# A Socio-economic Review of the Impacts of Northwest Territories' Inuvik to Tuktoyaktuk Highway 10

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## Abstract

We project and investigate 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 project and investigate Highway 10's likely socio-economic effects on the community of Tuktoyaktuk based on 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 and Manchin 2013, Atkins and Donaldson 2015, Donaldson 2018, Fellows and 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

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[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.

“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 increases 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 (potentially due to more effective detection and enforcement).

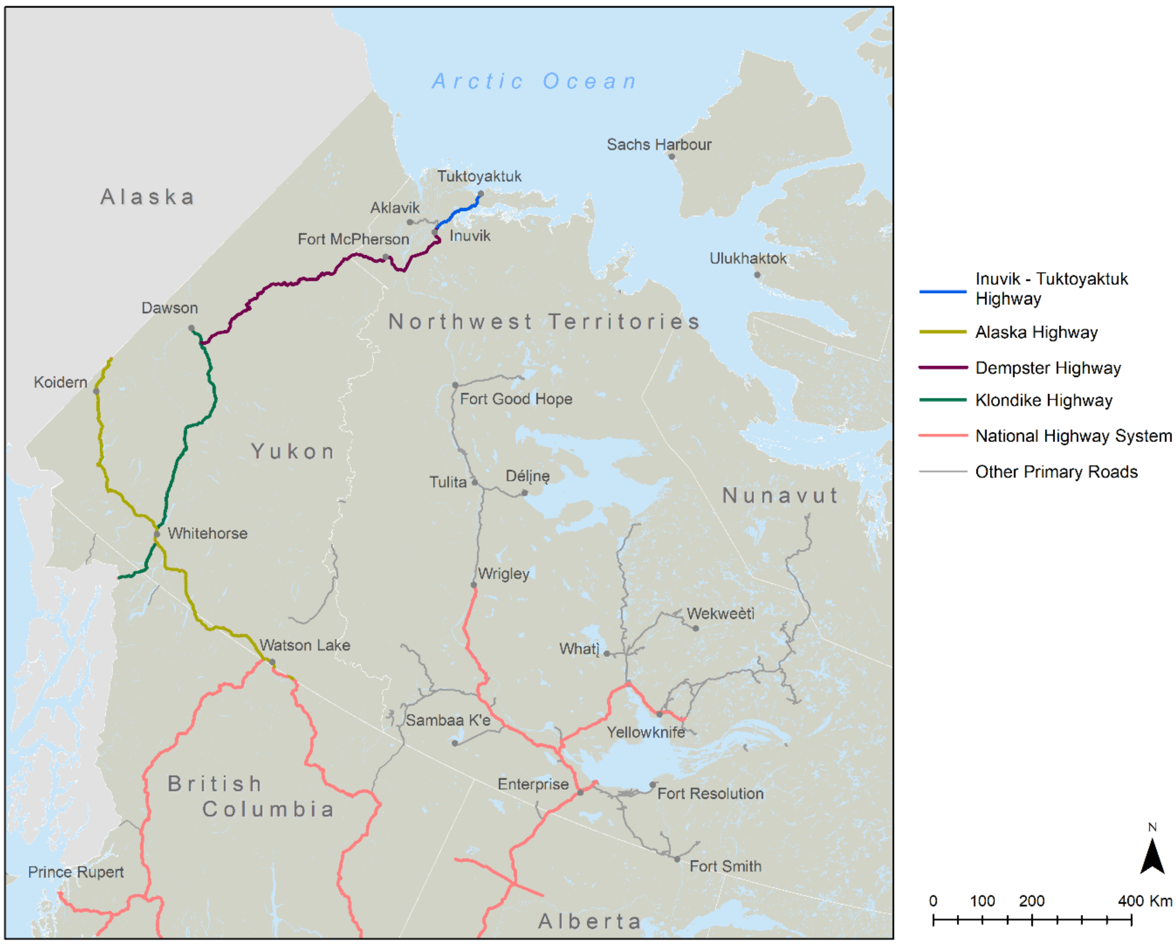
The remainder of the paper proceeds with a brief review of the Highway 10 project, followed by a description of relevant data used in our analysis. We then explain the statistical methodology used to estimate the projected impact of improved connectivity before discussing at greater length the likely 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. Inuvik is linked to the rest of Canada’s national highway system through the Dempster Highway, which 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). As indicated, 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, one of several in northern Canada that does not have its own traffic control tower) or via the Mackenzie River in summer.

FIGURE 1 Road Transportation Network in the Northwest Territories




Source: 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.

