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THE IMPACT OF ROAD CONNECTION ON EMPLOYMENT AND EDUCATION IN NORTHERN CANADA

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Abstract: Road connection is viewed as a contributing factor to a variety of positive economic outcomes. However, for remote subarctic communities, it can also mean a significant impact on in their way of life. To which extent does road connection impact socio-economic outcomes such as salary, education or employment? This paper uses census data from Northern Quebec and Labrador to assess the effects of road connection on municipalities connected between 1986 and 2016. Using a difference-in-differences specification to an OLS regression model, assorted with robustness checks, we find that road connection is correlated with increased employment rates and educational attainment and decreased unemployment. While we also find positive and significant correlations between road connection and income in many specifications, that particular result is not robust when ensuring that error terms are not subject to cross-sectional dependence. Overall, our results support the conjecture that road connection of remote municipalities generates non-negligible economic benefits.

Keywords: roads; economic development; northern communities; infrastructure

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INTRODUCTION

Canadian Arctic and subarctic communities are geographically remote and are located in harsh climates can have a higher cost of living, which often affects their poverty rate and quality of life (Daley et al., 2015). The cost of living is more expensive in these communities when they are not connected by road (Nunavut, 2012), which means that road construction could be especially beneficial to them in reducing poverty. Few studies specifically touch upon the economic impact of road connection on communities in Canadian Arctic or subarctic regions, and no study attempts to quantitatively measure this impact. Considering the growing importance of the Arctic in international geopolitics and trade, road construction may very well become a crucial part of any country's plan to access tide-water access points in the Arctic Ocean. Assessing the benefits associated with building roads is the first step towards any further project to be undertaken.

Canada is one of the few countries in the world that can boast a highly prosperous economy while having the vast majority of its nordic landmass uninhabited and undeveloped infrastructure-wise. Northern Canada is the part of the country that has experienced the least amount of infrastructure development, with many towns and villages still disconnected from Southern Canada's road network. Recently, various proposals of road connections to remote localities, such as the Northern Corridor Concept (Sulzenko & Fellows, 2016), the Yukon Resource Gateway Project (Yukon Gateway, 2016) or La Grande Alliance (Dutrisac, 2020), have been floated by different levels of government and think tanks. Each proposal includes the construction of land transport infrastructures to connect previously isolated communities to the country's main road network, purporting this will improve their living conditions and economic opportunities. Each proposal also includes natural resource extraction projects in varying detail. The Quebec-Labrador Peninsula in particular has had a complex history of infrastructure development in its northern region, leading to differing views on whether infrastructure growth is positive for the inhabitants of these regions (Stringer & Joanis, 2022).

As mentioned above, existing research suggests that education, labour and income indicators react positively to a new road connection. However, this has not been replicated in the northern context. According to historical data, what has been the effect of road connection on isolated Canadian Arctic and subarctic communities? Which socioeconomic indicators see the biggest increases or decreases after the construction of a road? What can explain these outcomes?

This paper uses census data from Northern Quebec and Labrador to assess the effects of road connection on municipalities connected between 1986 and 2016. Using a difference-in-differences specification of a linear regression model, we find that road connection is correlated with increased employment rates and educational attainment and decreased unemployment rates. These results are robust to the inclusion of fixed effects, covariates and Driscoll-Kraay standard errors. While we also find positive and significant correlations between road connection and income in many specifications, that particular result is not robust when ensuring that error terms are not subject to cross-sectional dependence.

LITERATURE REVIEW

The impact of infrastructure development on the economic growth of a country has been subject to a wide breadth of research. Whether it be a reduction of social inequality (Calderón & Servén, 2004), higher wages (Donaldson, 2018; Fingleton & Szumilo, 2019), ease in exporting goods (Ng et al., 2019), firm growth (Barzin et al., 2018), population changes (Iacono & Levinson, 2016) or possible changes in productivity (Aschauer, 1989; Gramlich, 1994; Chandra & Thompson, 2000; Harchaoui & Tarkhani, 2003; Sahoo & Dash, 2009, 2012; Sahoo et al., 2010; Konno et al., 2021), existing literature tends to show significant effects of infrastructure construction on economic development. Road connection, and more specifically rural road access, has been shown to generate tangible benefits for newly connected communities by reducing poverty rates (Fan & Chan-Kang, 2005, 2008; Khandker et al., 2009), improving local employment opportunities (Olsson, 2009), bettering accessibility of remote communities to schooling and healthcare (Asher & Novosad, 2018) and catalyzing the economic competitiveness of connected regions (Démurger, 2001). However, no studies that quantitatively measure these effects have been specific to Northern Canada.

Employment

Road connection has been shown to improve employment outcomes in existing literature, including the development of new types of jobs (Olsson, 2009), increases in non-agricultural job growth (Asher & Novosad, 2014), participation of rural inhabitants in new sectors of the economy (Qiao et al., 2014) and the adherence of small communities to larger labour markets (Hussain et al., 2017). These outcomes are the result of better connectivity between rural locations and more populated centers. Matching people with jobs generates better employment outcomes. As Gobillon et al. (2007) have shown, a substantial body of literature has focused on the impact of urban and suburban road development on physically connecting unskilled workers with jobs by reducing spatial mismatch in cities in the United States. Berg et al. (2015) go further by suggesting these conclusions can be applied to a variety of contexts. This is because the mechanism of spatial mismatch applies to many different spatial configurations, not just American urban development. This mechanism "revolves around the role of high transport costs in deterring the unemployed from accepting distant jobs, the harmful effects of long commutes on productivity or decreasing productivity, or high search costs that make the matching between unemployed workers and jobs less efficient."

Education

Transportation and better access to education has also been the subject of various studies. Vasconcillos (1997) underlines the importance of physical road access to allow pupils to get to school. Stifel et al. (2016) explain that access to schools is often an overlooked benefit of road construction not factored into studies examining economic effects of road construction. Jacoby and Minten (2009) & Khandker et al. (2009) quantitatively evaluate the impact of roads on educational attendance and attainment in villages in the developing world, finding positive correlations. All of these studies underline in different ways a fairly similar explanation for this correlation: better physical access and reduced transportation costs make accessing education for inhabitants of areas connected easier.

Income

Better wages and poverty reduction have been associated with road construction and road access. Fan & Chan-Kang (2005, 2008), Khandker et al. (2009), Emran & Hou (2013), Donaldson (2018) and Fingleton & Szumilo (2019) link infrastructure construction in rural areas with higher wages and bettered quality of life. The reductions in poverty are a consequence of the diversification of the local economy (Fan & Chan-Kang, 2005; Khandker et al., 2009), new job opportunities that arise from access to other parts of a region (Olsson, 2009), higher wages as a result of production output (Donaldson, 2018) and better access to domestic and international markets (Emran & Hou, 2013). Investment in road construction also provides a greater benefit to the poor than to the not-poor (Khandker et al., 2009), a result of lower living costs.

