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Résumé de l'article

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A SOCIO-ECONOMIC REVIEW OF THE IMPACTS OF NORTHWEST TERRITORIES' INUVIK TO TUKTOYAKTUK HIGHWAY 10

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Abstract: We investigate and project the likely socio-economic effects on the community of Tuktoyaktuk from completion of the all-season Highway 10 (the Inuvik-Tuktoyaktuk Highway) in Northwest Territories, Canada. Prior to the highway's completion, Tuktoyaktuk was connected to the rest of Canada by air, winter road, and the Mackenzie River in summer. Our analysis is based on estimated relationships between community remoteness and quantifiable socio-economic metrics using the recently developed Index of Remoteness and associated agglomeration data from Statistics Canada (Alasia et al. 2017). Most notable among our results is a statistically strong relationship between agglomeration and both the mean and distribution of household and family incomes, implying that Highway 10 increases incomes across the income distribution. We find similar evidence suggesting increased rates of high school completion. We find no statistically significant relationship between agglomeration and employment participation rates. There is a positive relationship for some forms of crime but no relationship for violent or property crime rates.

Keywords: Remoteness; Agglomeration; Socio-Economic Outcomes; Infrastructure; Community Outcomes

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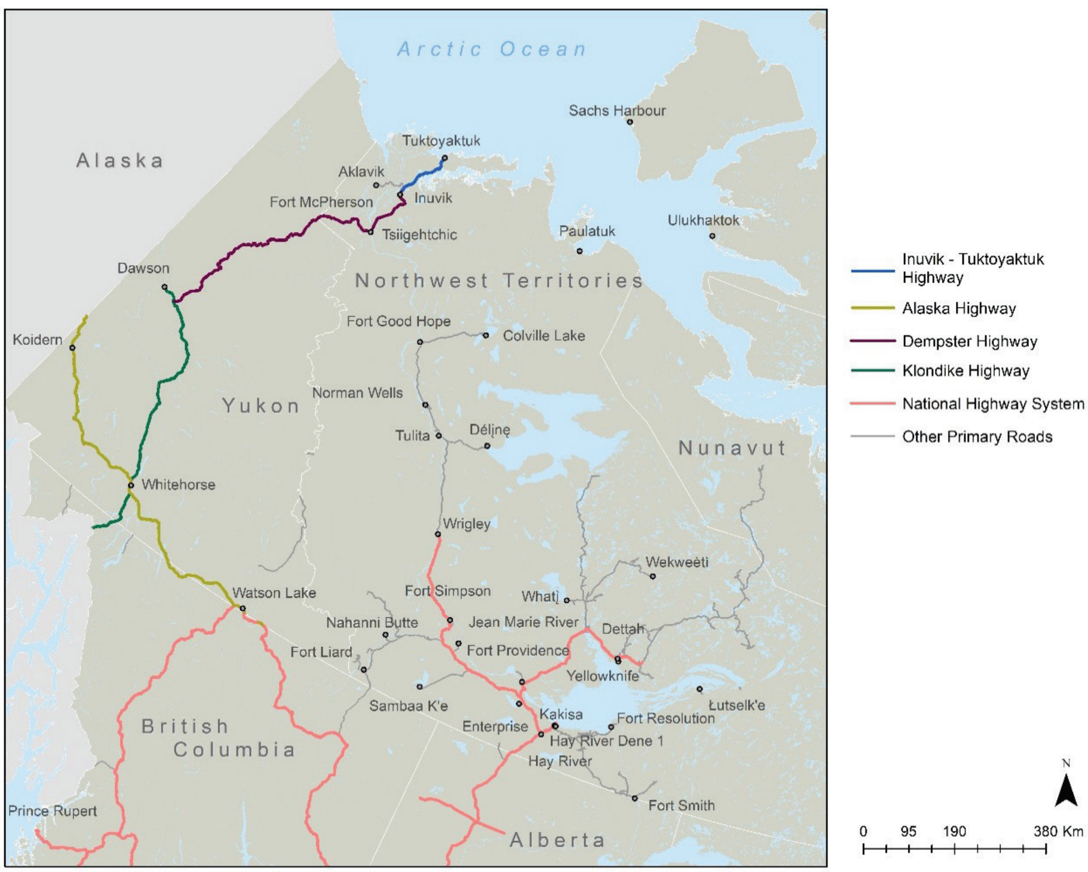
INTRODUCTION

Highway 10 (more commonly known as the Inuvik-Tuktoyaktuk Highway) in Northwest Territories, Canada officially opened on November 15, 2017. It is the first all-weather road to Canada's Arctic Coast, replacing a seasonal winter road that was previously annually reconstructed across the frozen Mackenzie River delta and Arctic Ocean.[1] In this paper, we investigate and subsequently project Highway 10's likely socio-economic effects on the community of Tuktoyaktuk using estimated relationships between community remoteness and quantifiable socio-economic metrics. This analysis is not intended to replicate the cost-benefit analyses already conducted by the Government of Northwest Territories (GNWT 2010, 2011); we proceed from an assumption that persistent socio-economic impacts of the highway will occur because of the reduction in Tuktoyaktuk's remoteness.[2]

The link between transportation infrastructure and macroeconomic performance is well understood. At a basic level, improving infrastructure quality or adding infrastructure where needed reduces transportation costs. This reduction in trade costs increases scope to benefit from gains from trade, promoting economic efficiency (Banerjee et al. 2012, Francois & Manchin 2013, Atkins & Donaldson 2015, Donaldson 2018, Fellows & Tombe 2018). However, improvements in macroeconomic factors are not, and should not be, the only goal of effective public policy and infrastructure planning. Community-level micro-outcomes are important and deserve attention. While this analysis focuses specifically on Highway 10, it is illustrative of how improvements in transportation infrastructure affect community-level socio-economic outcomes in northern and remote communities.

We use simple regression analysis to identify the strength and relative magnitudes of the relationships between community remoteness and several socio-economic metrics across communities in Northwest Territories. Combining these estimates with the known reduction in "remoteness" as measured by Statistics Canada's Index of Remoteness (Alasia et al. 2017), we can generate projections for the highway's likely impact on the aforementioned socio-economic metrics. Specifically, we show that the long-term effect of highway connectivity on annual average employment income in Tuktoyaktuk is likely to be an increase of approximately $4,500 CAD. While we are somewhat limited by data availability, our results also suggest that the implied income increase shifts the entire income distribution up, such that the share of lower income tax-filers (below $15,000 per year) falls by over 4% while the share of higher income tax-filers (above $50,000 per year) increases by around 4.5%. Surprisingly, we find the implied reduction in remoteness does not have a significant effect on the unemployment and employment rates. Per capita income assistance cases and the number of income-assistance beneficiaries per capita likely fall (by 0.013 and 0.022 respectively). We find no clear effect on property, or violent crimes although the projected per capita rate of "other criminal code violations" increases by 0.035.

Figure 1. Road Transportation Network in the Northwest Territories



Sources: Map prepared by the authors (2021) using Statistics Canada (2016, 2019b, 2020a, 2020b); US Census Bureau (2018); NRCan (2020). For illustrative purposes only. The following software was used: Esri, ArcGIS Desktop, version 10.7.1. Contains information licensed under Open Government Licence – Canada.