Historically, the timing and frequency of freezing degree-days (days with temperature below 0°C) was sufficient to allow for four-month a 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 and 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). Much of this issue is averted through the construction and maintenance of an all-weather road.

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.). More recently, the conception of Highway 10 came from a campaign promise made by then-Prime Minister Stephen Harper in the 2011 federal election (MacCharles and Campion-Smith 2011). The Conservative Party of Canada under Harper formed government following the 2011 election and allocated $200 million CAD to the project in the 2012 and 2013 federal budgets with the Government of Northwest Territories providing the remaining $100 million (Stewart 2017).

Construction of the highway began in early 2014. In addition to the road surface and ballast, construction included 8 bridges and 359 culverts. The project employed more than 600 people, approximately 450 of which were Northwest Territories residents during peak construction. Related skills training included licensing for class 1 and class 3 drivers, equipment operators, summer students and apprentices (Infrastructure Canada 2017). The highway opened to the public in November 2017 and became the first highway in Canada to reach the Arctic Ocean. The Government of Northwest Territories (GNWT) Department of Transportation estimates annual maintenance costs of the road as $2 million CAD (Miltenberger 2013).

## 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).

As noted by Roger Epp (University of Alberta professor and director of UAlberta North) "one person's 'remote' is another's epicenter" (as quoted in Young et al. 2016b: 59). This perspective is important in motivating a focus on relative remoteness rather than treating remoteness as a binary factor (remote vs non-remote). Accordingly, we restrict our econometric analysis to Northwest Territories communities.[3]

Many communities in Canada's 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). In contrast, 97% of communities in Yukon are accessible by all-season roads, 85% are served by a regional electricity grid and 93% have connectivity with a terrestrial information technology backbone (National Aboriginal Economic Development Board 2016).[4] 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.

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[3] Dr. Epp goes on to argue that the term "remote" is problematic in many contexts as it "unconsciously exposes the speaker's perspective, which is that of an outsider, often an external expert attempting to impose solutions on communities" (Young et al. 2016b). While we acknowledge this concern, as used in this context we feel the language is nonetheless appropriate, particularly (and perhaps unfortunately) since our regression analysis makes use of Statistics Canada's Index of Remoteness, implying that the term is inescapable here.

[4] While the consumer retail "front face" of modern IT and internet connectivity is often wireless, terrestrial wired networks (usually carbon fiber) 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.

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, O'Neill & Chapman, 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 (van der Velden and Wolbers 2007; Riddell 2006). 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 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 and 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:pp 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 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 and Young 2015: 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 and 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 and 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.

Related to these health concerns, remoteness can also affect leisure, recreation, and social activities and by extension healthy lifestyle choices. Kowalski et al. (2012: 332) find that a lack of transportation means significantly reduced participation in leisure activities when "residents cannot get to [a recreation] facility or return home owing to inclement weather, the absence of a ferry or road or bridge closing." Additionally, individual communities often suffer from lack of recreation facilities, which further limits participation in recreational activities for remote or inaccessible communities (Kowalski et al. 2012).

However, the effects of remoteness and isolation are not all negative. As Burten et al. (2015) note, 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.

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.

**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:

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

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*.[5]

As *Equation 1* implies, agglomeration measures "proximity" using the travel cost between a community *i* and its neighboring communities. Statistics Canada (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).

[5] The set of communities in this case includes all communities within a 150-minute one-way commute unless there are no communities within a 150-minute one-way commute, in which case the set only includes a single element k representing the closest community. For Tuktoyaktuk, this set includes only Inuvik.

## 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 impact on several socio-economic metrics. The bulk 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. The completion of Highway 10 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. Whereas 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 impacts of Highway 10.

