaton and Lipka, 2021). There are many factors that may prevent a First Nation from engaging in a WSA, some more directly measurable than others. In terms of measurable factors, Deaton and Lipka (2021) find northerness, 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, for example, 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 historic 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 U.S. (Trosper, 1978; Carlson, 1981; Anderson and Lueck, 1992; Alcantara, 2007; Anderson and Parker, 2009; Aragón, 2015; Anderson and Parker, 2017; Aragón and Kessler, 2020; Frye and Parker, 2021). For example, in the U.S., 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 American reservations was positively correlated with income growth. At the same time, the authors acknowledge the historic role that federal control over land and resources has played in stunting development on American 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 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 the provision of drinking water (Baijius and Patrick, 2019). While participation in a WSA may be viewed as a potentially cost-effective water provision solution for some First Nation communities, participation in a WSA may also be viewed as the downloading of this water provision responsibility from the federal 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 Nation water systems. Second, we expect First Nation 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, since 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. Put differently, 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 Nation 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 then develop that model in a manner that mirrors the presentation of our empirical results. A simple model characterizes the performance of a water system as follows:

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

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 neighbour via a WSA. If a WSA allows a First Nation water system to tap into the state capacity of the province, then state capacity is expected to be greater for First Nation water systems that are engaged in a WSA, compared to those that are independently supplied. (In the previous section, we developed arguments consistent with this expectation.) Of course there are a host of other factors that 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:

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

Given the above 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:

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

We discuss our identification concerns more fully below, but Equation 3 allows us to clarify our main hypotheses regarding the WSA effect. For First Nation 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 paper, then we hypothesize: $\lambda_{FN} < 0$. Put differently, WSAs are expected to reduce the likelihood of poor performance for First Nation water systems. Our hypothesis for municipal systems, however, is less clear. As discussed, municipalities all already access – or alternatively put, 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 intra-municipality WSAs. Therefore, we would expect the magnitude of λ_{mun} to be small. We begin by estimating Equation 3 using separate probit models for First Nation and municipal water systems.[16] Next, and appreciative of the caveats discussed in the following section, the data are pooled to estimate the regression below:

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

In the pooled regression we expect α to be positive, β to be insignificant, and τ to be negative. Again, we hypothesize the marginal effect on the interaction term, *FN*WSA*, to be negative based on the idea

that when a First Nation 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 above 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 both their participation and subsequent water system performance. In this case, the estimated $\hat{\beta}_{FN}$ may conflate the state capacity of the First Nation itself with the state capacity afforded by the province through WSA participation. Since 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)):

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

$$WSA_{i,j}{}^* = \gamma x''_i + \mu z''_{i,j} + v_{i,j}, \quad WSA_{i,j} = 1[WSA^* > 0] \quad [6]$$

The error terms, u and v, are assumed to follow a bivariate normal distribution. As with the probit regressions described above, we estimate bivariate probit models for First Nation and municipal water systems separately. We then compare our estimates of β_{FN} and β_{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 that follows. (For a complete list of variables included in our analysis, see Table A1 of Appendix A.)

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, socio-economic, 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, limiting our original probit regression samples to only those drinking water systems that are 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 that follows.

While the bivariate probit approach addresses issues associated with selectivity bias, we remain concerned that there are other omitted variables that may influence state capacity and be correlated with both WSAs and DWAs. For this reason, we include a third and final sensitivity examining how our key results for the First Nation 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.[17] The FNLMA allows First Nations who become signatory to the FA to opt out of certain provisions of the *Indian Act* (1985) 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 the inclusion of 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 a

First Nation having a mix of independent and WSA supplied drinking water systems.[18] Hence, community-level fixed effects cannot be used to address omitted variable issues. Further, as discussed earlier, 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 in the next section, 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 socio-economic situations that might vary across the communities we observe.

Given these concerns, this paper 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 is available. For example, the United States Environmental Protection Agency (EPA) makes detailed longitudinal water system and quality data available through the Safe Drinking Water Information System (SDWIS) Federal Reporting Services (EPA, 2022).[19] 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 Nation water systems, and 565 municipal water systems – as well as their surrounding communities. Figure A1 in Appendix A 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 is from the years 2009 and 2010. In the remainder of this section, we provided a brief overview of key variables included in our analysis.[20] We place particular emphasis on our discussion of

the collection of water system data, specifically our key variable of interest: drinking water advisories (DWAs).