The North

Economic development in relation to infrastructure in the North has been the subject of a variety of studies. Bennett (2018) explores the economic and political impacts of the Inuvik-Tuktoyaktuk Highway on local Indigenous communities. Koch (2021) outlines the importance of defining the North from a geographical perspective in guiding infrastructure construction in the Arctic. Povoroznyuk et al. (2022) qualitatively examine the socio-economic benefits of arctic roads and railways of different projects in Canada, the United States and Russia. Serova & Serova (2021) conclude that infrastructure development and increased trade in Northern Russia have not resulted in tangible economic benefits for local communities. This resonates with our prior research (Stringer & Joanis, 2022), in which we come to similar conclusions in our analysis of infrastructure development in Northern Quebec. Koch (2021) underlines the importance of capturing the specific socio-economic conditions of Northern Canada to better support public policy decisions. Understanding the socio-economic impact of infrastructure development as a result of policy decisions is crucial in planning future projects, including the effects of road connection on employment, education and wages.

EMPIRICAL MODEL

We apply a difference-in-differences (DID) approach to quantify the benefits of road construction on remote communities. We focus on community-level outcome measures ranging from average individual income and the labour market to education and demography.

The basic DID model allows for two time periods and two groups, where one group is treated and one is not, and where both groups follow parallel trends until the treatment occurs (Wing et al., 2018). However, the basic model does not suit many applications, including the application examined in this study, where many groups are treated at different periods over the course of 30 years. Several studies have taken different approaches to modify the basic DID specification for more complex applications (Bitler & Carpenter, 2016; Harper et al., 2012; Joanis, 2011; Mark Anderson et al., 2015), notably by using regression models that register year fixed-effects specific to trends between time periods and municipality fixed-effects specific to trends within cross-sectional units.

The basic DID model is modified here to accommodate multiple time periods and multiple groups, considering each census year as a time period, and each municipality as a group. The connection of a municipality by road to the southern ecumene of Canada is interpreted as the "treatment". Control variables are added to account for possible confounders. A dummy variable denoting if treatment has occurred for a specific time period and municipality was also added to the model.

The following Ordinary Least Squares (OLS) linear regression model is used for estimation purposes:

$$Y_{mt} = \beta_0 + \beta_1 \bullet RC_{mt} + \beta_2 \bullet X_{mt} + \gamma_t + \delta_m + \varepsilon_{mt} \quad (1)$$

where Y_{mt} is the dependent variable (Average Income, Unemployment Rate, Employment Rate, Participation Rate, Rate of Degree Attainment or Total Population) measured in municipality m in census year $t \in$\{1986, 1991,..., 2016\}, RC_{mt} is a dummy variable indicating whether or not a municipality m had a road connection to Southern Canada in census year t, X_{mt} is a vector of two additional covariates (Aggregate Income of the community, Percentage of Indigenous Population) varying for each municipality m and each census year t, γ_t is the fixed effect for each year t, δ_m is the fixed effect for each municipality m, and ε_{mt} is a municipality-year-specific error term. All variables are defined in the next section.

The year fixed effects allow to control for trends in time that are common to all municipalities. The municipality fixed effects control for time-invariant factors within a specific municipality. Because of potentially large jumps in aggregate income occurring in certain towns or small cities that experience rapid development due to a large resource extraction project close by, controlling for this variable prevents these changes to be conflated as an effect of road connection. The Aggregate Income confounding variable is omitted for regressions estimating the effect of road connection on outcome variables Average Income and Total Population to avoid multicollinearity issues. This is because Aggregate Income is equal to a multiplication of Average Income by Total Population. The proportion of indigenous inhabitants is also controlled for, as cursory means comparisons seemed to indicate differences between municipalities that have mostly indigenous inhabitants and those that do not. An estimation with the above model is executed for each dependant variable. All analyses were conducted with Stata using fixed-effects panel data functions (version 13).

Further, robustness tests are conducted by estimating outcome values with alternative specifications with varying combinations after removing year fixed effects, municipality fixed effects and control variables. Nevertheless, our preferred specification is the full model (as specified in (6) in the Appendix tables). In that preferred specification, a robust standard error method known as the Driscoll-Kraay method is employed to ensure the error terms estimated are not subject to cross-sectional dependence. Because we use panel data between municipalities that are geographically similar, it is possible that spatial dependence would be included in the standard error terms of a DID regression model that does not estimate robust standard errors. Driscoll & Kraay (1998) designed a method that specifically addresses cross-sectional dependence. Failing to account for this type of dependence is known to cause potential biases in standard error estimates. For this reason, we prefer this method to other robust standard error methods.

DATA AND DESCRIPTIVE STATISTICS

To examine the effect that road connection has on the socio-economic outcomes of remote municipalities in Northern Canada, we estimate our empirical model on a sample of northern communities for which we are able to evaluate outcomes over time while controlling for the characteristics of municipalities that are very different from one another. The provinces of Quebec and Newfoundland-and-Labrador were chosen because of their high level of isolated road construction during the period of time for which data is available.

The sample

To determine whether remote municipalities saw a change in their economic outcomes after the construction of a road connecting them to Canada's primary ecumene, it was important to select a critical mass of towns or villages for which a road was constructed during the period of time studied as well as towns or villages that still had no road constructed by the end of the period of time studied. Each municipality had to:

- be located in Quebec or Newfoundland-and-Labrador;
- be considered part of Northern Canada;
- had to have not been connected by road to Southern Canada before 1986; and
- have a sufficient number of inhabitants for the census to have collected reliable data for each variable.

Determining what constitutes the "North" has been challenging, and previous studies have tried to shed light on the different Canadian "Norths" (Simard, 2017; Koch, 2021; Stringer & Joanis, 2022). Simard (2017) finds that a reliable and objective measure of the North can be made using Louis-Edmond Hamelin's definition of the North. To be able to rely on an empirical measure of what constitutes the North, we wanted to choose an objective definition. Thus, for this study, the limit between Northern Canada and Southern Canada is established using Hamelin's definition of the North. Hamelin created an indicator known as "VAPO" or "polar value" that can measure the nordicity of a town or locality by generating a score of 1000, where 0 is "least Nordic" and 1000 is "most Nordic". The sum of ten criteria each evaluated on scales of 1 to 100 is calculated to obtain a score on 1000. Six of the ten criteria are strictly geospatial or biophysical (Latitude, Number of summer days, Annual freezing days, Level of permafrost, Levels of precipitation, Vegetation) and four are socioeconomic (Access by road or boat, Access by plane, Population density, Economic activity) (Hamelin, 1968). Similar to a topographic altitude map, Hamelin's VAPO indicator axis is perpendicular to lines Hamelin qualifies as "Isonords", or lines on a map delimiting the zones of a given VAPO score. Scores of 200 or less are qualified as forming the "Pre-North". From a score of 200 to 300, Hamelin considers the zone to be the "Lower Middle North"; from 300 to 500, the "Upper Middle North"; above 500, the "Great North" (Hamelin, 2000). The limit between Northern and Southern Canada used in this study is the 200 VAPO isonord. The reason for using this delineation is because Hamelin defined what constitutes the "North" from this score on.