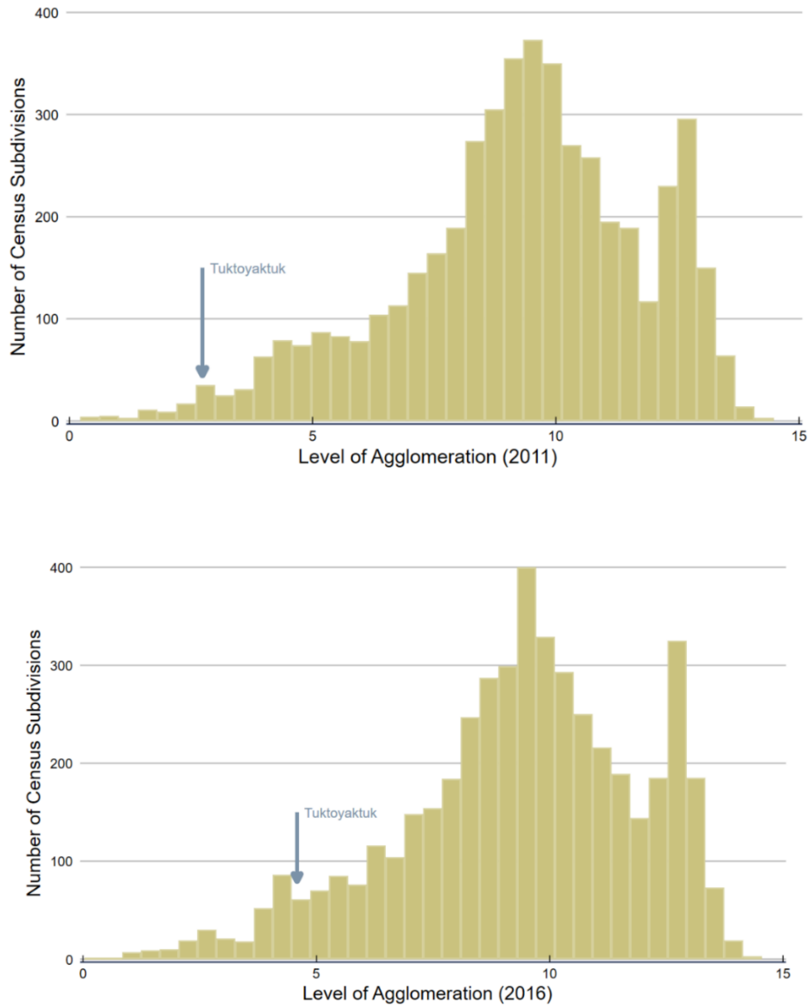
FIGURE 2 shows the change in agglomeration for Tuktoyaktuk from 2011 to 2016. It is worth noting that, while Highway 10 was officially completed in 2017, the 2016 agglomeration measure was calculated using 2016 census data but distances and travel costs measured after the completion of Highway 10.[6] As such, the 2016 data reflects agglomeration for Tuktoyaktuk immediately following the completion of Highway 10.

FIGURE 3 shows how the agglomeration and population changed for a set of northern communities from 2011 to 2016/2017. 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)[7], while some smaller agglomeration changes have resulted due to population growth in adjacent communities.

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

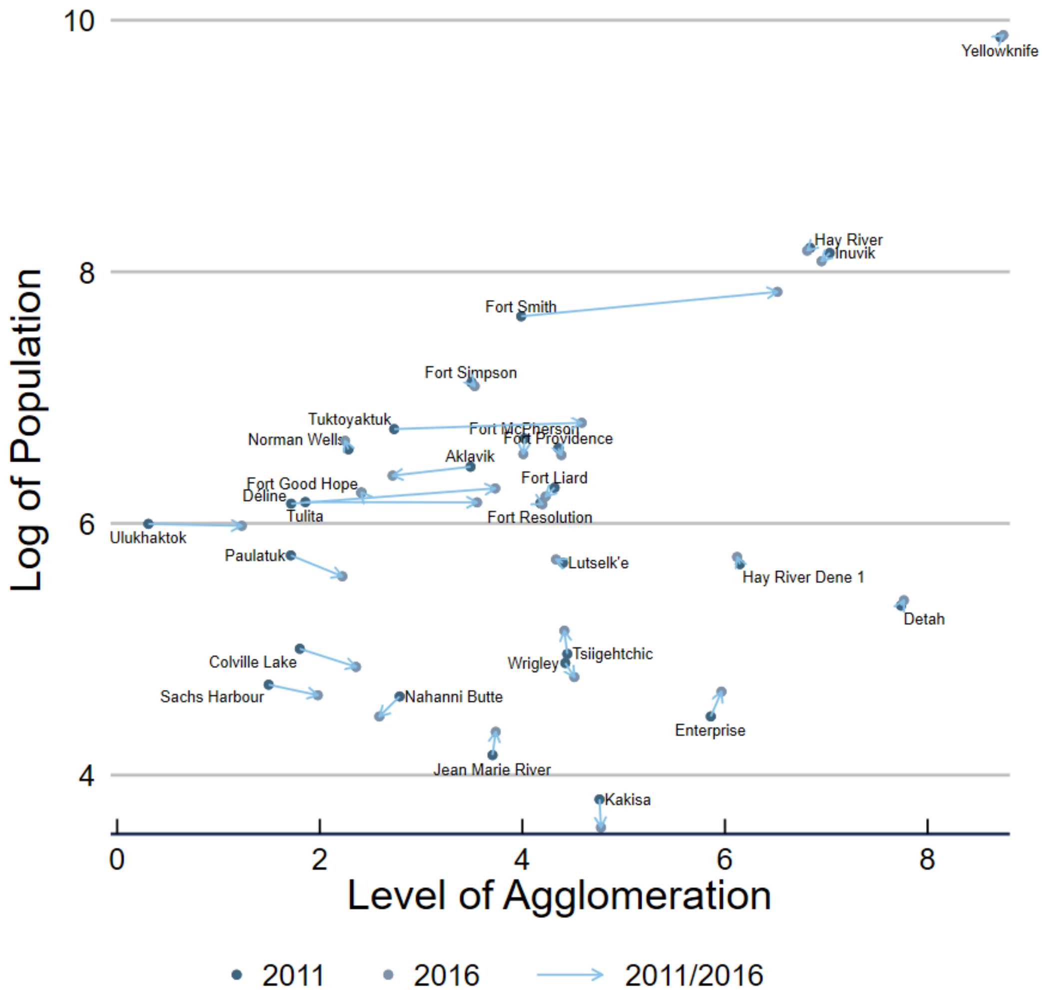
[7] Both Highway 10 and the upgrades to Highway 5 were officially completed in 2017. However, as per the previous footnote, the 2016 calculations for the remoteness index are based on travel costs calculated for 2017, after the completion of Highway 10.