Drinking Water Advisories (DWAs)

There are significant data gaps in Canada with respect to DWAs. Despite the improvement of water quality in First Nation 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 Nation communities and municipalities during our study period of 2009-2010.[21] As 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 Nation and municipal water systems. Importantly, this variable – DWA – was identically defined for both First Nation 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 off of 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 Nation water systems was taken from the *Ontario Regional Roll-up Report* of the Neegan Burnside (2011) *Survey of First Nations Water and Wastewater Systems*, which took place between 2009 and 2010. This survey is the only detailed Canada-wide inspection of First Nation water systems[22] to ever take place, 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 Nation water system at the time it was surveyed. No similar survey exists that allows us to identify municipal DWAs during the same time period. The Ontario *Chief Drinking Water Inspector's Report* (Stager, 2011) from 2009-2010 indicates municipal water system compliance with provincial standards, and water system inspection ratings; but it does not provide DWA data. Our municipal DWA data was provided by the organization Water Today (2021), an independent ad-based media group with a key

focus on DWAs. Municipal DWA data for the study period of 2009-2010 was collected by Water Today (2021) 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 (2021) 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 Nation water system at the time that the system was visited (with site visits taking place in September and October of 2009, and May through 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; and in that case, it would not be noted in the data. In contrast, Water Today (2021) provided us with a list of municipal DWAs that were publicly reported between 2009-2010, which should reduce the potential for missed advisories. However, Water Today's (2021) municipal DWA data was collected case-by-case via secondary sources, and therefore may be incomplete due to human error or missing information.

Water System and Community Characteristics

First Nation water system data are taken from the same Neegan Burnside (2011) report described above. In addition to DWA data and other quality indicators, this report provides detailed water system characteristics for each First Nation 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 *2009/10 Chief Drinking Water Inspector's Report (CDWIR)* for Ontario (Stager, 2011). The municipal owners of these systems were then contacted, and we requested water system documentation[23] that would allow us to identify key system characteristics, such as: ownership, source water (i.e., groundwater, surface water, etc.), supply information (i.e. independent supply or WSA), and general scale information (i.e., large or small

system).[24]. In cases where no relevant system documents were available, a municipal contact was used to confirm the water system details we required.[25]

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[26] (2017). Census characteristics taken 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 kilometers or less from the closest neighbour with water infrastructure (measured from boundary to centroid), and 2) water systems located in communities that are greater than 5 kilometers but less than or equal to 10 kilometer from the closest neighbour with water infrastructure. These distances were calculated using GIS software and 2006 Census subdivision boundary files (Statistics Canada, 2019a).[27] 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 above, as a sensitivity to address the potential endogenous determination of the WSA variable, we run each of our probit models 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 both Equations 5 and 6. Both models include community northerness, population density, and median regional income. These community characteristics are expected to influence both 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. And 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 sharing and water quality. Both 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 (Wallsteen and Kosec, 2008). Access to secure groundwater is also expected to influence the likelihood that a community will seek out potable water from a neighbour – i.e., 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 therefore 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 an 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 21.8km, between Whitefish Lake First Nation and the City of Sudbury.

As a final sensitivity we include a dummy variable, *FNLMA*, in our probit and biprobit model estimations for the First Nations subset of our data. This variable identifies water systems located in communities governed by First Nations that are signatory to the *Framework Agreement* (FA) *on First Nation Land Management* (1996). As discussed above, under the *First Nations Land Management Act* (FNLMA) (1999), opting into this framework allows First Nations to opt out of certain sections of the

Indian Act (1985) 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, in the form of pie charts, of the prevalence of drinking water advisories (DWAs) for water systems supplied through water sharing arrangements (WSAs), and those with independent supply. These comparisons are made for all water systems included in our regression analysis (in the top panel), municipal water systems included in our regression analysis (in the centre panel), and First Nation water systems included in our regression analysis (in the bottom panel). The top panel comparison shows that water systems supplied through WSAs have a much lower DWA prevalence – 6%, compared to a 17% prevalence for systems with no water sharing. The centre and bottom panels of the figure make it clear that this difference is driven by First Nation water systems. The centre 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 Nation water systems supplied through WSAs have a much lower prevalence of DWAs – 11%, compared to a 50% prevalence for First Nation water systems with no water sharing. This summary data is consistent with our first hypothesis that municipal water systems would have fewer DWAs than First Nation water systems.

[[Insert Figure 2 here.]]

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

systems in our regressions is 209, and for First Nation communities hosting water systems it is 34. Additionally, 87% of First Nation water systems in our regressions are located in Northern Ontario communities, compared to only 17% of municipal water systems.