It is interesting to note that since "Access by road" is part of the criteria to determine whether a municipality is northern, the very construction of a road could change the VAPO score of the locality, and thus reduce its nordicity. Consequently, for this study, to determine which municipalities were to be analyzed, only the definition of North according to Hamelin before 1986 was taken into account.

The 40 municipalities in Quebec (QC) and Newfoundland-and-Labrador (NL) sampled for the study as well as the year of their road connection, if applicable, are enumerated in Table 1. Between 1986 and 2016, 18 of these municipalities were connected to Southern Canada's road system. Note that two periods of road construction comprise close to 80% of municipalities connected to Canada's southern ecumene: 1991-1996 and 2006-2011. The high intensity of road construction in these periods can be explained by the connection of Cree towns in Quebec in the 1990s and two phases of the construction of the Trans-Labrador Highway, completed in 1992 and 2009. For more on the history of road connection in the Quebec-Labrador Peninsula, refer to our previous paper (Stringer & Joanis, 2022).

Table 1. List of municipalities in the sample

Municipality	Year connected by road	Province	Source (Road Construction)
Happy Valley - Goose Bay	1992	NL	Higgins and Callanan, 2008
North West River	1992	NL	Higgins and Callanan, 2008
Sheshatsiu	1992	NL	Higgins and Callanan, 2008
Nemaska	1993	QC	Route du Nord, 2020
Eastmain	1994	QC	MTQ, 2020
Wemindji	1996	QC	Wemindji, 2020
Nastashquan (Town)	1996	QC	SRC, 2019
Natashquan 1 (Reserve)	1996	QC	SRC, 2019
Waskaganish	2001	QC	Waskaganish, 2020
Blanc-Sablon	2009	QC	Gov NL, 2012
Bonne-Espérance	2009	QC	Gov NL, 2012
L'Anse-Au-Loup	2009	NL	Gov NL, 2012
Cartwright	2009	NL	Gov NL, 2012
Charlottetown	2009	NL	Gov NL, 2012
Forteau	2009	NL	Gov NL, 2012
Mary's Harbour	2009	NL	Gov NL, 2012
Port-Hope Simpson	2009	NL	Gov NL, 2012
Côte-Nord-du-Golfe-du-Saint-Laurent	2013	QC	SRC, 2019
Akulivik	Not connected	QC	n/a
Davis Inlet / Natuashish	Not connected	NL	n/a
Gros-Mécatina	Not connected	QC	n/a
Hopedale	Not connected	NL	n/a
Inukjuak	Not connected	QC	n/a
Ivujivik	Not connected	QC	n/a
Kangiqsualujjuaq	Not connected	QC	n/a
Kangiqsujuaq	Not connected	QC	n/a
Kangirsuk	Not connected	QC	n/a
Kuujjuaq	Not connected	QC	n/a
Kuujjuarapik	Not connected	QC	n/a
La Romaine	Not connected	QC	n/a
Makkovik	Not connected	NL	n/a
Nain	Not connected	NL	n/a
Puvirnituq	Not connected	QC	n/a
Quaqtaq	Not connected	QC	n/a
Rigolet	Not connected	NL	n/a
Saint-Augustin	Not connected	QC	n/a
Salluit	Not connected	QC	n/a
Tasiujaq	Not connected	QC	n/a
Umiujaq	Not connected	QC	n/a
Whapmogoostui	Not connected	QC	n/a

Outcome variables

Data at the municipal level was collected from the publicly available census profiles of Canada's Census of Population from 1986 to 2016. This time period was chosen because of the easy access to reliable data as well as the constancy of the definitions of data variables during this period1. As censuses are conducted in Canada every 5 years, data from 7 censuses (1986, 1991, 1996, 2001, 2006, 2011, 2016) were used for this study. Except in 2011, all of the data was collected from the long-form and short-form surveys of each census. In

1 All of the data was retrieved online on the Government of Canada's website, except for the data from the 1986 census, which was retrieved through the Census Analyzer online platform of the University of Toronto's Arts and Sciences Library.

Table 2. List of variables for which census data was collected

Total Population	Refers to the number of individuals in a particular municipality.
Indigenous Population	Refers to the number of people who identify as having First Nations, Métis or Inuit origins in a particular municipality.
Population 15 years and over	Refers to the number of individuals in a particular municipality whose age is 15 years or over.
Labour Force	Refers to persons who are either employed or unemployed.
Employed	Refers to the number of individuals in a municipality who have a labour force status of "employed". That is, those who: (a) Do any work at all at a job or business, that is, paid work in the context of an employer-employee relationship, or self-employment. This also includes persons who do unpaid family work, which is defined as unpaid work contributing directly to the operation of a farm, business or professional practice owned and operated by a related member of the same household; or (b) Have a job but were not at work due to factors such as their own illness or disability, personal or family responsibilities, vacation or a labour dispute. This category excludes persons not at work because they were on layoff or between casual jobs, and those who do not then have a job (even if they have a job to start at a future date).
Unemployed	Refers to the number of individuals in a municipality who are without paid work or without self-employment work and are available for work and either: (a) have actively looked for paid work in the past four weeks; or (b) are on temporary lay-off and expected to return to their job; or (c) have definite arrangements to start a new job in four weeks or less.
Employment rate	The employment rate for a particular municipality is the number of employed individuals in that municipality, expressed as a percentage of the population aged 15 or over.
Participation rate	The participation rate for a particular municipality is the total labour force in that municipality, expressed as a percentage of the population aged 15 or over.
Unemployment rate	The unemployment rate for a particular municipality is the unemployed in that municipality, expressed as a percentage of the labour force in that municipality.
Average income	Refers to the average total income of an individual in a particular municipality in 2016 constant Canadian dollars. Total income refers to receipts from certain sources, before income taxes and deductions, during the year prior to the census year.
Aggregate income	Refers to the sum of all incomes of all individuals in a particular municipality in 2016 constant Canadian dollars.
No degree, certificate or diploma	Refers to the number of individuals in a municipality that have not earned a degree, certificate or diploma.