1 Winter roads are seasonal roads re-constructed every winter over land and/or across frozen water bodies (i.e. rivers, lakes, and sea) and used for the duration of winter. Local communities, provincial and territorial governments, and industry (mainly mining and energy) rely on winter roads for resupply of fuel, construction material and other bulk goods.

2 We give a more formal definition of community remoteness below, based on the concept of agglomeration: proximity to population centers, measured by the travel cost to, and population of, nearby communities.

The remainder of the paper proceeds with a brief review of the Highway 10 project. We follow this with a description of the nature of remoteness, its relationship to other community outcomes and an explanation of the relevant data used in our analysis. We then explain the statistical methodology used to estimate the projected impact of improved connectivity before discussing at greater length the likely effects of the completion of Highway 10.

DESCRIPTION AND BACKGROUND OF HIGHWAY 10

Highway 10 is a two-lane raised gravel roadway that runs approximately 138 km from Inuvik to Tuktoyaktuk. The Dempster Highway links Inuvik to the rest of Canada's national highway system; it runs approximately 737 km connecting to the Klondike and Alaska Highways in Yukon (FIGURE 1). The hamlet of Tuktoyaktuk is in Canada's western Arctic, near the Mackenzie Delta on the Beaufort Sea. It is one of the six communities in the Inuvialuit Settlement Region of Northwest Territories and has a population of 869 (Statistics Canada 2017a). Prior to the opening of Highway 10, Tuktoyaktuk could only receive overland transit during the winter road season via a 177 km winter road (39 km longer than Highway 10) with a route mostly following the Mackenzie River delta channels and crossing part of the Arctic Ocean. Any transportation to or from Tuktoyaktuk that did not use this winter road was via air (into and out of Tuktoyaktuk's airport) or via the Mackenzie River in summer.

Historically, the timing and frequency of freezing-degree-days (days with temperature below 0°C) was sufficient to allow for a four-month winter road season (January to April). However, climate change and a corresponding change to the frequency and distribution of freezing-degree-days versus thawing-degree-days raises serious concerns for the integrity and season length of winter roads in the Canadian Arctic (Hori et al. 2017, Mullan et al. 2017, Barrette & Charlebois 2018, Pearce et al. 2020). As the winter road season becomes shorter, logistics become more difficult as shipments need to be organized around a smaller window or diverted to non-overland transportation modes (via air or barge as appropriate and feasible). Oil and gas exploration in the Beaufort Sea and Mackenzie Delta in the 1960s prompted discussion of an all-weather road from Inuvik to Tuktoyaktuk and the idea remained (CBC Digital Archives n.d.). Pre-feasibility and feasibility studies along with community consultations took place between 1974 and 2013 (GNWT n.d.). Highway construction began in early 2014. The highway opened to the public in November 2017 and became the first highway in Canada to reach the Arctic Ocean.

THE IMPORTANCE OF REMOTENESS AS A DETERMINANT OF SOCIO-ECONOMIC OUTCOMES

Outside of the direct short-term socio-economic impacts of construction, we posit that the primary channel of persistent benefits associated with Highway 10 are embodied by the reduction in the remoteness of Tuktoyaktuk. Proceeding from this assertion, we employ a set of simple regressions that exploit differences in "agglomeration" across communities in Northwest Territories as a determinant of other measurable socio-economic metrics. We employ Statistics Canada's Index of Remoteness dataset (Alasia et al. 2017), which includes measures of remoteness and agglomeration. Other community level socio-economic metrics are from the Government of Northwest Territories' Bureau of Statistics (GNWT 2020).

Given our use of the GNWT Bureau of Statistics data, we restrict our regression analysis to a sample of communities in Northwest Territories. While it should be possible to obtain similar socio-economic metrics for other (northern and non-northern) communities from additional sources, we do not do this. Using socio-economic metrics from a single source (the GNWT Bureau of Statistics) ensures that the metrics are collected and defined consistently across the dataset, eliminating an important source of potential bias.

Many communities in Northwest Territories and Nunavut have less-developed trade infrastructure compared to Yukon and the southern provinces (TABLE 1). In Northwest Territories only 35% of communities are accessible via all-season roads, 50% are served by a regional electricity grid and 69% have access to a terrestrial information technology backbone (National Aboriginal Economic Development Board 2016). While additional telecommunications infrastructure has been introduced into the region in the form of the recently completed Mackenzie Valley Fibre Link (owned by the GNWT) local interconnection to communities has been left to the individual service providers. It is unclear which communities are still waiting to be connected but a recent GNWT standing committee highlighted the need for a communications plan for outlying communities not already connected to the new fibre link (Standing Committee on Government Operations 2020, Munzur, 2022). Moreover, Koch (2022) shows many northern rural and First Nations communities are dependent on satellite links, with broadband internet service below the Government of Canada's universal service objective.

In contrast to Northwest Territories, 97% of communities in Yukon are accessible by all-season roads and 85% are served by a regional electricity grid and 93% have connectivity with a terrestrial information technology backbone (National Aboriginal Economic Development Board 2016).[3] Given the lack of infrastructure connectivity, the implications of community remoteness in Canada's north have been the subject of considerable study. We highlight a portion of that work here to further motivate the treatment of "remoteness" as a causal channel through which physical infrastructure can influence community-level socio-economic metrics.

Table 1. Community Accessibility Measures across the Territories (% of all communities)

	Yukon	Northwest Territories	Nunavut
Accessible via All-Season Roads	97%	36%	0%
Access to a Regional Electricity Grid	85%	50%	0%
Terrestrial information technology backbone	90%	69%	0%

Source: National Aboriginal Economic Development Board (2016)

Remoteness makes it difficult to attract and retain teachers and education administrators (Sharplin et al., 2011; Doering 2014). When considered in the context of community development, this problem is concerning since educational outcomes are widely recognized as critical in motivating other positive socio-economic outcomes (Riddell 2006; van der Velden & Wolbers 2007). Remote learning can help mitigate some of the issues related to a lack of retention of teaching staff. Unfortunately, a lack of sufficient-quality internet access (resulting from a lack of access to a terrestrial telecommunication "backbone") hinders this option. In a comparative study of Arctic schools, Doering (2014) found that those in the Northwest Arctic

3 While the consumer retail "front face" of modern IT and internet connectivity is often wireless, terrestrial wired networks handle the bulk of telecommunications traffic backhaul. With the exception of costly and lower reliability satellite uplinks in remote communities, the overwhelming majority of "wireless" telecom occurs on the so-called "last mile," the portion of the network between the end consumer and the backhaul network serving a local distribution hub or cellular network tower.

Borough of Alaska (US) had acceptable bandwidth speeds whereas those on Baffin Island (Canada) had inadequate access relative to that required for distance learning.

Food security is also an issue for remote northern communities. Loring & Gerlach (2015) find that in 2011, the reported rates of food insecurity in Nunavut ranged from 36% to 68%, as compared to a national average of 12%. Loring and Gerlach (2015, p. 387) note that while healthy foods are available in these communities, residents "do not enjoy consistent and reliable access to these foods, whether we are speaking of food from the land or food from the market." Loring and Gerlach also note that while long supply chains are not the only determining factor in northern food insecurity, the remoteness of these communities does play a significant role.