[[Insert Table 1.]]

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

[[Insert Table 2 here.]]

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 the of average marginal effect point estimates for the key variable, *WSA*, for municipal and First Nation 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 Nation water systems (generated from our interaction effect: *FN*WSA*). As both of these figures help to demonstrate, a WSA is associated with a significant decline in the likelihood of a DWA for First Nation water systems. However, the WSA effect is not significant – statistically or economically – for municipal water systems.

[[Insert Figure 3 here.]]

[[Insert Figure 4 here.]]

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 Nation 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 our first hypothesis – that First Nation water systems are more likely to experience DWAs. The marginal effect on *FN* can be interpreted to indicate that First Nation 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 Nation water systems supplied through WSAs are approximately 33 percentage points less likely to be under a DWA compared to independently supplied First Nation water systems. Overall, these results are consistent with our expectation that the WSA effect would be large for First Nation 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 Nation water systems. First Nation water systems supplied exclusively by secure groundwater sources are approximately 33 percentage points less likely to experience a DWA. For First Nation 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 $1000 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 Nation communities located 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 income variable, and is used because income data for many First Nation communities are not available through the Census.[28] 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; though these findings were much less robust than those described above. A water system located in a northern Ontario municipality was approximately 6 percentage points more likely to be under a DWA, and this results 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 Nation 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 *Framework Agreement on First Nations Land Management* (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 described above. As this table demonstrates, our key findings remain statistically and economically significant across all model specifications. Across all regressions we find that First Nation water systems supplied through WSAs are significantly less likely to be under a DWA.

[[Insert Table 3 here.]]

As outlined in Section 3.1, 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). Table A2 in Appendix A 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 Nation 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 Nation subset of our 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 Nation 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*WSA*) of -0.33 and -0.35, both significant at the 1% level. This indicates that First Nation water systems supplied through WSAs were between 33 and 35 percentage points less likely to be under a DWA compared to independently supplied First Nation 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 ρ — 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 Fellipini, et al. (2018) point out, if one suspects that a recursive data generating process exists, then a zero ρ is not enough evidence to support exogeneity.[29] 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 estimation approaches across all three models. The signs and significance of all other key findings across the three models are also consistent across both estimation approaches.

We also 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 Table A3 of Appendix A. Again, our key finding remains unchanged: WSAs are still found to reduce the likelihood of DWAs for First Nation water systems in the First Nation 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 Nation 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 also reduced the marginal effect by approximately half – from approximately 0.08 to approximately 0.04.

As a final sensitivity, we run the probit and bivariate probit regressions again for the First Nations subset, with the inclusion of an additional variable: *FNLMA*. These results are overviewed in Table 3 and provided in full in Table A4 in Appendix A. This variable identifies signatories to the *Framework Agreement on First Nations Land Management* (1996), communities that may have a greater state capacity as indicated by their desire to opt out of certain sections of the *Indian Act* (1985) 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 chosen. A Wald test of ρ indicates that the bivariate probit results may be the most robust, however results are consistent across both estimation approaches. In both 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 chosen. Findings for regional income and groundwater supply remain consistent in both regressions as well.

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 together by the province per force of law. First Nations are not similarly networked with province for a host of important reasons we discussed earlier. That said, some First Nation drinking water systems are supplied with treated water by neighbouring 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 Nation drinking water systems in Ontario are more likely than municipal water systems to experience a drinking water advisory (DWA). Our empirical results suggest that WSAs enhance drinking water quality for recipient First Nation 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 under tapped area of research. Theoretical, empirical, and case-study research remains an important area of inquiry.[30] There are also opportunities to study these issues in the United States. Institutional differences between the U.S. 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 paper. For example, on November 7, 2022, the Atlantic First Nations Water Authority (AFNWA) became the first Indigenous Water Utility in the country. The AFNWA has an expanded scope of responsibility to coordinate water and wastewater system for those First Nations who 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.[31]

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 neighbouring municipalities. During the time period we study, there were at least 36 First Nation drinking water systems under a DWA within what we determine to be a feasible distance[32] to a potential municipal donor – approximately 23% of the total number of First Nation water systems in our data set.