2011, the Canadian National Household Survey data was conducted in place of the usual long-form census. Statistics pertaining to population, labour, income and education were used. The variables for which data were collected are explained in Table 2.

With respect to education data, the scarcity of sample data used to infer the number of individuals with specific types of degrees earned in the least populated municipalities meant a significant number of data points were rounded up or down in the censuses, which often led to significant inaccuracy in compiling higher education statistics for this study. Consequently, a different measure of educational progress had to be designed. A new variable, the "Rate of degree attainment" was created. This variable refers to the percentage of the population of a municipality that has earned a degree, certificate or diploma of any kind. Because it is possible to infer that anybody who does not fall into the category of "No degree, certificate or diploma" possesses a degree, certificate or diploma, the new variable is obtained by subtracting the number of individuals from "No degree, certificate or diploma" from that of "Population 15 years and over", then divided by that of "Population 15 years and over" to obtain a ratio. A "Percentage of Indigenous Population" was also created. It refers to the "Indigenous Population" variable divided by the "Total Population" variable.

Descriptive statistics

Table 3 shows comparisons between the means of the variables used in the model, categorized by year, as well as cumulatively for the whole time period studied. Clear time trends are present for several variables in the table. Average Income, Employment Rate, Participation Rate, Rate of Degree Attainment and Aggregate Income increase steadily between 1986 and 2016, indicating that this is a period of economic prosperity for these northern communities. This justifies year-fixed effects controls in further estimations. These controls are necessary to better distinguish what outcomes in municipalities with a road connection are caused by the actual construction of the road rather than a trend relative to all municipalities in time. Furthermore, the municipalities in the sample are far from being monolithic and homogeneous in their characteristics. Important differences in minimums and maximums for all variables indicate that the municipalities examined are vastly different. The large variance in these differences could suggest that the municipalities that have benefited from a road connection differ at some time-invariant level from those that do not. Some of these time-invariant components will be inevitably impossible to control for, underlining the usefulness of a DID model that can control for municipality-fixed effects.

Comparing means of treatment and control groups of certain variables over time can highlight whether there is a positive or negative effect associated with road connection. Time-series data can best be illustrated with explicative graphs. Because road connection has occurred in different periods for different municipalities, charting all treatment means versus control means for all municipalities will not be accurate in illustrating a change in trends occurring during the period where roads were constructed. To more properly reflect the reality of road connection, different treatment groups were formed based on the period in which they were connected for means comparisons.

Table 3. Descriptive statistics of select municipality census data variables; by year

	1986	1991	1996	2001	2006	2011	2016	All Periods
Average Income ($)								
Mean	22292	23364	26134	26914	30005	33596	38804	29027
Std. Dev.	5157	5814	4927	4361	6106	7203	7498	8018
Min.	15648	14581	15730	19223	14217	14286	19568	14217
Max.	35381	35935	42749	42726	50814	50789	58417	58417
Unemployment Rate								
Mean	26.3%	27.3%	28.6%	25.8%	28.0%	21.4%	23.6%	25.9%
Std. Dev.	19.5%	19.8%	17.2%	15.6%	15.1%	12.5%	12.4%	16.1%
Min.	0.0%	3.4%	6.7%	4.2%	7.6%	3.1%	8.2%	0.0%
Max.	76.9%	76.8%	63.4%	66.7%	63.9%	53.8%	53.8%	76.9%
Employment Rate								
Mean	35.1%	40.7%	43.9%	45.4%	46.1%	50.0%	48.6%	44.5%
Std. Dev.	11.0%	13.5%	16.3%	12.3%	13.0%	12.5%	12.6%	13.8%
Min.	13.6%	18.0%	12.5%	22.2%	20.6%	21.6%	24.5%	12.5%
Max.	58.6%	66.8%	70.8%	73.4%	72.1%	73.4%	75.8%	75.8%
Participation Rate								
Mean	50.2%	57.3%	60.1%	61.2%	63.3%	63.4%	63.2%	60.1%
Std. Dev.	14.7%	13.5%	12.4%	8.9%	8.4%	9.7%	9.5%	11.8%
Min.	15.3%	29.4%	20.8%	38.9%	41.3%	32.6%	36.4%	15.3%
Max.	75.5%	79.8%	77.8%	79.5%	80.9%	80.2%	82.6%	82.6%
Rate of Degree Attainment								
Mean	22.3%	29.1%	36.2%	40.3%	45.0%	44.8%	49.3%	38.6%
Std. Dev.	11.5%	12.1%	13.0%	12.8%	11.6%	13.9%	15.6%	15.5%
Min.	4.5%	6.1%	12.8%	20.0%	16.0%	20.1%	18.5%	4.5%
Max.	55.4%	60.2%	77.1%	73.6%	72.3%	77.7%	82.1%	82.1%
Total Population								
Mean	745.5	875.1	912.1	937.5	944.0	1045.9	1025.5	930.2
Std. Dev.	1236.0	1381.0	1338.9	1235.9	1174.8	1284.6	1285.9	1265.5
Min.	135	265	255	300	264	303	290	135
Max.	7248	8610	8655	7970	7572	7552	8109	8655
Aggregate Income (millions of $)								
Mean	11.5	14.3	16.7	17.5	20.7	26.1	31.2	20.1
Std. Dev.	25.8	33	32.6	29.8	36.2	47.0	57.8	39.3
Min.	2.3	3.1	3.4	3.9	5.5	6.7	7.5	2.3
Max.	139.0	201.0	206.0	189.0	230.0	275.0	366.0	366.0
Indigenous Population (%)								
Mean	64.0%	57.4%	68.7%	72.2%	73.7%	88.0%	77.5%	71.7%
Std. Dev.	39.4%	40.2%	37.1%	34.5%	33.2%	14.4%	29.9%	34.4%
Min.	0.0%	0.0%	0.0%	1.3%	6.7%	38.5%	9.3%	0.0%
Max.	99.5%	100.0%	100.0%	97.4%	98.9%	100.0%	99.5%	100.0%

Figures 1-6 illustrate the comparisons of the means of average income, unemployment rate and rate of degree attainment between the municipalities connected during the specified period and the control group. All municipalities that had no road connection between 1986 and 2016 constituted a control group for these graphs. Each graph was divided in three time periods: *Before Construction (B), During Construction (C), After Construction (A). During Construction (C)* refers to the 5-year period in which a road connection was constructed.