Healthcare access is also a major concern exacerbated by community remoteness. The per capita cost of healthcare provision is higher in the north (Canadian Institute for Health Information 2020), and health outcomes are worse in the north compared to the rest of Canada (Young et al. 2016a). There are several factors contributing to this disparity, the majority of which relate to a combination of community size and regional accessibility. Community size is important since healthcare (like many other services) exhibits economies of scale. It is simply less expensive (per patient) to serve a moderate-to-large patient base when compared to a small one. This is less of an issue if communities can share healthcare resources by being close together with low-cost and high-quality transportation modes between them. Unfortunately, many northern communities are small and lack sufficient connectivity to neighboring communities. This leads patients to make "regular, time-consuming and extended medical travels to larger communities for non-emergency care" which can in turn imply an extended loss of income for those patients (Oosterveer & Young 2015, p. 6). As with teachers, northern communities also have difficulty attracting and retaining healthcare professionals, compromising delivery of both emergency and non-emergency care delivery (Oosterveer & Young 2015). There are non-infrastructure-related policies to address this issue, one of which (already in place) is the use of nurse practitioners as a primary care entry point rather than higher cost family physicians in remote communities (Young & Chatwood 2017). However, this system is supported in part by teleconferencing services and as such may suffer from the same detriment as described above for distance learning.

However, the effects of remoteness and isolation are not all negative. Burten et al. (2015) find Indigenous adolescents in the North exhibit less stress than southern counterparts and express a more positive body image and a stronger sense of belonging. They further speculate that these results may reflect the more cohesive and mutually supportive nature of remote communities.

DesBrisay (1994) also outlines important detrimental sociological effects on Indigenous communities associated with resource development projects, which are often accompanied by highway construction and reduced remoteness. DesBrisay observes that:

> "When traditional roles and responsibilities which are grounded in foraging activities are disrupted, the bonds between family members have tended to atrophy… Aboriginal families have also experienced stress when husbands are away working for extended periods, when families have relocated to resource towns, or when communities have experienced an influx of non-Aboriginal workers."

This sentiment is also echoed in more recent research on the effects of resource development projects on First Nations' communities. Parlee (2015) notes that resource development may undermine a community's traditional land-base which may in turn undermine the community's local social capital. Zurba & Bullock (2020) similarly observe that exploitation of the land-base associated with resource extraction impacts a community's relationship with the land which may have negative implications for social wellbeing.

On the more specific topic of transportation infrastructure, Tsetta et al. (2005) note that new road infrastructure accompanying diamond mining development in Canada's north has increased access to the area with corresponding increasing pressure on local wildlife via increased hunting. This phenomenon has been noted by the leaders, organizers, and staff of Yellowknives Dene First Nation.

There is an important distinction between reducing remoteness to support community socio-economic goals and reducing remoteness to support resource development projects. However, much of the transportation network improvements in the north to date were motivated by resource development projects, so it is a natural source of context for our study.

The economic gains projected to accompany improved trade infrastructure are related to sectoral shift and specialization (Fellows & Tombe 2018). That is, high-cost goods produced in the region benefiting from improved connectivity may be displaced by lower-cost variants imported from other regions. This displacement may affect traditional land-based activities for Indigenous community members (such as substitution between country food and imported food). However, traditional participation in land-based activities is not fully motivated by economic outcomes. Other aspects of land-based activities carry important sociological and cultural attributes reflecting spiritual, psychological and intrinsic process based benefits to Indigenous community members.[4] There is a possibility that economic gains (measured by contributions to gross domestic product or improvements in household monetary incomes) come with a trade-off against land-based activities that carry traditional cultural and personal value. Predicting the socio-economic effects of major infrastructure projects in the north is difficult and attempts to assess the potential impacts are historically criticized for failing to adequately consider cumulative effects (Munzur, 2021).

The Berger Commission cites dramatic increases in alcohol consumption in northern communities proximate to prior developments to argue that resource development projects in the north motivate increased rates of alcohol abuse (Berger, 1977). This assertion is based on observed relationships between alcohol abuse and other social problems including violent crimes. More recent research emphasizes these issues, asserting that substance abuse in Indigenous communities may increase as a result of increased in-community access to drugs and alcohol (Campbell 2007) and increased incomes (North Slave Metis Alliance 1999; Gibson & Klinck 2005; Amnesty International 2016). While this is an important area of socio-economic impact, our own results below show no clear relationship between "remoteness" and violent crime. So, it may be that the nature of improved infrastructure (and whether it accompanies a resource development project) matters for how it affects community outcomes.

Pursuant to the above literature, our empirical methodology relies on the identifiable relationships between remoteness and measured quantitative socio-economic outcomes. At the core of this exercise, we employ Statistics Canada's Index of Remoteness, which includes a community agglomeration measure. We turn to a description of this index presently.

4 See Dacks (1981), Berger (1977), Kruse (1991), and Bone (1992), (all 4 as cited in DesBrisay 1994), as well as Angell and Parkins (2011); and Smith (2006).

STATISTICS CANADA'S INDEX OF REMOTENESS

Statistics Canada's Index of Remoteness dataset (Statistics Canada 2017) includes a measure of agglomeration at the community level. As a basic simplifying description, agglomeration represents a community's "proximity to centres of economic activity and population agglomerations" (Alasia et al. 2017). Less technically, it is a summary index of a community's proximity to its neighboring communities weighted by the population of those neighboring communities. For a community i the agglomeration measure takes the mathematical form:

$$A_i = ln \sum_k \left(\frac{Population_k}{Travel\ Cost_{i,k}} \right) \quad 1$$

where A_i is the agglomeration value for a community i, k represents each element of a set of communities neighboring a community i and $Travel\ Cost_{i,k}$ is a measure of the cost to travel between community i and a neighbor k. The set of communities in this case includes all communities within a 150-minute one-way commute unless there are no communities within that scale, in which case the set only includes a single element k representing the closest community. For Tuktoyaktuk, this set includes only Inuvik.

As equation (1) implies, agglomeration measures "proximity" using the travel cost between a community i and its neighboring communities. Alasia et al. (2017) makes a convincing argument for the use of travel cost as a measure of proximity rather than other potential measures such as physical distance, travel time, or network distance. For communities that do not have persistent access to the transportation network (like Tuktoyaktuk prior to the completion of Highway 10) the concept of "network distance" is not directly comparable (since a mile of winter road or air travel is not equivalent to a mile of highway travel). Travel time and physical distance are similarly deficient. The Index of Remoteness is not a time series, but there are currently two years of data available: 2011 and 2016 (with the latter year based on 2016 census populations and travel costs collected later in 2017).

EMPIRICAL ANALYSIS

Using a simple regression analysis, we find that agglomeration has strong statistical relationships with several important socio-economic metrics. Furthermore, since the intended purpose of the highway is to reduce travel times between Tuktoyaktuk and neighboring Inuvik, the highway's completion is directly equivalent to an increase in the agglomeration level of Tuktoyaktuk. This can be verified by comparing the agglomeration measure for Tuktoyaktuk pre- and post-highway completion. Thus, we can combine the coefficient estimates from our regression analysis with the known increase in agglomeration caused by the completion of Highway 10 to project the likely socioeconomic impacts.