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




Data Source: Alasia et al. (2017)

FIGURE 3 Changes in the Levels of Agglomeration 2011 to 2016




Data Source: Alasia et al. (2017)

**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.

TABLE 2 Socio-economic Metrics for Regression Analysis

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

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:

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

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, $\alpha_t$ 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. 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.

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 the 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 Northwest Territories average and 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).

TABLE 3 Summary Statistics for Tuktoyaktuk

| Variables | (1) N | (2) mean | (3) s.d. | (4) min | (5) max |
|---|---|---|---|---|---|
| Family Income <$30,000 (%) | 10 | 28.44 | 3.004 | 22.73 | 31.82 |
| Family Income >$75,000 (%) | 10 | 31.11 | 2.855 | 27.27 | 36.36 |
| Taxfiler Income <$15,000 (%) | 10 | 38.82 | 3.527 | 33.90 | 43.86 |
| Taxfiler Income >$50,000 (%) | 10 | 20.07 | 1.531 | 17.54 | 22.22 |
| Households in Core Need (%) | 5 | 36.75 | 5.769 | 31.90 | 43.30 |
| Households with 6 or More People (%) | 9 | 16.72 | 5.264 | 11.89 | 29.27 |
| Minimum High School Education (%) | 13 | 36.97 | 4.092 | 31.62 | 46.14 |
| Average Employment Income ($) | 10 | 32,773 | 1,468 | 30,686 | 35,024 |
| Average Family Income ($) | 10 | 70,877 | 3,755 | 66,659 | 78,022 |
| Average Personal Income ($) | 10 | 33,419 | 2,215 | 30,698 | 37,517 |
| Employment Rate | 13 | 41.56 | 3.159 | 35.35 | 45.23 |
| Deaths with External Causes Including Suicides (%) | 10 | 26.64 | 18.61 | 0 | 66.67 |
| Federal Statute Violations (per capita) | 10 | 0.0126 | 0.00656 | 0.00514 | 0.0264 |
| Income Assistance Beneficiaries (monthly, per capita) | 10 | 0.223 | 0.0260 | 0.200 | 0.284 |
| Income Assistance Cases (monthly, per capita) | 10 | 0.130 | 0.0119 | 0.116 | 0.156 |
| Income Assistance Payments per capita ($) | 10 | 1,416 | 277.1 | 1,060 | 2,003 |
| Aboriginals that Speak an Aboriginal Language (%) | 8 | 29.43 | 5.434 | 22.34 | 37.71 |
| Births (Per Capita) | 10 | 0.0222 | 0.00466 | 0.0143 | 0.0308 |
| Deaths (Per Capita) | 10 | 0.00609 | 0.00220 | 0.00330 | 0.0103 |
| Other Criminal Code Violations (per capita) | 10 | 0.131 | 0.0383 | 0.0679 | 0.193 |
| Participation Rate | 13 | 60.15 | 4.389 | 50.80 | 65.83 |
| Property Crimes (per capita) | 10 | 0.314 | 0.0394 | 0.245 | 0.365 |
| Deaths resulting from Suicide (%) | 10 | 6.524 | 8.566 | 0 | 20 |
| Teen Births (%) | 10 | 10.95 | 6.147 | 0 | 18.18 |
| Traffic Crimes (per capita) | 10 | 0.0255 | 0.0149 | 0.0119 | 0.0560 |
| Unemployment Rate | 13 | 31.13 | 5.561 | 25.98 | 45.59 |
| Violent Crimes (per capita) | 10 | 0.156 | 0.0455 | 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