Figures 1, 3 and 5 clearly show a change in trend in average income, unemployment rate and rate of degree attainment after the 1991-1996 period, with the treatment group's curve's slope changing steadily over the following 20 years. Figures 2 and 6 show a similar phenomenon after the 2006-2011 period, with an important increase in average income and a modest increase in the rate of degree attainment for the treatment group. Figure 4 does not display the same trend for the unemployment rate seen in Figure 3, due to an accelerating downwards trend in the treatment group starting as early as 1991. Apart from Figure 4, all figures show treatment and control groups following relatively similar trends prior to the treatment period, which helps confirm the parallel trends assumption of difference-in-differences analyses. Moreover, by showing a trend that likely does not have anything to do with road construction, the treatment group's curve in Figure 4 underlines the need for better control of time-invariant factors pertaining to the municipalities included in that group.

Figure 1. Average income of municipalities by year; control group vs. treatment group with road constructed between 1991 and 1996.

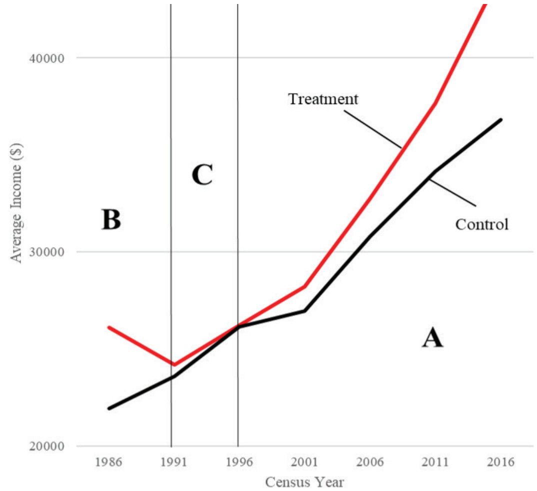


Figure 2. Average income of municipalities by year; control group vs. treatment group with road constructed between 2006 and 2011.

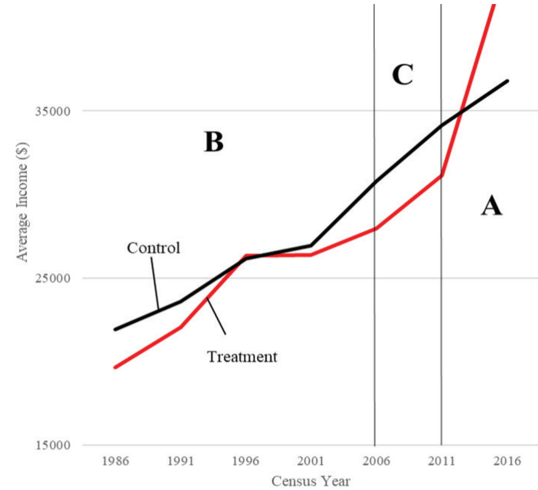


Figure 3. Unemployment rate of municipalities by year; control group vs. treatment group with road constructed between 1991 and 1996.

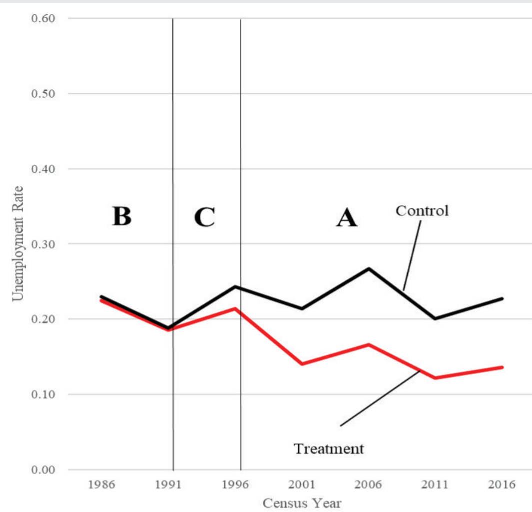


Figure 4. Unemployment rate of municipalities by year; control group vs. treatment group with road constructed between 2006 and 2011.

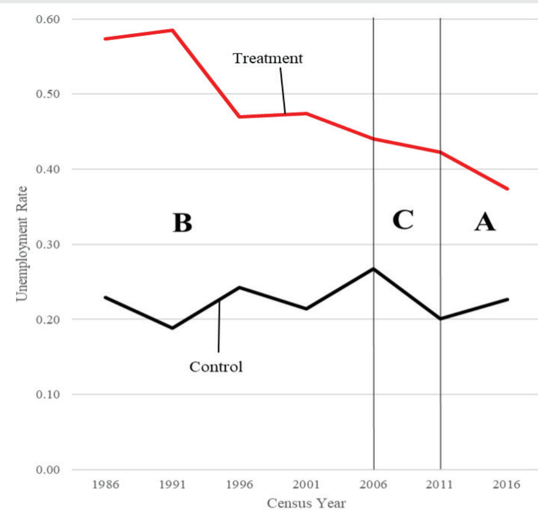


Figure 5. Rate of degree attainment of municipalities by year; control group vs. treatment group with road constructed between 1991 and 1996.

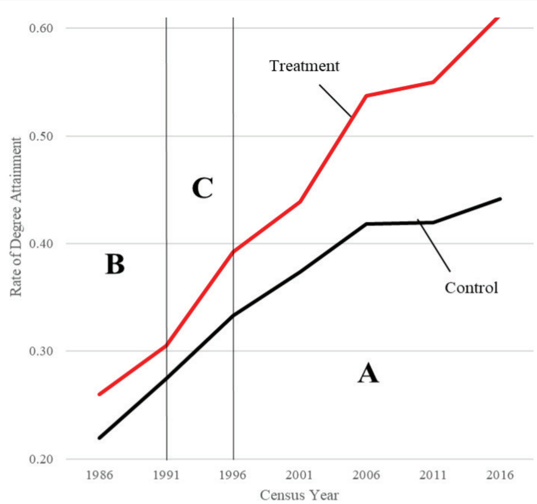
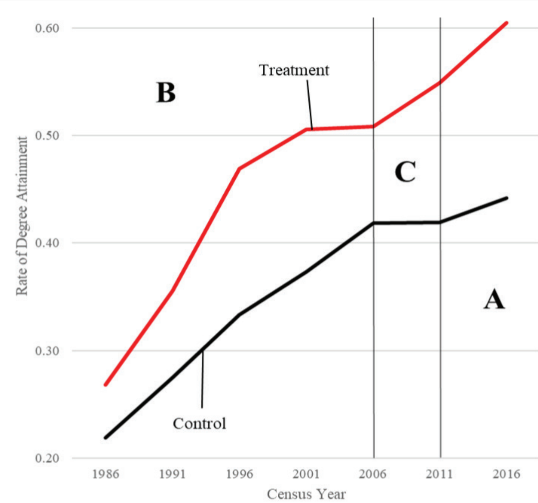


Figure 6. Rate of degree attainment of municipalities by year; control group vs. treatment group with road constructed between 2006 and 2011.