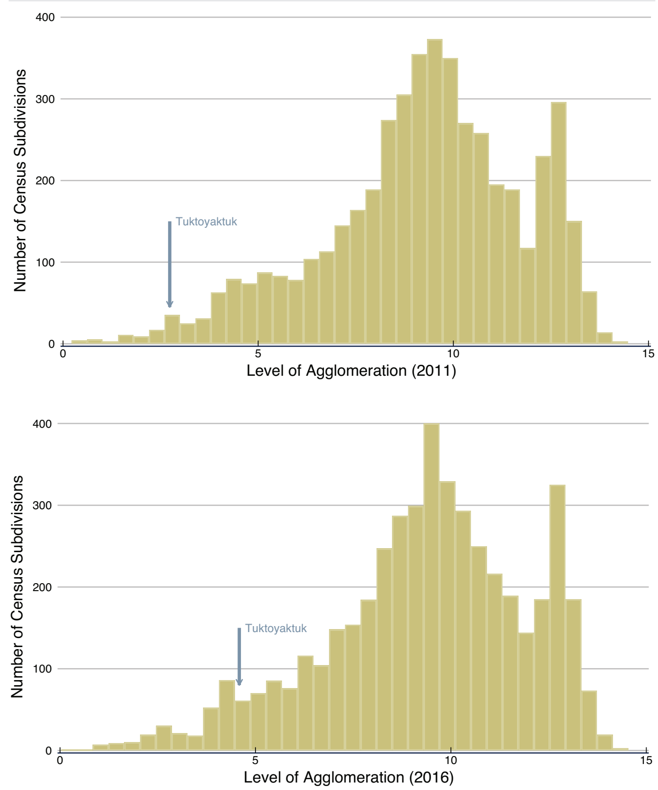
Methodology

We use a very simple regression methodology to assess the highway's effect on several socio-economic metrics. The majority of data for this analysis comes from the Government of Northwest Territories' Bureau of Statistics (GNWT 2020). Given the short period and lack of data post-completion of the highway, we exploit inter-community variation in socio-economic outcomes and agglomeration rather than attempting an alternative approach (such as difference-in-difference, or methods based on identifying a statistical break in a time series). The continuous nature of the agglomeration measure (as opposed to binary or integer representations of remoteness) is a benefit to our approach as it provides a higher degree of variation in the independent variable across communities, which we exploit to identify the statistical relationships between agglomeration and socio-economic metrics.

Using travel cost as a measure of proximity in equation (1) is particularly important for our purposes. Highway 10's completion implies a change in travel cost but does not change Tuktoyaktuk's physical proximity to other communities and creates a limited change in network distance when measured against historic winter road use. As such, an identified statistical relationship based on physical proximity produces inappropriate parameters for the implied counterfactual. The completion of Highway 10 implies a change in the agglomeration measure for Tuktoyaktuk (because it changes travel cost) which allows us to use the estimated relationships based on agglomeration to project the effect of Highway 10.

FIGURE 2 shows the change in agglomeration for Tuktoyaktuk from 2011 to 2016. While Highway 10 was officially completed in 2017, the 2016 agglomeration measure was calculated using 2016 census data with distances and travel costs measured after its completion.[5] As such, the 2016 data reflects agglomeration for Tuktoyaktuk immediately following the completion of Highway 10.

Figure 2. Distribution of Agglomeration Levels (2011 and 2016) Across All Census Subdivisions



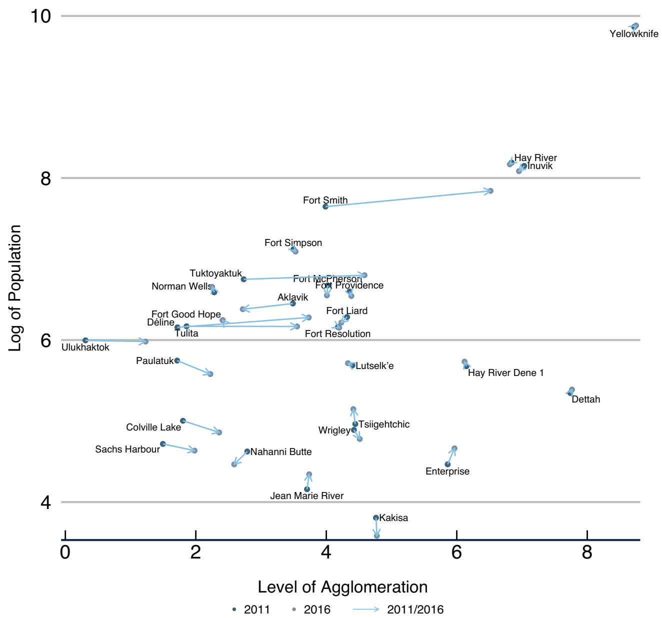
Data Source: Alasia et al. (2017).

FIGURE 3 shows how the agglomeration and population changed for a set of northern communities from 2011 to 2016. The increased agglomeration level for Tuktoyaktuk can largely be explained by the completion of Highway 10. Other agglomeration changes (particularly Fort Smith) are likely related to upgrades from gravel to pavement on Highway 5, which connects Fort Smith and Hay River (Town of Fort Smith, 2017)[6], while some smaller agglomeration changes have resulted due to population growth in adjacent communities.

5 This was verified through personal correspondence with Statistics Canada staff responsible for the Remoteness Index calculations.

6 Both Highway 10 and the upgrades to Highway 5 were officially completed in 2017. However, per the previous footnote, the 2016 calculations for the remoteness index are based on travel costs calculated for 2017, after Highway 10's completion.

Figure 3. Changes in the Levels of Agglomeration 2011 to 2016



Data Source: Alasia et al. (2017).

Table 2. Socio-economic Metrics for Regression Analysis

Income and Employment Outcomes
% Families Less than $30,000
% Families More than $75,000
% Taxfilers Less than $15,000
% Taxfilers More than $50,000
Average Employment Income ($)
Average Family Income ($)
Average Personal Income ($)
Employment Rate
Income Assistance Beneficiaries (monthly average per 1,000 persons)
Income Assistance Cases (monthly average per 1,000 persons)
Income Assistance Payments per capita ($)
Participation Rate
Unemployment Rate
Births and Deaths
% Deaths that have External Causes
Births (Per 1,000 persons)
Deaths (Per 1,000 persons)
% Deaths that are Suicides
Social Outcomes
% of Households in Core Need
% of Households with 6 or More People
% with High School Diploma or More
% Aboriginals that Speak an Aboriginal Language
% Births that are Teen Births
Crime
Federal Statutes Crime Rate (per 1,000 persons)
Other Criminal Code Crime Rate (per 1,000 persons)
Property Crime Rate (per 1,000 persons)
Traffic Crime Rate (per 1,000 persons)
Violent Crime Rate (per 1,000 persons)

Data

We match the agglomeration data with several relevant community outcomes for 33 NWT communities, using data from the Northwest Territories Bureau of Statistics. We assess the effect of agglomeration on the 27 socio-economic metrics listed in TABLE 2.