| Variables | (1)<br>N | (2)<br>mean | (3)<br>s.d. | (4)<br>min | (5)<br>max |
|---|---|---|---|---|---|
| Family Income <$30,000 (%) | 10 | 8.575 | 0.983 | 6.922 | 10.10 |
| Family Income >$75,000 (%) | 10 | 76.34 | 1.759 | 74.17 | 78.87 |
| Taxfiler Income <$15,000 (%) | 10 | 15.57 | 0.854 | 14.50 | 16.92 |
| Taxfiler Income >$50,000 (%) | 10 | 56.66 | 2.094 | 53.88 | 59.54 |
| Households in Core Need (%)** | 5 | 10.48 | 4.787 | 4.700 | 17.92 |
| Households with 6 or More People (%) | 9 | 4.385 | 0.678 | 3.326 | 5.375 |
| Minimum High School Education (%) | 13 | 79.57 | 5.571 | 66.73 | 88.69 |
| Average Employment Income ($) | 10 | 67,562 | 4,397 | 61,518 | 72,851 |
| Average Family Income ($) | 10 | 148,433 | 9,945 | 134,645 | 161,976 |
| Average Personal Income ($) | 10 | 68,605 | 4,263 | 62,711 | 74,181 |
| Employment Rate | 13 | 80.20 | 2.153 | 75.65 | 83.26 |
| Deaths with External Causes Including Suicides (%) | 10 | 14.36 | 5.417 | 5.970 | 24.19 |
| Federal Statute Violations (per capita) | 10 | 0.0123 | 0.00378 | 0.00741 | 0.0182 |
| Income Assistance Beneficiaries (monthly, per capita) | 10 | 0.0266 | 0.00383 | 0.0223 | 0.0348 |
| Income Assistance Cases (monthly, per capita) | 10 | 0.0170 | 0.00261 | 0.0142 | 0.0225 |
| Income Assistance Payments per capita ($) | 10 | 5,082 | 1,004 | 3,695 | 7,189 |
| Aboriginals that Speak an Aboriginal Language (%) | 8 | 28.95 | 11.10 | 18.02 | 51.53 |
| Births (Per Capita) | 10 | 0.0151 | 0.00105 | 0.0134 | 0.0171 |
| Deaths (Per Capita) | 10 | 0.00300 | 0.000356 | 0.00254 | 0.00359 |
| Other Criminal Code Violations (per capita) | 10 | 0.133 | 0.0141 | 0.110 | 0.154 |
| Participation Rate | 13 | 85.03 | 2.297 | 79.36 | 87.45 |
| 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 | 0.00982 | 0.00322 | 0.00413 | 0.0159 |
| Unemployment Rate | 13 | 5.663 | 0.951 | 4.408 | 7.863 |
| Violent Crimes (per capita) | 10 | 0.0416 | 0.00622 | 0.0289 | 0.0479 |

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.

## 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).

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 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).

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 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.[8] 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.

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 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 |

[8] 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.

| | | | | | |
|---|---|---|---|---|---|
| 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).

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"[9] 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

[9] External causes of death are deaths due to accidents and/or violence.

“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).

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).

The results suggest that the only statistically likely relationships between agglomeration and crime are traffic crimes and “other criminal code violations” (a classification that does not include violent or property crimes). A possible reason for this pattern could be related to the detection rate for these crimes, not the underlying criminal activity. It seems reasonable to speculate that higher agglomeration (and in particular the lower travel costs) would allow for more effective law enforcement (particularly of traffic laws) at a community level.

**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 completion of Highway 10 — 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 a 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:

$$\Delta Y_{Tuktoyaktuk,2017} = \hat{\beta}_1(1.8) \qquad \textit{Equation 3}$$

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

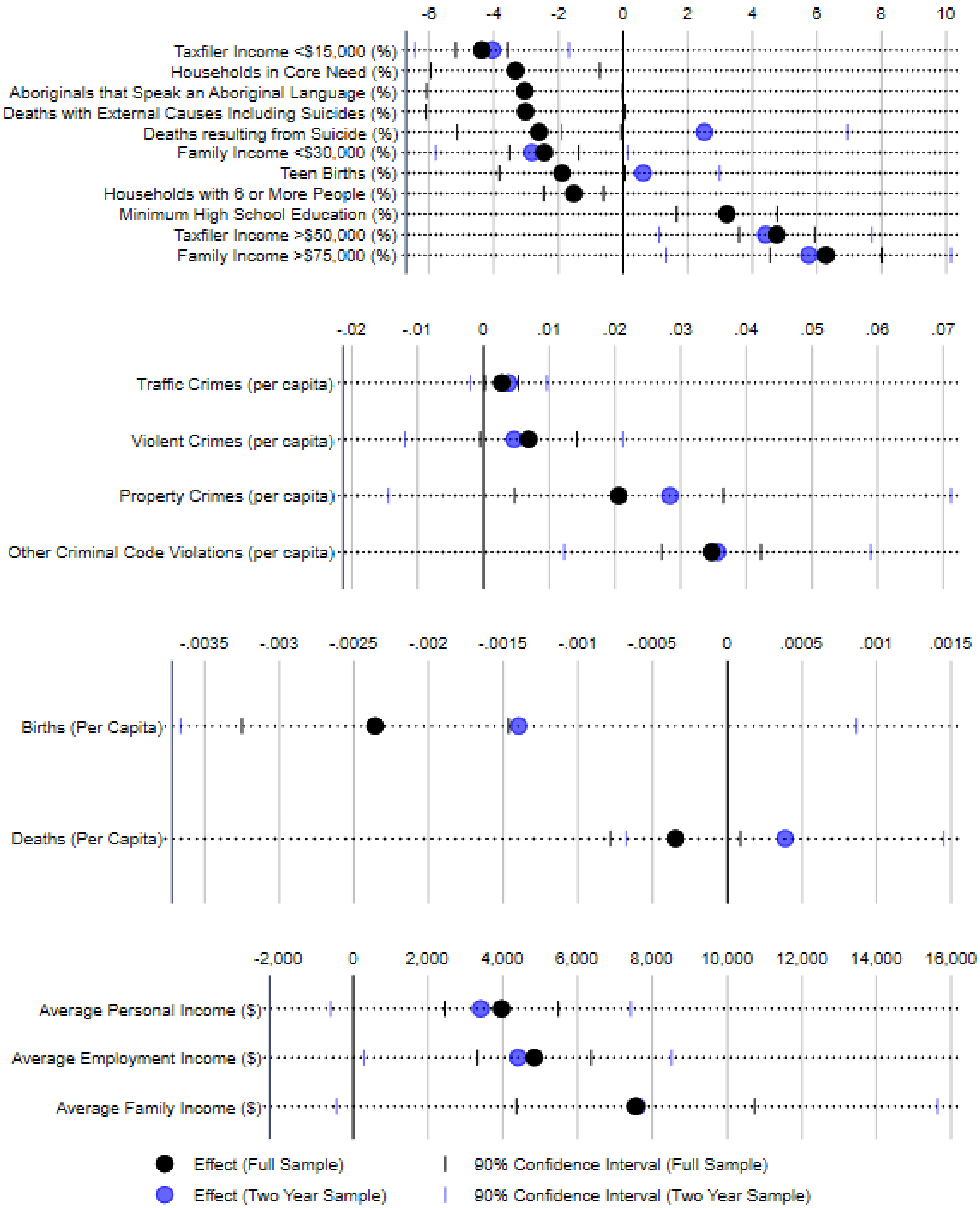
- There is also a strong indication that highway completion will promote an approximate 4% increase in high school completion rates.
- Highway completion is also likely to lead to a 0.035 per capita increase in other (nonviolent, non-traffic and non-property) annual criminal code violations. Although, as discussed above, we speculate that this could be due to more accurate (higher quality) detection and enforcement.

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 |
| Taxfiler Income <$15,000 (%) | -4.371 | -4.049 | Both | Yes |
| Taxfiler 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.

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



## 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 and 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 an overall positive net present value of total income for Tuktoyaktuk from Highway 10's completion in 2017 and suggests areas for follow-up work using other methods (such as case studies or community engagement) and analysis of future data as it becomes available.

## References

Alasia, Alessandro, Frédéric Bédard, Julie Bélanger, Eric Guimond, and Christopher Penney. 2017. *Measuring remoteness and accessibility-A set of indices for Canadian communities*. No. 18-001-X. 2017.

Atkin, D., and Donaldson, D. (2015). *Who's getting globalized? The size and implications of intra-national trade costs* (No. w21439). National Bureau of Economic Research.

Banerjee, A., Duflo, E., & Qian, N. (2012). *On the road: Access to transportation infrastructure and economic growth in China* (No. w17897). National Bureau of Economic Research.