EMPIRICAL RESULTS AND DISCUSSION

Main Results

Table 4 summarizes the regression estimates on the outcome variables using the difference-in-differences method, including controls for year-fixed effects, municipality-fixed effects, confounding variables, as well as Driscoll-Kraay robust standard errors. Comparing cross-data means to these results, the model estimates that having a road connection during a given period is correlated with a decrease in unemployment rate of 6 percentage points, an increase in employment rate of 13 percentage points and an increase in rate of degree attainment of 4 percentage points. All three of these results are statistically significant, with the unemployment rate and rate of degree attainment significant at the 5% level and the employment rate significant at the 10% level. These effects are independent of trends over time and of time-invariant characteristics specific to the municipalities. The significance of the estimation for the employment rate ascertains a large standard deviation, which could suggest that while the direction of the effect of road connection on income can be inferred, caution is to be taken as to its precision. This may be a result of the relatively small sample size and high variability of the characteristics of the different municipalities. Effects on the average income, participation rate and total population within a municipality are non-significant when using the Driscoll-Kraay robust standard error method, and thus can be assumed as null for these estimates.

After the construction of a road connection, municipalities that were connected by road saw an increase in their employment rate and rate of degree attainment as well as a decrease in their unemployment rate in subsequent periods. Because of the year-fixed effects and municipality-fixed effects taken into account by the DID method, it can be inferred that these changes in metrics would not have occurred had a road connection not been built. The year-fixed effects control for the trends that occur in all municipalities over time, while the municipality-fixed effects control for time-invariant characteristics specific to each municipality that could have an impact on the variation of the independent variables. Moreover, confounding variables that change over time were controlled to better hone in on the changes that can be explained by road connection.

Table 4. Summary of the estimated effect of road connection on the outcomes of a municipality

Outcome variable	DID estimate (Std. Dev.)
Average Income ($)	1429.16
	(1609.25)
Unemployment Rate	-0.0599**
	(0.0221)
Employment Rate	0.0132*
	(0.00626)
Participation Rate	-0.0273
	(0.0266)
Rate of Degree Attainment	0.038**
	(0.0149)
Total Population	-95.20
	(54.70)
Observations	249
Year fixed effects	Yes
Municipality fixed effects	Yes
Covariates	Yes
Robust standard error (Driscoll-Kraay)	Yes

*: p < 10%; **: p < 5%; ***: p < 1%
Note: See Appendix for detailed results. These results correspond to column (6) in Appendix tables.

Testing for robustness

Appendices 1-6 (at the end of the document) show the full regression results for the estimates in Table 4 as well as different regression results for each outcome variable while removing controls for year fixed effects, municipality fixed-effects, confounding variables or a combination of any of these controls. In all, six different estimates were done for each dependent variable:

1. shows the results of an OLS regression.
2. shows the results of an ordinary OLS regression with year fixed effects controls.
3. shows the results of an OLS regression with municipality fixed effects controls.
4. shows the results of a difference-in-differences specification of an OLS regression.
5. shows the results of a difference-in-differences specification of an OLS regression with controls for confounding variables.
6. shows the results of the same regression as in (5) but with robust standard errors using the Driscoll-Kraay estimation method, i.e., the same results presented in Table 4.

The comparison of results from the different regressions offers important insight concerning the relationships between the variables. Despite removing controls, similar effects can be inferred with most of the outcome variables in which a significant effect is estimated using specification (5). Removing controls does not radically change the effect of road connection on Average Income, Unemployment Rate and Rate of Degree Attainment and only alters the values of the estimated coefficients, not their direction or significance. Moreover, the Employment Rate and Participation Rate remain broadly insignificant when removing controls. The Employment Rate only becomes significant when using the Driscoll-Kraay robust standard error method. This could mean that the other regressions in this study fail to take into account cross-sectional dependence that could occur between municipalities that directly affects the Employment Rate. Further, Total Population behaves quite differently when estimated with regression specifications (1) and (2). This is inevitably a result of taking out municipality fixed effects controls: the large variance in the sample, as can be seen in the descriptive statistics in Table 3, makes regressions omitting controls for municipality fixed effects inaccurate.

For the estimates of Average Income and Rate of Degree Attainment, the regression specifications in (2), (4) and (5) have much more modest results than specifications (1) and (3), having lower coefficients for these outcome variables. Specifications (2), (4) and (5) all have controls for year fixed effects, which suggests that improvements in salaries and education follow stronger time trends than labour or population variables. This could mean that country-wide trends influencing education and salaries are more ubiquitous and wider-reaching than time trends that influence labour market or population variables. Thus, controlling for these trends was important.

The significance of dependent variables when estimating robust standard errors in (6) paints a different picture than the conclusions drawn from (5). Only the Unemployment Rate and Rate of Degree Attainment figures stay consistently significant using the Driscoll-Kraay method for robust standard errors, with the Employment Rate only becoming significant when using that robust standard error method. It can thus be inferred that these three variables are clearly influenced significantly by road connexion. Results pertaining to Average Income and Total Population in regards to estimates from (5) suggest that there is some form of interaction between these variables and road connexion, but that the sample used for this study does not allow to conclusively determine the magnitude or significance of these interactions. Larger sample sizes and more time periods could serve as a way to better explore these interactions.

As there is a chance that nearby municipalities may experience spillover economic effects from close neighbours, we also test for spatial autocorrelation by estimating Moran's I in Stata (Kondo, 2018). To do so, we use latitude and longitude measures taken from Google Maps for each of the municipalities in our sample to create a Euclidian distance matrix that logs the distances between each pair of municipalities. With this matrix, we are able to estimate Moran's I for each independent variable and each time period. Moran's I values range from -1 to 1, with a value of 1 denoting perfectly clustered observations, 0 that of randomly dispersed observations and -1 that of perfectly dispersed observations. For all time periods, most independent variables show a statistically significant degree of spatial autocorrelation, with Moran's I values ranging from roughly 0 to 0.25. Only Total Population can be considered to have no spatial autocorrelation in any time period. This means that income, labour and education indicators are mildly spatially clustered across the sample. Because municipalities that are nearby are typically connected during the same time period, it is unsurprising that economic indicators are slightly more similar as a function of spatial proximity. Further, common characteristics specific to subregions of our study area also influence these indicators. For example, municipalities in Nunavik may have socio-economic indicator values that are more similar with one another than with those of the municipalities of the James Bay region due to their extreme remoteness. This underlines the importance of the difference-in-differences specification of our model, which controls for unobserved municipality-specific characteristics.