For uniformity, and due to a relative lack of community-level data, we implement a very simple regression equation, using agglomeration as an explanatory variable along with time fixed-effects. Formally, our regression analysis takes the form:

$$Y_{i,t} = \beta_0 + \beta_1 (A_{i,t}) + \alpha_t + \mu_{i,t} \qquad 2$$

where the dependent variable $Y_{i,t}$ represents the values across communities (i) and time periods (t) of one of the socio-economic metrics from TABLE 2, α_t are year fixed-effects and $A_{i,t}$ is the individual community i's agglomeration level. The dataset runs from 1984 to 2018; however, data is not available for every metric in every year. We have only two years of data (2011 and 2016) for the agglomeration values $A_{i,t}$. To maximize the effective use of our data, we address this limitation by running two sets of regressions.

In the first set, we fix the agglomeration measure using the 2011 data and perform our analysis using the full set of panel data for communities. For clarity, in this set of regressions equation 2 takes the form:

$$Y_{i,t} = \beta_0 + \beta_1 (A_{i,2011}) + \alpha_t + \mu_{i,t} \qquad 3$$

While this set of regressions ignores inter-temporal (within-community) variation in the agglomeration measure, it allows us to use the more complete set of data on socio-economic metrics. Additionally, FIGURE 3 shows a reasonably high persistence of the agglomeration measure except for communities directly affected by the new Tuktoyaktuk highway and the upgrades to Highway 5, both of which happen at the end of our panel data series.[7]

In the second set of regressions, we allow the agglomeration measure to vary within community using both the 2011 and 2016 measures and we drop all years except 2011 and 2016 (T=2). We do not have measures for every socio-economic metric listed in TABLE 2 for both 2011 and 2016 and are therefore unable to conduct a full slate of regressions using this approach. For the socio-economic metrics where we can run regressions with and without intra-community variation, many of the estimated coefficients are highly consistent in both magnitude and statistical significance, which is promising.

To give some indication of the varying frequencies of our data, TABLE 3 reports the number of observations for each metric for Tuktoyaktuk as well as related summary statistics. These contrast with the same statistics for Yellowknife (the least-remote community in Northwest Territories, with the highest agglomeration level) displayed in TABLE 4. A cursory browsing of these tables reveals the relative merits of the less-remote and larger Yellowknife versus the more remote and smaller Tuktoyaktuk. Tuktoyaktuk's population mostly self-identifies as Inuit (93%) and about 23% of the residents speak Inuinnaqtun (an Inuit language) (Statistics Canada 2017a). In both Tuktoyaktuk and Yellowknife, more than 99% of the population is also fluent in English.

The data shows housing conditions are a serious problem in Tuktoyaktuk. In 2016, one year before the completion of Highway 10, 44% of the occupied private dwellings needed major repairs while the Northwest Territories average was 18% (Statistics Canada 2017a). In 2016, 60% of the Tuktoyaktuk population aged 15 years and over had no secondary or post-secondary certificate, diploma or degree. The labour force participation rate is significantly lower in Tuktoyaktuk compared to the

7 Restricting the agglomeration data to a single time-invariant measure introduces a bias into our estimation as we know agglomeration varies over time with changes in the population of neighbouring communities and the travel costs between communities. However, imposing time-invariant agglomeration on the analysis allows for more efficient estimation as we are able to use more of the other available data with this restriction in place. It is therefore encouraging that our more efficient (but potentially biased) results closely follow our less efficient (but unbiased) results.

Table 3. Summary Statistics for Tuktoyaktuk

	(1)	(2)	(3)	(4)	(5)
Variables	**N**	**mean**	**s.d.**	**min**	**max**
Family Income <$30,000 (%)	10	28.440	3.004	22.730	31.820
Family Income >$75,000 (%)	10	31.110	2.855	27.270	36.360
Taxfiler Income <$15,000 (%)	10	38.820	3.527	33.900	43.860
Taxfiler Income >$50,000 (%)	10	20.070	1.531	17.540	22.220
Households in Core Need (%)	5	36.750	5.769	31.900	43.300
Households with 6 or More People (%)	9	16.720	5.264	11.890	29.270
Minimum High School Education (%)	13	36.970	4.092	31.620	46.140
Average Employment Income ($)	10	32,773.000	1,468.000	30,686.000	35,024.000
Average Family Income ($)	10	70,877.000	3,755.000	66,659.000	78,022.000
Average Personal Income ($)	10	33,419.000	2,215.000	30,698.000	37,517.000
Employment Rate	13	41.560	3.159	35.350	45.230
Deaths with External Causes Including Suicides (%)	10	26.640	18.610	0.000	66.670
Federal Statute Violations (per capita)	10	0.013	0.007	0.005	0.026
Income Assistance Beneficiaries (monthly, per capita)	10	0.223	0.026	0.200	0.284
Income Assistance Cases (monthly, per capita)	10	0.130	0.012	0.116	0.156
Income Assistance Payments per capita ($)	10	1,416.000	277.100	1,060.000	2,003.000
Aboriginals that Speak an Aboriginal Language (%)	8	29.430	5.434	22.340	37.710
Births (Per Capita)	10	0.022	0.005	0.0143	0.031
Deaths (Per Capita)	10	0.006	0.002	0.003	0.010
Other Criminal Code Violations (per capita)	10	0.131	0.038	0.068	0.193
Participation Rate	13	60.150	4.389	50.800	65.830
Property Crimes (per capita)	10	0.314	0.0394	0.245	0.365
Deaths resulting from Suicide (%)	10	6.524	8.566	0.000	20.000
Teen Births (%)	10	10.950	6.147	0.000	18.180
Traffic Crimes (per capita)	10	0.0255	0.0149	0.012	0.056
Unemployment Rate	13	31.130	5.561	25.980	45.590
Violent Crimes (per capita)	10	0.156	0.046	0.111	0.233

Notes: N (number of observations) varies due to years of data collection. No single metric is available for the entire timespan (1984-2018). A household in core housing need is one whose dwelling is considered unsuitable, inadequate or unaffordable and whose income levels are such that they could not afford alternative suitable and adequate housing in their community.

Table 4. Summary Statistics for Yellowknife

	(1)	(2)	(3)	(4)	(5)
Variables	**N**	**mean**	**s.d.**	**min**	**max**
Family Income <$30,000 (%)	10	8.575	0.983	6.922	10.100
Family Income >$75,000 (%)	10	76.340	1.759	74.170	78.870
Taxfiler Income <$15,000 (%)	10	15.570	0.854	14.500	16.920
Taxfiler Income >$50,000 (%)	10	56.660	2.094	53.880	59.540
Households in Core Need (%)	5	10.480	4.787	4.700	17.920
Households with 6 or More People (%)	9	4.385	0.678	3.326	5.375
Minimum High School Education (%)	13	79.570	5.571	66.730	88.690
Average Employment Income ($)	10	67,562.000	4,397.000	61,518.000	72,851.000
Average Family Income ($)	10	148,433.000	9,945.000	134,645.000	161,976.000
Average Personal Income ($)	10	68,605.000	4,263.000	62,711.000	74,181.000
Employment Rate	13	80.200	2.153	75.650	83.260
Deaths with External Causes Including Suicides (%)	10	14.360	5.417	5.970	24.190
Federal Statute Violations (per capita)	10	0.012	0.004	0.007	0.018
Income Assistance Beneficiaries (monthly, per capita)	10	0.027	0.004	0.022	0.035
Income Assistance Cases (monthly, per capita)	10	0.017	0.003	0.014	0.023
Income Assistance Payments per capita ($)	10	5,082.000	1,004.000	3,695.000	7,189.000
Aboriginals that Speak an Aboriginal Language (%)	8	28.950	11.100	18.020	51.530
Births (Per Capita)	10	0.015	0.001	0.0134	0.017
Deaths (Per Capita)	10	0.003	0.000	0.003	0.004
Other Criminal Code Violations (per capita)	10	0.133	0.014	0.110	0.154
Participation Rate	13	85.030	2.297	79.360	87.450
Property Crimes (per capita)	10	0.169	0.0217	0.145	0.208
Deaths resulting from Suicide (%)	10	4.282	2.333	1.493	8.475
Teen Births (%)	10	4.050	1.312	1.724	5.763
Traffic Crimes (per capita)	10	0.010	0.003	0.004	0.0159
Unemployment Rate	13	5.663	0.951	4.408	7.863
Violent Crimes (per capita)	10	0.042	0.006	0.029	0.048