Canadian Institute for Health Information. 2020. "National Health Expenditure Trends." Accessed October 18, 2021. https://www.cihi.ca/sites/default/files/document/nhex-trends-2020-narrative-report-en.pdf

CBC Digital Archives. n.d. "1979: Dempster Highway opens 'road to resources' across Arctic." https://www.cbc.ca/archives/entry/1979-dempster-highway-opens-road-to-resources-across-arctic. Accessed March 14, 2022.

Davidson, R., and J. G. MacKinnon. 1993. Estimation and Inference in Econometrics. New York: Oxford University Press.

Donaldson, D. (2018). Railroads of the Raj: Estimating the impact of transportation infrastructure. *American Economic Review*, *108*(4-5), 899-934.

Dunlop, B., Gessner, S., Herbert, T., & Parker, A. 2018. Report on the status of B.C. First Nations languages. Brentwood Bay, BC: First Peoples' Cultural Council (FPCC).

Fellows, G. Kent, and Trevor Tombe. 2018. "Opening Canada's North: A Study of Trade Costs in the Territories." *The School of Public Policy Publications* 11:17.

Francois, J., and Manchin, M. 2013. Institutions, infrastructure, and trade. *World development*, *46*, 165-175.

GNWT. 2010. "Inuvik to Tuktoyaktuk all-weather road economic analysis." Department of Transportation, Government of Northwest Territories, Yellowknife. Accessed October 18, 2021. https://www.inf.gov.nt.ca/sites/inf/files/resources/ith_economic_analysis_0.pdf

GNWT. 2011. "Environmental impact statement for construction of the Inuvik to Tuktoyaktuk Highway, NWT." Hamlet of Tuktoyaktuk, Town of Inuvik, Government of Northwest Territories. EIRB File No. 02/10-0. Accessed October 14, 2021. https://www.inf.gov.nt.ca/sites/inf/files/resources/ith_eis.pdf

GNWT. 2020. "Tuktoyaktuk - Statistical Profile." Bureau of Statistics, Government of Northwest Territories, Yellowknife. Accessed October 18, 2021. https://www.statsnwt.ca/community-data/infrastructure/Tuktoyaktuk.html.

Hori, Y., Gough, W.A., Butler, K. and Tsuji, L.J.S. 2017. “Trends in the seasonal length and opening dates of a winter road in the western James Bay region, Ontario, Canada.” Theoretical and Applied Climatology, 129: pp. 1309-1320.

Infrastructure Canada. 2017. “Backgrounder: History in the making: Completion of the Inuvik Tuktoyaktuk Highway links Canada from coast to coast to coast.” Accessed November 14, 2020. https://www.canada.ca/en/office-infrastructure/news/2017/11/backgrounder_historyinthemakingcompletionoftheinuviktuktoyaktukh.html

Kowalski, Christopher L., Oksana Grybovych, Samuel Lankford, and Larry Neal. 2012. "Examining Constraints to Leisure and Recreation for Residents in Remote and Isolated Communities: An Analysis of 14 Communities in the Northwest Territories of Canada." *World Leisure Journal* 54, no. 4 (2012): 322-36.

Loring, Philip, and S. Gerlach. 2015. "Searching for Progress on Food Security in the North American North: A Research Synthesis and Meta-analysis of the Peer-Reviewed Literature." *Arctic* 68, no. 3: 380-92.

MacCharles, Tonda, and Bruce Campion-Smith. 2011. “Conservatives to flex majority muscle in new Parliament.” *Toronto Star*, June 3. https://www.thestar.com/news/canada/2011/06/03/conservatives_to_flex_majority_muscle_in_new_parliament.html.

Miltenberger, M. 2013. “Bill 4 – Appropriation Act (Operations Expenditures), 2013-2014.” Northwest Territories. Legislative Assembly. Debates of the Legislative Assembly Hansard.17th Assembly. 4th Session. March 11, 2013. Accessed October 15, 2021. https://www.ntassembly.ca/sites/assembly/files/hn130311.pdf

Mullan, D., Swindles, G., Patterson, T., Galloway, J., Macumber, A., Falck, H., Crossley, L., Chen, J. and Pisaric, M. 2017. “Climate change and the long-term viability of the world’s busiest heavy haul ice road.” *Theoretical and Applied Climatology*, 129: pp. 1089-1108.

National Aboriginal Economic Development Board. 2016. *Recommendations on Northern Infrastructure to Support Economic Development* http://www.naedb-cndea.com/reports/recommendations-on-northern-infrastructure.pdf

Natural Resources Canada [NRCan]. 2020a. “Geographical Names Data – Canada.” Accessed August 30, 2021. https://www.nrcan.gc.ca/earth-sciences/geography/download-geographical-names-data/9245

Oosterveer, Tim M., and T. Kue Young. 2015 "*Primary health care accessibility challenges in remote indigenous communities in Canada's North.*" International Journal of Circumpolar Health 74, no.1:29576.