Importantly, even where feasible, WSAs may not be desirable for all First Nation communities. There are many challenges, including concerns regarding autonomy and funding obligations that may not be easily generalized. Similarly, though less explored in our paper, municipalities may have concerns regarding inter-jurisdictional exchanges. Hence, though our results indicate that these exchanges may be quality enhancing, we recognize the many complexities associated with these situations. However, in situations where First Nations are interested in exploring WSAs, a better understanding of the costs and barriers may help to 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 the provision of services. These costs are likely to be exacerbated by historical, 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 manner 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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Tables

Table 1: Regression Summary Statistics – All Systems, Municipal Systems and First Nation Systems

Variable	All Systems (N=710)			Municipal Systems (N=565)			First Nation Systems (N=145)		
	Mean (Std. Dev.)	Min	Max	Mean (Std. Dev.)	Min	Max	Mean (Std. Dev.)	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 <=5km away from closest neighbour 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 >5km and <=10km away from closest neighbour 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	3200.56	653.43 (810.46)	2.109	3200.56	52.73 (76.48)	0.093	412.97
Natural Log of Regional (Census Division) Median Income – $1000s) (*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 Nation FNLMA Signatory (*FNLMA*)	-	-	-	-	-	-	0.400 (0.492)	0	1

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

Variable[b]	First Nation Water Systems (145)	Municipal Water Systems (N=565)	Full Sample with Interaction Effect (N=710)
System is Supplied Through a Water Sharing Arrangement *(WSA)*	-0.438*** (0.086)	0.034 (0.027)	-0.075** (0.030)
System is Located in a First Nation Community (*FN*)	-	-	0.218*** (0.054)
System is Located in a First Nation Community & Supplied Through a WSA (*FN*WSA*)	-	-	-0.331***[c] (0.086)
Host Community is Located in Northern Ontario *(NORTH)*	0.090 (0.136)	0.056* (0.031)	0.069* (0.038)
Host Community is <=5km away from closest neighbour with water infrastructure (*dumdis1*)	-0.139 (0.129)	-0.018 (0.029)	-0.051 (0.036)
Host Community is >5km and <=10km away from closest neighbour with water infrastructure (*dumdis2*)	-0.080 (0.121)	-0.019 (0.026)	-0.034 (0.034)
Natural Log of Host Community Population Density – 100s/km^2 *(lnPOPDEN)*	-0.022 (0.037)	0.003 (0.006)	-0.002 (0.009)
Natural Log of Regional (Census Division) Median Income - $1000s *(lnINC)*	1.580*** (0.601)	-0.184 (0.118)	0.138 (0.170)
System is Supplied Exclusively by Groundwater Sources *(GW)*	-0.334*** (0.094)	-0.069*** (0.026)	-0.127*** (0.029)
System is Classified as "Large Residential" – 100+ Connections *(LARGE)*	-0.040 (0.100)	0.034* (0.019)	0.012 (0.027)
Pseudo R^2	0.1398	0.1538	0.3338

Notes: [a] Standard errors are in parentheses, and are clustered by census subdivision (i.e., community housing the water system). Significance level of result: *** 1% significance level; ** 5% significance level; * 10% significance level.

[b] Dependent variable = 1 if Drinking Water Advisory was in effect at some point during the study period (2009/10), 0 otherwise.

[c] 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 Nation water systems supplied through WSAs to First Nation water systems that are independently supplied.

Table 3: Sensitivity Analyses, Average Marginal Effects Reported – Summary of Key Findings Compared to Base Probit Models[a,b]

		Marginal Effect on *WSA*	Marginal Effect on *FN*WSA*[c]
First Nation 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)[d]	-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)

Notes: [a] Standard errors are in parentheses, and are clustered by census subdivision (i.e., community housing the water system). Significance level of result: *** 1% significance level; ** 5% significance level; * 10% significance level.

[b] Dependent variable = 1 if Drinking Water Advisory was in effect at some point during the study period (2009/10), 0 otherwise.

[c] 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 Nation water systems supplied through WSAs to First Nation water systems that are independently supplied.

[d] 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 Table A2.3.

Figures

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

Figure 2: Proportion of Water Systems with DWAs reported in 2009/10 – Regression Sample: All Systems, Municipal Systems and First Nation Systems

Figure 3: Average Marginal Effect of *WSA* - Probit and Biprobit Model Estimations on Municipal and First Nation Data Subsets

Figure 4: Predictive Margins for *WSA* - Municipal and First Nation Water Systems

Endnotes

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

[2] In 2015, Prime Minister Justin Trudeau made it a campaign promise to end boil water advisories in First Nation communities within five years, if elected (The Canadian Press, 2015). While some progress has been made towards this goal (the details of which can be found here: https://www.sac-isc.gc.ca/eng/1506514143353/1533317130660), Indigenous Services Minister Marc Miller confirmed in December 2020 that the 5 year target would not be met (Stefanovich, 2020).