Notes: N (number of observations) varies due to years of data collection. No single metric is available for the entire timespan (1984-2018). A household in core housing need is one whose dwelling is considered unsuitable, inadequate or unaffordable and whose income levels are such that they could not afford alternative suitable and adequate housing in their community.

Northwest Territories average and the unemployment rate has been persistently higher. Participation in traditional activities like hunting, fishing, trapping, and producing arts and crafts is common in Tuktoyaktuk. In 2013, 66% the adult population reported that they participated in harvesting activities and 61% reported that harvesting provides more than half of the meat consumed in their households (GNWT 2018).

RESULTS

TABLE 5 shows the regression results for the income and employment metrics. Panel A presents results using the full set of socio-economic metric data (assuming no intra-community variation in agglomeration) and Panel B shows the results using only the 2011 and 2016 data (allowing for intra-community variation in agglomeration).

The statistical relationship between remoteness and the majority of the indicated employment and income metrics is very strong (as evidenced by the p-value measures), suggesting the importance of remoteness as a determinant of socio-economic outcomes. The unemployment rate is a notable outlier, with a p-value of 0.597 in the full sample and 0.832 in the two-year sample. The two-year sample also shows a weak relationship between agglomeration and the employment and participation rates; this makes sense if the employment impacts of agglomeration are persistent and vary slowly across time (limiting the effect of within-community variation).

Table 5. Regression Results for Income and Employment Metrics

Dependent Variable	Effect Estimate	P-Value	N	T	R^2
Panel A: Full Sample					
Family Income <$30,000 (%)	-1.356	0.000	174	10	0.108
Family Income >$75,000 (%)	3.489	0.000	174	10	0.134
Tax-filer Income <$15,000 (%)	-2.428	0.000	174	10	0.250
Tax-filer Income >$50,000 (%)	2.641	0.000	174	10	0.148
Average Employment Income ($)	2690.712	0.000	174	10	0.120
Average Family Income ($)	4194.387	0.000	172	10	0.100
Average Personal Income ($)	2202.540	0.000	174	10	0.094
Employment Rate	0.668	0.124	346	13	0.080
Participation Rate	0.666	0.053	346	13	0.128
Unemployment Rate	-0.179	0.598	346	13	0.055
Income Assistance Beneficiaries (monthly, per capita)	-0.012	0.000	261	10	0.133
Income Assistance Cases (monthly, per capita)	-0.007	0.000	261	10	0.141
Income Assistance Payments per capita ($)	44.692	0.025	270	10	0.061
Panel B: Two Year (2011 and 2016) Sample					
Family Income <$30,000 (%)	-1.568	0.118	41	2	0.054
Family Income >$75,000 (%)	3.190	0.034	41	2	0.112
Tax-filer Income <$15,000 (%)	-2.249	0.007	41	2	0.224
Tax-filer Income >$50,000 (%)	2.448	0.030	41	2	0.134
Average Employment Income ($)	2446.175	0.079	41	2	0.111
Average Family Income ($)	4215.646	0.120	41	2	0.098
Average Personal Income ($)	1894.310	0.160	41	2	0.086
Employment Rate	0.435	0.639	61	2	0.022
Participation Rate	0.563	0.382	61	2	0.024
Unemployment Rate	-0.168	0.832	61	2	0.001
Income Assistance Beneficiaries (monthly, per capita)	-0.010	0.036	60	2	0.081
Income Assistance Cases (monthly, per capita)	-0.006	0.043	60	2	0.081
Income Assistance Payments per capita ($)	83.185	0.102	62	2	0.088

Notes: P-values are based on heteroscedasticity-robust standard error estimates using a bias correction for robust variance as suggested by Davidson and McKinnon (1993, 554–556).

Table 6. Regression Results for Social Outcomes

Dependent Variable	Effect Estimate	P-Value	N	T	R^2
Panel A: Full Sample					
Households in Core Need (%)	-1.849	0.036	135	5	0.138
Households with 6 or More People (%)	-0.848	0.007	217	9	0.266
Minimum High School Education (%)	1.785	0.001	346	13	0.136
Aboriginals that Speak an Aboriginal Language (%)	-1.691	0.098	206	8	0.129
Teen Births (%)	-1.048	0.109	234	10	0.041
Panel B: Two Year (2011 and 2016) Sample					
Minimum High School Education (%)	2.520	0.055	61	2	0.117
Aboriginals that Speak an Aboriginal Language (%)	-1.829	0.527	30	2	0.014
Teen Births (%)	0.346	0.660	56	2	0.031

Note: P-values are based on heteroskedasticity robust standard error estimates using a bias correction for robust variance as suggested by Davidson and McKinnon (1993, 554–556).

Table 7. Regression Results for Birth and Death Metrics

Dependent Variable	Effect Estimate	P-Value	N	T	R^2
Panel A: Full Sample					
Births (Per Capita)	-0.001	0.000	261	10	0.089
Deaths (Per Capita)	0.000	0.189	261	10	0.048
Deaths with External Causes Including Suicides (%)	-1.676	0.106	202	10	0.086
Deaths resulting from Suicide (%)	-1.444	0.092	200	10	0.055
Panel B: Two Year Sample					
Births (Per Capita)	-0.001	0.306	60	2	0.060
Deaths (Per Capita)	0.000	0.545	60	2	0.011
Deaths with External Causes Including Suicides (%)	0.629	0.757	44	2	0.026
Deaths resulting from Suicide (%)	1.396	0.344	44	2	0.067

Note: P-values are based on heteroskedasticity robust standard error estimates using a bias correction for robust variance as suggested by Davidson and McKinnon (1993, 554–556).

Table 8. Regression Results for Crime Related Metrics

Dependent Variable	Effect Estimate	P-value	N	T	R^2
Full Sample					
Federal Statute Violations (per capita)	0.000	0.430	190	10	0.075
Other Criminal Code Violations (per capita)	0.019	0.000	190	10	0.199
Property Crimes (per capita)	0.011	0.034	190	10	0.043
Traffic Crimes (per capita)	0.002	0.073	190	10	0.103
Violent Crimes (per capita)	0.004	0.125	190	10	0.036
Two Year Sample					
Federal Statute Violations (per capita)	0.000	0.782	44	2	0.105
Other Criminal Code Violations (per capita)	0.020	0.014	44	2	0.163
Property Crimes (per capita)	0.016	0.271	44	2	0.040
Traffic Crimes (per capita)	0.002	0.275	44	2	0.035
Violent Crimes (per capita)	0.003	0.638	44	2	0.018

Note: P-values are based on heteroskedasticity-robust standard error estimates using a bias correction for robust variance as suggested by Davidson and McKinnon (1993, 554–556).