Discussion

Improved labour market conditions

Heightened economic activity could be part of the explanation for lower unemployment experienced in connected municipalities. However, another part of the explanation may lie in the accessibility to jobs rather than job creation, supported by the overall decrease in municipality population count. The spatial mismatch analysis brought forth by Gobillon et al. (2007) and Berg et al. (2015) may hold true for the Northern Canadian context, as high transport costs deterring unemployed persons accepting distant jobs could be relevant to arctic and subarctic municipalities. Better spatial matching through easier access to remote municipalities may allow local organizations to save on search costs and access a larger pool of applicants that would otherwise be deterred by prohibitive transportation costs to a distant locality.

Amongst the labour market indicators, the unemployment rate and the employment rate are significantly affected by road connection. Since the employment rate uses the number of people employed and the unemployment rate uses the number of people that are unemployed as the numerators in their equations, these indicators usually follow axiomatically an inverse trend. A decrease in unemployment should equal an increase in employment. By applying the spatial mismatch logic explained above, it is possible to infer that people in small towns who do not have a job could be using the newly built roads to seek employment elsewhere. Similarly, people from other towns could seek jobs in connected municipalities, increasing the employment rate. Thus, road connection does not unquestionably create jobs in connected municipalities. Instead, it would allow for a better reallocation of human resources within a broader region and more effective job skills matching. The higher value in employment rate change in comparison to unemployment rate change suggests that there could also be net job creation in newly connected municipalities.

While not a statistically significant result in the most robust of our model specifications, (6), total population decreases when time and municipality-fixed effects are controlled for, in specifications (4) and (5). This may be another part to the explanation outlined above: when a municipality is connected, unemployed persons leave the municipality in search of work elsewhere, possibly in Southern Canada. This would, in turn, increase the employment rate and decrease the unemployment rate in the municipality.

Better access to education

As shown in previous literature, road connection improves physical access to educational institutions (Vasconcillos, 1997; Minten, 2009; Khandker et al., 2009; Stifel et al, 2016). This is undoubtedly also the case for towns and small cities in Northern Canada. Many smaller towns in the north do not have an establishment that offers professional trades diplomas, let alone university degrees. Accessing one of these establishments when the only available modes of transportation are planes and ships is difficult and bears considerable transportation costs. Many localities are only accessible through air travel that is often prohibitively expensive. Sea travel is limited to the summer, is time-consuming and also relatively expensive. Road access allows citizens to sustainably and more easily connect year-round with neighbouring towns that may have better educational facilities. It also allows northern localities to better connect with Southern Canada, where almost all universities and higher education institutions are located. Figure 5 shows how educational attainment in the 1991-1996 treatment group is not only higher than in the control group until 2016 but also rises faster. This shows how road connection conduces perennial educational opportunities for the connected municipalities.

Higher average income?

This study examines the average income of remote communities in Northern Canada. While results of the main regression model with Driscoll-Kraay standard errors note average income changes as insignificant, results from other regressions do infer some degree of significance. This could indicate that road connection to Southern Canada could possibly increase the average income in connected communities, which could be better determined with a larger sample size and more time periods. Even though this study does not successfully demonstrate this interaction, it certainly lays tracks for more research in the area. Such an interaction does have a basis in existing literature (Fan & Chan-Kang, 2005, 2008; Khandker et al., 2009; Emran & Hou, 2013; Donaldson, 2018; Fingleton & Szumilo, 2019), and should be explored more thoroughly given the mixed results in this study.

In the Canadian context, an increase in average income due to road connection could be generally interpreted as an indicator of increased gains from trade between two regions and reduced transport costs (Berg et al., 2015) and increased production (Harchaoui & Tarkhani, 2003). More specifically, this activity could be a result of better access to Canada's national market, meaning more interregional connectivity with other organizations, institutions and industry branches (Holl, 2004). In turn, this results in a more efficient allocation of funds resulting in higher production, paired with decreased trade costs (Fellows & Tombe, 2018). Ultimately, by increasing local communities' buying power, together with the possible consumer benefits of cheaper goods by way of lower cost structures, their cost of living is reduced and their quality of life bettered.

CONCLUSION

This quantitative analysis has attempted to estimate the effect of road connection of remote municipalities to more populated centers on the economic outcomes of these municipalities. The findings in this paper suggest that there is a correlation between road connection and education and labour market indicators. The difference-in-differences method used in this study is consistent with a large body of literature linking road construction to positive economic outcomes. Even after controlling for year-fixed effects and group-fixed effects, the estimation model shows that municipalities experience significant gains in educational attainment and employment rate as well as a significant decrease in unemployment rate. Benefiting from a road connection during a given period is correlated with a decrease in unemployment rate of 6 percentage points, an increase in employment rate of 13 percentage points and an increase in rate of degree attainment of 4 percentage points.

Changes in educational attainment and employment can be explained by the increased accessibility associated with the construction of a physical connection between remote localities and urban centers offering more diverse services and opportunities. Proposals for developing Northern Canada and the Arctic have been touted as a new source of productivity and wealth. Local communities in remote parts of Canada have a long history of poverty. For these proposals to be equitable, governments have to take these communities into account and offer solutions that enhance their quality of life. Road connection to the South, while not being a failsafe solution, seems to offer appreciable benefits in this direction.

All in all, this study shows that there is a relationship between road connection of isolated areas and better education and employment outcomes in those areas. Extractivism, or development focused solely on natural resources, rarely ensures prosperity for inhabitants of the regions exploited (Acosta, 2013). If governments are going to develop remote resource-rich territories, they should try to generate tangible benefits for the impacted municipalities. This study shows that, minimally, road connection can improve the quality of life by enhancing access to education and job opportunities of local communities in remote locations. Public and private interests should consider these relationships when planning infrastructure and development projects in subarctic and arctic regions.

The limitations of this study include the oversight of estimating other independent variables that could potentially serve as supplementary indicators of certain phenomena discussed above, the lack of international points of comparison and the number of observations. Future research could encompass analyses with such variables to better understand the effect of road connection on the development of remote municipalities. Notably, mobility data could be collected to further understand how many people come to or leave municipalities with road connection, possibly confirming the hypothesis that better labour spatial matching causes the drop observed in unemployment rates. It could also be used to understand the flux of residents leaving the municipalities to obtain better educational credentials. Data on poverty rates could be collected to help get a clearer picture of the true impact on poverty reduction that the results of this study can bring about. Similar methods using municipalities in other countries with identical variables would also shed light on if the effects studied in this article are unique to Canada or are omnipresent throughout the world. Finally, because of the modest sample sizes used, the conclusions of this article have to be considered with prudence. Bigger sample sizes and more time periods would augment the predictive power of the mathematical model and guard against differences in results when using robust standard error estimation methods. Finally, the values of the independent variables measured across our sample show mild spatial autocorrelation. Since roads are built at punctual spatial locations, a model that can consider the spatial implications of road connection, such as a spatial regression model, would be valuable to future analyses.