[3] Reserves are defined by the *Indian Act* (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 Nation] 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 *Indian Act* (1985). Importantly, many First Nations operate under self-governance agreements and have created their own governance systems outside of the constraints of the Indian Act; and many others have separate and complex traditional modes of governance in addition to the Band council system imposed by the federal government.

[4] WSAs can vary across different contexts, with respect to duration, pricing, infrastructure responsibilities, etc. The Federation of Canadian municipalities provides a water and wastewater service agreement template on their website 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: https://fcm.ca/en/resources/fnmcp/service-agreement-templates.

[5] In some cases a municipality or First Nation 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.

[6] As discussed later, a unique study during this time period provides the first and only access to detailed information on First Nation 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 today. 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 (though not common) for First Nations to be suppliers in WSA arrangements. The inclusion of this case does not influence our empirical or qualitative findings.

[8] In North America, the Royal Proclamation of 1763 (UofT Libraries, n.d.) established a unique relationship between Indigenous people 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 people was established by the workings of the Supreme Court in a series of cases referred to as the Marshall trilogy: *Johnson v McIntosh* (1823); *Cherokee Nation v. Georgia* (1831) and *Worcester v. Georgia* (1832). In theory, these cases limited U.S. states from interfering in governance matters within 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* (1832). 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 paper; that said, we emphasize the need for ongoing efforts to understand the consequences of these institutional differences and why they emerged.

[9] 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 speaking – 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.

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

[11] The *Indian Act (1985)* discusses water in the context of authorization of capital expenditures for water infrastructure, and 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).

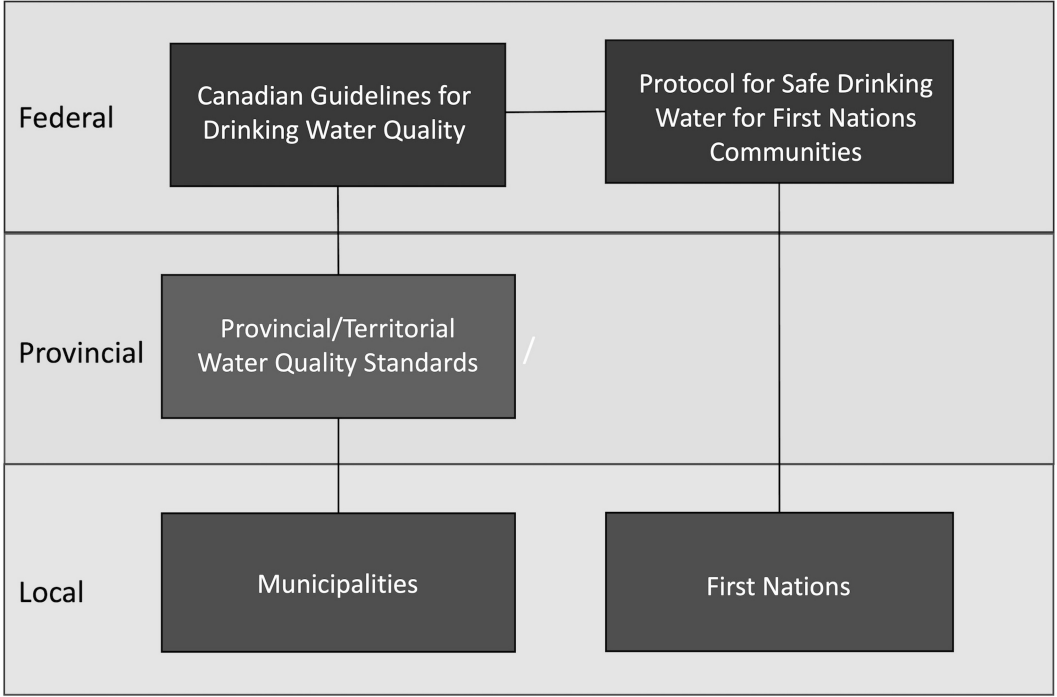
[12] In 2013 the *Safe Drinking Water for First Nations Act* was passed, creating a framework that would allow for the establishment of more enforceable standards for drinking water quality on First Nation reserves. However, this Act was strongly opposed by many First Nation stakeholders, as these new 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 MOECP 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.