TABLE 6 presents regression results for dependent variables indicating social outcomes. The available data is insufficient to estimate the effect of agglomeration on core housing need or household size using the two-year sample (Panel B). In the full sample (Panel A) the regressions indicate that increases in agglomeration lead to a reduction in the share of households with six or more people and a reduction in the percent of households in core need. A household in core housing need is one whose dwelling is considered unsuitable, inadequate, or unaffordable and whose income levels are such that they could not afford alternative suitable and adequate housing in their community. Recall that in 2016, 44% of the occupied private dwellings needed major repairs in Tuktoyaktuk compared to a Northwest Territories average of 18% (Statistics Canada 2017a). Our results therefore suggest that improved connectivity is associated with improved quality housing. This may be a direct result related to reducing transportation costs for building materials, or it may be a secondary effect of other socioeconomic improvements (such as the improvement in income).

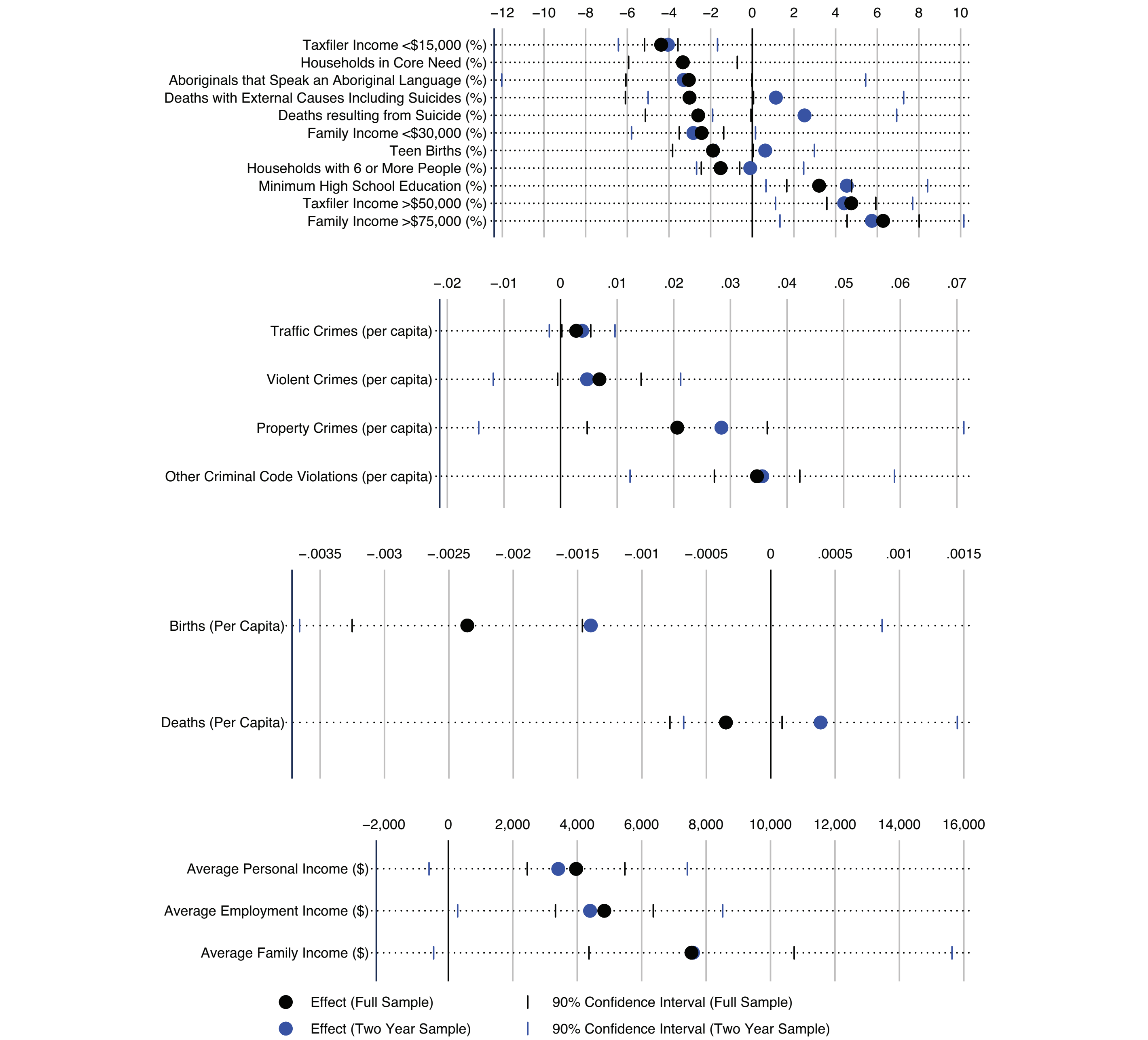
The relationship between agglomeration and high school completion is positive, of similar magnitude, and statistically significant across both the full sample and two-year sample estimates. Teen births (as a percent of all births) is one of the few metrics where the estimates from the two samples are directionally inconsistent (negative for the full sample, positive for the two-year sample). The p-value for the full sample estimate is 0.109 indicating a moderate-to-weak statistical significance, whereas the p-value for the two-year sample is 0.660 indicating weak statistical significance.

From TABLE 7 (birth and death metrics), the effects of agglomeration on birth and death rates, suicide rates or the broader classification "external causes of death"[8] remains somewhat unclear. The effect of agglomeration on the birth rate and the percent of deaths resulting from suicide are both significant and negative at 10% significance. The broader category of "deaths with external causes" is just outside the 10% significance level (p-value 0.106). However, when applying the estimation on the two-year sample, the p-values are all considerably higher and the sign on the coefficient estimates is reversed for all metrics except the birth rate. As such, we cannot make any reasonable conclusions about the relationship between agglomeration and the birth and death metrics using this methodology and data.

From TABLE 8, the coefficient estimates for crime-related metrics all maintain sign and are of very close magnitudes between the full sample and two-year sample estimates. However, "other criminal code violations (per capita)" is the only metric where statistical significance is maintained over the two estimation approaches. The relationship between agglomeration and "federal statute violations" is not statistically significant using either approach, and "violent crimes" has a weak statistical relationship (p-values of 0.125 and 0.638 in the full and two-year samples respectively). We find this result interesting as it contrasts with past assessments of the impact of resource development projects on social issues and crime rates. As mentioned above, past work finds that resource development projects may increase the risk of alcohol abuse in remote communities and (by extension) increased rates of violent crime. This may imply that alcohol abuse and violent crime rates are not caused by reduced remoteness accompanying resource development projects, but rather some other aspect of those projects.