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Table A1. Results on Average Income

	(1)	(2)	(3)	(4)	(5)	(6)
Road Connection	6402.81***	1872.59*	10454.35***	1513.26*	1429.16*	1429.16
	(1175.31)	(994.90)	(1179.67)	(803.57)	(798.42)	(1609.25)
Proportion of Indigenous Inhabitants					3581.68**	3581.68**
					(1755.40)	(1459.22)
Number of observations	249	249	249	249	249	249
R-squared overall	0.1073	0.465	0.1073	0.4644	0.3951	0.3951
R-squared within			0.2741	0.7761	0.7806	0.7806
Year fixed effects	No	Yes	No	Yes	Yes	Yes
Municipality fixed effects	No	No	Yes	Yes	Yes	Yes
Covariates	No	No	No	No	Yes	Yes
Robust standard error (Driscoll-Kraay)	No	No	No	No	No	Yes

*: p < 10%; **: p < 5%; ***: p < 1%

Table A2. Results on Unemployment Rate

	(1)	(2)	(3)	(4)	(5)	(6)
Road Connection	-0.0435*	-0.0331	-0.0799***	-0.0699***	-0.0599***	-0.0599**
	(0.0248)	(0.0270)	(0.0174)	(0.0209)	(0.0207)	(0.0221)
Proportion of Indigenous Inhabitants					-0.133***	-0.133***
					(0.0455)	(0.0274)
Aggregate Income (per billion $)					-0.0527	-0.0527
					(0.456)	(0.0882)
Number of observations	249	249	249	249	249	249
R-squared overall	0.0121	0.027	0.0121	0.0186	0.2277	0.2277
R-squared within			0.0902	0.109	0.1559	0.1559
Year fixed effects	No	Yes	No	Yes	Yes	Yes
Municipality fixed effects	No	No	Yes	Yes	Yes	Yes
Covariates	No	No	No	No	Yes	Yes
Robust standard error (Driscoll-Kraay)	No	No	No	No	No	Yes

*: p < 10%; **: p < 5%; ***: p < 1%

Table A2. Results on Employment Rate

	(1)	(2)	(3)	(4)	(5)	(6)
Road Connection	0.0407*	0.00254	0.0856***	0.0135	0.0132	0.0132*
	(0.0212)	(0.0221)	(0.0155)	(0.151)	(0.0152)	(0.00626)
Proportion of Indigenous Inhabitants					-0.0806**	-0.0806*
					(0.0335)	(0.0398)
Aggregate Income (per billion $)					-0.0954	-0.0954
					(0.336)	(0.0751)
Number of observations	249	249	249	249	249	249
R-squared overall	0.0145	0.106	0.0145	0.1031	0.0495	0.0495
R-squared within			0.1258	0.4367	0.4407	0.4407
Year fixed effects	No	Yes	No	Yes	Yes	Yes
Municipality fixed effects	No	No	Yes	Yes	Yes	Yes
Covariates	No	No	No	No	Yes	Yes
Robust standard error (Driscoll-Kraay)	No	No	No	No	No	Yes

*: p < 10%; **: p < 5%; ***: p < 1%

Table A4. Results on Participation Rate

	(1)	(2)	(3)	(4)	(5)	(6)
Road Connection	0.0100	-0.0262	0.0413**	-0.0307	-0.0273	-0.0273
	(0.0182)	(0.0185)	(0.0194)	(0.0205)	(0.0198)	(0.0266)
Proportion of Indigenous Inhabitants					-0.209***	-0.209**
					(0.0435)	(0.0592)
Aggregate Income (per billion $)					-0.219	-0.219***
					(0.437)	(0.0519)
Number of observations	249	249	249	249	249	249
R-squared overall	0.0012	0.1369	0.0012	0.1361	0.2029	0.2029
R-squared within			0.0209	0.255	0.3185	0.3185
Year fixed effects	No	Yes	No	Yes	Yes	Yes
Municipality fixed effects	No	No	Yes	Yes	Yes	Yes
Covariates	No	No	No	No	Yes	Yes
Robust standard error (Driscoll-Kraay)	No	No	No	No	No	Yes

Table A5. Results on Rate of Degree Attainment

	(1)	(2)	(3)	(4)	(5)	(6)
Road Connection	0.161***	0.100***	0.184***	0.0483***	0.0378**	0.0378**
	(0.0218)	(0.0209)	(0.0205)	(0.0158)	(0.0154)	(0.0149)
Proportion of Indigenous Inhabitants					0.0758**	0.0758**
					(0.034)	(0.0234)
Aggregate Income (per billion $)					0.246	0.246
					(0.341)	(0.327)
Number of observations	249	249	249	249	249	249
R-squared overall	0.1787	0.3723	0.1787	0.3562	0.2613	0.2613
R-squared within			0.2763	0.7052	0.7323	0.7323
Year fixed effects	No	Yes	No	Yes	Yes	Yes
Municipality fixed effects	No	No	Yes	Yes	Yes	Yes
Covariates	No	No	No	No	Yes	Yes
Robust standard error (Driscoll-Kraay)	No	No	No	No	No	Yes

*: p < 10%; **: p < 5%; ***: p < 1%

Table A6. Results on Total Population

	(1)	(2)	(3)	(4)	(5)	(6)
Road Connection	689.71***	718.68***	81.83*	-110.47**	-95.20**	-95.20
	(191.01)	(209.12)	(41.87)	(43.65)	(40.59)	(54.70)
Proportion of Indigenous Inhabitants					-524.99***	-524.99**
					(89.80)	(139.98)
Number of observations	249	249	249	249	249	249
R-squared overall	0.0494	0.0507	0.0494	0.0004	0.0201	0.0201
R-squared within			0.0177	0.2728	0.3768	0.3768
Year fixed effects	No	Yes	No	Yes	Yes	Yes
Municipality fixed effects	No	No	Yes	Yes	Yes	Yes
Covariates	No	No	No	No	Yes	Yes
Robust standard error (Driscoll-Kraay)	No	No	No	No	No	Yes

*: p < 10%; **: p < 5%; ***: p < 1%