[13] Formerly (during our study period of 2009/10) named the Ministry of the Environment (MOE).
[14] Regulations for large and small water systems are laid out in O. Reg. 170/03: Drinking Water Systems (under the *Safe Drinking Water Act (2002)*) and O. Reg. 319/08: Small Drinking Water Systems (under the *Health Protection and Promotion Act (1990))*.
[15] 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 funding programs can be found here: https://www.ontario.ca/page/funding-indigenous-economic-development.
[16]In the Data section we provide information on the data sources for the regressions. Key differences in the sources of municipal and First Nation water system and water quality data led us to estimate separate regressions for First Nation and municipal water systems.
[17] See Doidge, Deaton and Lipka (2013) for a detailed history of the *First Nations Land Management Act* (1999).
[18] At the time of the Neegan Burnside (2011) survey, there was only one First Nation 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 (MBQ) Band, Tyendinaga Mohawk Territory. This community had two water systems, one supplied by the neighbouring Town of Deseronto, and one supplied independently. This First Nation was dropped from the regression analysis due to missing census data. Interestingly, during the Neegan Burnside (2011) study period, MBQ's independent water system was under a drinking water advisory, while the system supplied through the WSA was not.
[19] This extensive dataset can be queried here: https://sdwis.epa.gov/ords/sfdw_pub/f?p=108:200.
[20] Table A1, in Appendix 1, details each variable included in our analyses and provides source information.
[21] Attempts to contact various federal and provincial government ministries to inquire about the availability of this data were not successful. Over the course of our data collection efforts, we contacted the Ontario Ministry of the Environment, Conservation and Parks (MOECP); Environment and Climate Change Canada (ECCC); and Public Health Ontario (PHO). None were able to provide us with a comprehensive list of drinking water advisories (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 Nation communities and municipalities) and did not include the historic data we required (2009-10). Indigenous Services Canada (ISC, 2021b) provides a list of current long-term DWAs in First Nation 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 2010-2019, collected through the Canadian Network for Public Health Intelligence Drinking Water Advisory Application (ECCC, 2020). However this data is collected from participating provincial and territorial regulatory agencies, and thus excludes First Nations; it also excludes some non-participating non-First Nation jurisdictions. And while this data does partially overlap with our study period (2010), it is only reported on aggregate, not at the system level.
[22] In the province of Ontario, 120 of 121 First Nation communities with water and wastewater assets opted to participate in this survey (Neegan Burnside, 2011). For the purpose of the survey, a First Nation water system was classified as a system receiving funding from the federal government (Indigenous and Northern Affairs Canada (INAC) at the time, Indigenous Services Canada (ISC) today), servicing five or more residences or public facilities.
[23] These documents included: Quality Management System (QMS) Operational Plans, annual water system reports, and annual Ministry of the Environment (MOE) Inspection reports.
[24] There are two main types of residential drinking water systems in Ontario: 1) small residential servicing 6 to 100 residences, and 2) large residential serving 100+ residences (MOECP, 2021).
[25] 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.
[26] The Canadian federal government's economic development agency for northern Ontario.
[27] This distance was calculated as the straight-line distance from the boundary of the community to the centroid of the neighbour, in kilometers.
[28] The correlation between this regional median income variable and community level median income for the subset of First Nation 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.
[29] See Fillipini et al. (2018) for a full discussion of this issue.
[30] To support ongoing and future inquiry into this area we provide our data and a description of our meta-data here: https://doi.org/10.5683/SP3/BE5R96. A more direct link to the data set used to generate the empirical results is available here: https://doi.org/10.5683/SP3/VMFJTA.

We hope this public dataset will support future research in this area and potentially allow researchers to provide improved and updated measures of many of the variables we provide.

[31] See https://www.canada.ca/en/indigenous-services-canada/news/2022/11/atlantic-first-nations-water-authority-makes-history-as-first-indigenous-water-utility.html (checked December 9, 2022).

[32] Again, 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 distance was approximately 21.8km, between Whitefish Lake First Nation and the City of Sudbury.



Source: author.