Pearce, T., Ford, J.D. and Fawcett, D., 2020. Climate Change and Implications for the Proposed Canadian Northern Corridor. *The School of Public Policy Publications*, 13.

Richards, M., and Burnaby, B. 2008. Restoring Aboriginal languages: Immersion and intensive program models in Canada. In T. Williams Fortune & D. J. Tedick (Eds.), *Pathways to* *multilingualism: Evolving perspectives on immersion education*. pp. 221–241. Clevedon, UK: Multilingual Matters Ltd.

Riddell, W. C. (2006). *The impact of education on economic and social outcomes: An overview of recent advances in economics*. Canadian Policy Research Networks.

Sharplin, E., O'Neill, M., & Chapman, A. 2011. *Coping strategies for adaptation to new teacher appointments: Intervention for retention* Teaching & Teacher Education, 27(1), 136-146

Statistics Canada. 2016. "2016 Census - Coastal Waters (polygons)." https://www12.statcan.gc.ca/census-recensement/2016/geo/index-eng.cfm

Statistics Canada 2017a. *Tuktoyaktuk, HAM [Census subdivision], Northwest Territories and Northwest Territories [Territory]* (table). *Census Profile*. 2016 Census. Statistics Canada Catalogue no. 98-316-X2016001. Ottawa. Released November 29, 2017. Retrieved from https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E Accessed on December 6, 2020.

Statistics Canada. 2017b. Census in Brief: The Aboriginal languages of First Nations people, Métis and Inuit. Statistics Canada Census of Population, 2016. (Catalogue no. 98-200-X2016022). Ottawa, ON. Retrieved from http://www12.statcan.gc.ca/census-recensement/2016/as-sa/98-200-x/2016022/98-200-x2016022-eng.cfm Accessed on December 6, 2020.

Statistics Canada. 2018. TABLE 23-10-0032-01 Aircraft movements, by class of operation and type of operation, airports without air traffic control towers, annual. Retrieved from https://doi.org/10.25318/2310003201-eng

Statistics Canada. 2019a. TABLE 23-10-0238-01 Average domestic fares for Canada and ten major cities, annual. Retrieved from https://doi.org/10.25318/2310023801-eng

Statistics Canada. 2019b. "2016 Census – Boundary Files. Provinces and Territories." https://www12.statcan.gc.ca/census-recensement/2011/geo/bound-limit/bound-limit-2016-eng.cfm

Statistics Canada. 2020a. "Inventory of publicly owned road assets, Infrastructure Canada." TABLE 34-10-0176-01. DOI: https://doi.org/10.25318/3410017601-eng

Statistics Canada. 2020b. "Road Network File, 2020." Catalogue no. 92-500-X. https://www150.statcan.gc.ca/n1/en/catalogue/92-500-X2020001

Stewart, Briar. 2017. "New Arctic coast highway opens up remote Tuktoyaktuk." *CBC News*. Oct. 23. https://www.cbc.ca/news/canada/north/new-arctic-coast-highway-opens-up-remote-tuktoyaktuk-1.4363029.

Town of Fort Smith, 2017 "Say Goodbye to Gravel! Hwy 5 Fully Paved!" https://www.fortsmith.ca/news/say-goodbye-gravel-hwy-5-fully-paved

United States (US) Census Bureau. 2018. "Cartographic Boundary Files – National Boundaries Shapefile." https://www2.census.gov/geo/tiger/GENZ2018/shp/cb_2018_us_nation_5m.zip van der Velden, R.K.W. and Maarten H. J. Wolbers. 2007. “How Much Does Education Matter and Why? The Effects of Education on Socio-economic Outcomes among School-leavers in the Netherlands.” *European Sociological Review*, Volume 23, Issue 1, Pages 65–80, https://doi.org/10.1093/esr/jcl020

Young, T. K., Chatwood, S., & Marchildon, G. P. 2016a. Healthcare in Canada's North: are we getting value for money? *Healthcare Policy*, *12*(1), 59.

Young, T. Kue, Susan Chatwood, James Ford, Gwen Healey, Michael Jong, Josée Lavoie, and Mason White. 2016b. “*Transforming Health Care in Remote Communities: Report on an International Conference.*” BMC Proceedings 10 (August): 59–66. doi: 10.1186/s12919-016-0006-0.

Young, T. Kue, and Susan Chatwood. 2017. "Delivering More Equitable Primary Health Care in Northern Canada." CMAJ: Canadian Medical Association Journal 189, no. 45. E1377-E1378.