8 Deaths due to accidents and/or violence.

Figure 4. Projected Impact of the New Highway on Community Level Socio-Economic Metrics



The results suggest that the only statistically likely relationships between agglomeration and crime are "other criminal code violations" (a classification that does not include violent or property crimes). This suggests that improved connectivity (agglomeration) may increase the rate of "other" (non-violent, non-property, non-traffic and non-federal) crimes (which have no statistical impact on the other three crime categories).[9]

Interpreting the econometric estimates within the context of the completion of Highway 10

A comparison of the 2011 and 2016 data — recall that the 2016 calculations of the remoteness index and agglomeration measures are based on travel costs in 2017 after Highway 10's completion — shows an increase in agglomeration for Tuktoyaktuk of 1.852 points (from 2.7342 to 4.5862), placing Tuktoyaktuk within the same range as other highway-connected communities in Northwest Territories. During the same period, Tuktoyaktuk's population increased from 854 to 898. This increase in population accounts for 0.05 of the increase in agglomeration $(\ln(898) - \ln(854) = 0.05)$. Therefore, we conclude that the change in the level of agglomeration attributable to the completion of Highway 10 is approximately 1.8 points $(1.852 - 0.05 \approx 1.8)$. From equation 2, the implied change in the outcome variables attributable to the highway is:

$$\Delta Y_{Tuktoyaktuk,2017} = \hat{\beta}_1(1.8) \quad (4)$$

Using this equation, the observed increase in agglomeration due to Highway 10, and the coefficient estimates presented above, we

9 It is worth mentioning that not all northern communities have a persistent police detachment. Only 21 of the 33 communities in our sample have RCMP detachments, with smaller more remote communities less likely to have detachments (RCMP 2022). So, it may be that less remote communities have higher crime detection rates (rather than higher crime rates) due to the presence of police detachments. This is an area for future research.

Table 9. Projected Effect of Highway 10 on Socio-Economic Metrics

Metric	Full Sample	Two-Year Sample	Significance of Estimates	Consistency of Estimates
Family Income <$30,000 (%)	-2.440	-2.822	Full Sample Only	Yes
Family Income >$75,000 (%)	6.281	5.742	Both	Yes
Tax-filer Income <$15,000 (%)	-4.371	-4.049	Both	Yes
Tax-filer Income >$50,000 (%)	4.754	4.407	Both	Yes
Average Employment Income ($)	4843.282	4403.116	Both	Yes
Average Family Income ($)	7549.896	7588.161	Full Sample Only	Yes
Average Personal Income ($)	3964.571	3409.758	Full Sample Only	Yes
Employment Rate	1.202	0.784	Neither	Yes
Participation Rate	1.198	1.013	Full Sample Only	Yes
Unemployment Rate	-0.323	-0.302	Neither	Yes
Income Assistance Beneficiaries (monthly, per capita)	-0.022	-0.019	Both	Yes
Income Assistance Cases (monthly, per capita)	-0.013	-0.011	Both	Yes
Income Assistance Payments per capita ($)	80.445	149.733	Full Sample Only	No
Households in Core Need (%)	-3.328		Yes	N/A
Households with 6 or More People (%)	-1.526	-0.103	Full Sample Only	No
Minimum High School Education (%)	3.212	4.536	Both	Yes
Aboriginals that Speak an Aboriginal Language (%)	-3.043	-3.293	Full Sample Only	Yes
Teen Births (%)	-1.887	0.623	Neither	No
Births (Per Capita)	-0.002	-0.001	Full Sample Only	No
Deaths (Per Capita)	0.000	0.000	Neither	No
Deaths with External Causes Including Suicides (%)	-3.017	1.133	Neither	No
Deaths resulting from Suicide (%)	-2.599	2.513	Full Sample Only	No
Federal Statute Violations (per capita)	0.001	0.001	Neither	Yes
Other Criminal Code Violations (per capita)	0.035	0.036	Both	Yes
Property Crimes (per capita)	0.021	0.028	Full Sample Only	Yes
Traffic Crimes (per capita)	0.003	0.004	Full Sample Only	Yes
Violent Crimes (per capita)	0.007	0.005	Neither	Yes

Notes: The "Significance of Estimates" column indicates whether the coefficient estimates underlying the projections are statistically significant at the 90% confidence level using one or both sample methodologies. When only the full sample methodology is feasible this column indicates significance (Yes) or lack of significance (No) for the full sample only. The "Consistency of Estimates" column indicates whether the coefficient estimates on which the calculations are based are within each other's 90% confidence interval.

construct point estimates and confidence intervals for the expected effect of the Highway 10's completion on the metrics in TABLE 2. FIGURE 4 and TABLE 9 summarize the results for both methods. TABLE 9 also includes whether the coefficient estimates underlying the projected expected impacts are statistically significant (at 10%) and whether the coefficient estimates are consistent between the two approaches. We define consistency between the approaches as the coefficient for each estimate falls within the 90% confidence interval for the alternate approach. While fewer estimates in the two-year sample are statistically significant there is a high degree of consistency between approaches, which is encouraging.

The effect estimates in FIGURE 4 and TABLE 9 have a much more direct interpretation than the coefficient estimates (particularly since the concept of "agglomeration" is well defined but does not have natural units). These results are directly interpreted as the projected persistent socioeconomic effects of Highway 10's completion and the associated increase in agglomeration. Summarizing only the consistent results with a dual significance (using both full and two-year samples):

- Income and employment: the results show that highway completion likely promotes a $4,500/year increase in tax-filer income; a ~6% increase in the percent of households with incomes above $75,000; a ~4% reduction in tax-filers with incomes below $15,000; and a ~4.5% increase in tax-filers with incomes above $50,000. Consistent with these income increases, the results also indicate that highway completion likely promotes a reduction of 0.01 income assistance cases and a reduction of 0.02 beneficiaries per capita per month.
- There is also a strong indication that highway completion will promote an approximate 4% increase in high school completion rates.
- Highway completion may also lead to a 0.035 per capita increase in other (nonviolent, non-traffic and non-property) annual criminal code violations.

CONCLUDING REMARKS

Our focus only on consistent results based on dual significance should not be taken to suggest that there are no effects on other metrics. A lack of statistical significance implies that we are unable to reject the null hypothesis of no effect of agglomeration on a metric at a 90% significance level for one or both estimation approaches (full sample or two-year sample). A lack of consistency similarly implies a higher degree of uncertainty regarding the likely effects of agglomeration.

Increased connectivity through infrastructure development can potentially bring significant socio-economic changes to remote communities. Combining Statistics Canada's recently developed Index of Remoteness and demographic data with a simple statistical analysis, in this paper we estimate the effect of Highway 10 on a set of socio-economic outcomes in Tuktoyaktuk. We find that improved connectivity substantially improves certain socio-economic outcomes like average household income, high school completion rates, and a reduction in income assistance cases and beneficiaries. Loss of Indigenous culture and language across the remote and small communities of Canada's north has been a concern (Richards & Burnaby 2008, Statistics Canada 2017b, Dunlop et al. 2018) and while our results demonstrate a weak statistical relationship between agglomeration and aboriginal language proficiency, this remains a policy concern and suggests additional research may be needed.

This analysis is a first step towards exploring the effect of Canada's first all-weather road to the Arctic Coast on the socio-economic outcomes of a remote community. Despite the data limitations, our results point towards a set of positive employment and income impacts as well as a mix of positive and negative statistically significant effects on other socio-economic metrics for Tuktoyaktuk from Highway 10's completion in 2017 and suggest areas for follow-up work using other methods (such as case studies or community-based research) and analysis of future data as it becomes available.

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