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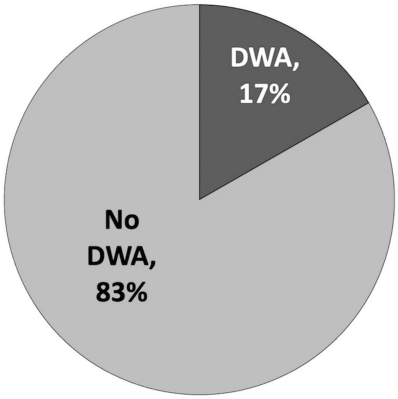
No Water Sharing (N=508)



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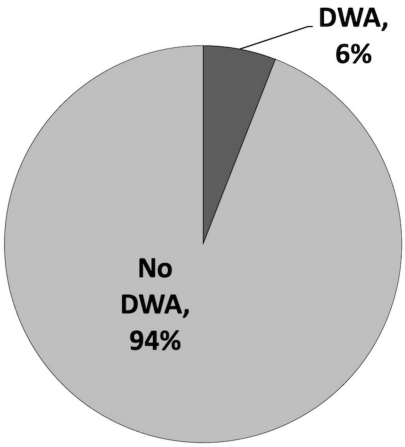
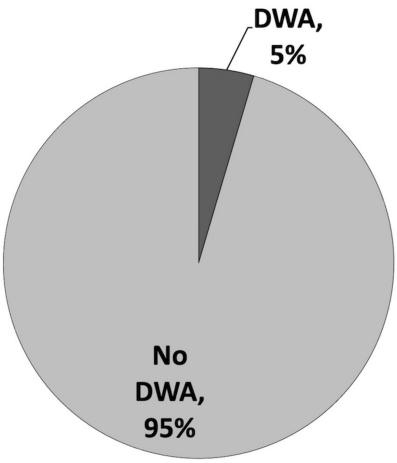
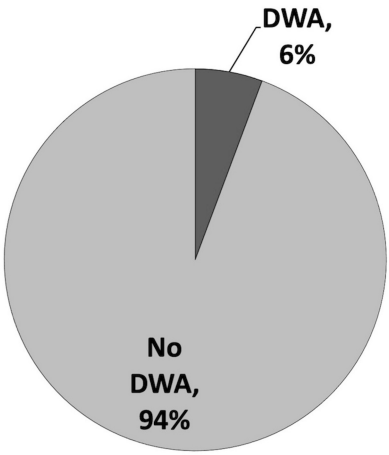


Municipal Systems (N=565)

No Water Sharing (N=372)

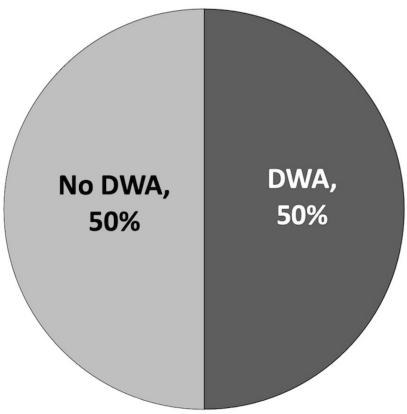


Water Sharing (N=193)

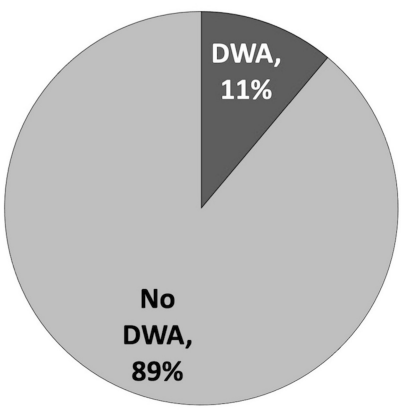


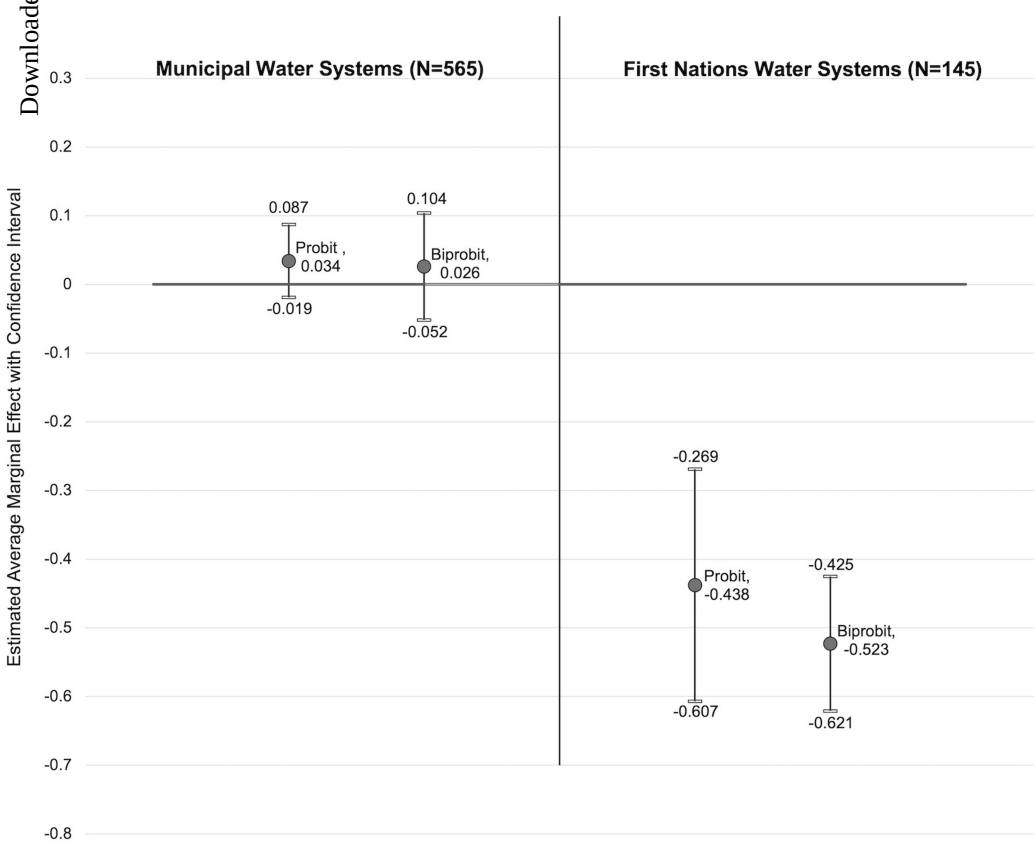
First Nation Systems (N=145)

No Water Sharing (N=136)



Water Sharing (N=9)




Municipal Water Systems (N=565)
First Nations Water Systems (N=145)
Estimated Average Marginal Effect with Confidence Interval
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0
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-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
0.087
Probit ,
0.034
-0.019
0.104
Biprobit,
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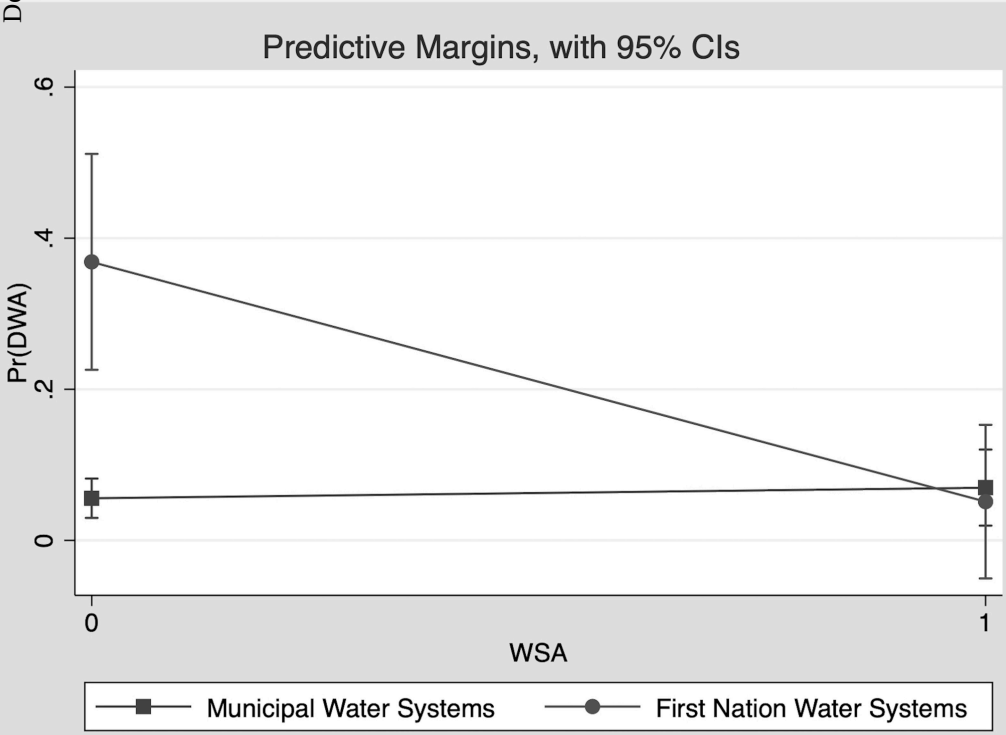
-0.621


Predictive Margins, with 95% CIs
Pr(DWA)
0
.2
.4
.6
0
1
WSA
Municipal Water Systems
First Nation Water Systems