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Illuminating Economic Development in Indigenous Communities

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October 23, 2017

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Keywords: Light density, nighttime light density, Indigenous peoples, Economic development, Community Well-Being Index
JEL Classifications: I15, J15, J24

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1 Introduction

For decades, a significant challenge faced by development economists has been a lack of reliable and accurate data measuring economic activity in developing countries and regions within those countries (Henderson, Storeygard, and Weil, 2012). This is of lesser concern for developed countries, where data quality is often higher. However, due to specific reporting restrictions, data on GDP per capita is not always publicly available for many small communities within developed countries. In Canada, this problem is particularly acute for Indigenous communities, where remoteness, size, and jurisdictional issues limit data collection and validation.[1] Beyond that, many standard measures of economic well-being have been criticized for embedding culturally specific values that are not grounded in Indigenous realities (Quinless, 2017; Walter and Andersen, 2013).

We propose that publicly available satellite data that measures nighttime light density in Indigenous communities is a useful and potentially more culturally appropriate alternative to traditional indicators of economic well-being.[2] There are over 1,000 Indigenous communities in Canada; however, the most comprehensive data source containing socioeconomic indicators only includes consistent data for 357 of these communities every five years between 1991 to 2011.[3] Known as the Community Well-Being (CWB) database, this data source includes community-level information on GDP per capita, in addition to a CWB index–akin to the Human Development Index–which assigns communities a score between 0 and 100 based on community-wide levels of education, income, labour force participation, and housing conditions.[4] We compare community-level nighttime light density to GDP per capita, the CWB index, and the CWB component scores for the set of First Nations and Inuit communities for which this these data are available.[5] We find that nighttime light density is an effective proxy for per capita income, education, and

[1]For instance, in 2011 there were a total of 31 Indian reserves and Indian settlements that were incompletely enumerated. Reasons for the incomplete enumeration ranged from natural events that prevented data collection to a lack of permission from the community. More information is available at: http://www12.statcan.gc.ca/nhs-enm/2011/ref/aboriginal-autochtones-eng.cfm.

[2]While our analysis focuses on Indigenous communities in Canada, nighttime light density data may be useful for assessing economic development of rural areas more generally.

[3]Communities are defined in terms of census subdivisions (CSDs) here to be consistent with the CWB geography. CSDs are municipalities or areas that are the equivalent to municipalities such as Indian reserves. "First Nations communities" are CSDs that Indigenous and Northern Affairs Canada and Statistics Canada classify as "on-reserve". They include all CSD types that are legally affiliated with Indian bands. Inuit communities are included in similar census definitions. See Indigenous and Northern Affairs Canada (2010) for details.

[4]For further discussion of this index and its relationship to the Human Development Index, see O'Sullivan (2011) and Cooke (2005).

[5]We focus on First Nations and Inuit communities, defined below, because economic development among these communities is a pressing public policy issue (Feir and Hancock, 2016; The Truth and Reconciliation Comission of Canada, 2015) and publicly available data are subject to limitations.

housing quality.

We also show that the characteristics of communities that have available per capita income or CWB data differ markedly from those that do not, revealing clear evidence of sample selection issues within the pre-existing indicators of well-being in First Nations and Inuit communities. Given this issue, in addition to other advantages of nighttime light data, such as its annual availability since 1992, we suggest that nighttime light data should be considered a core outcome variable when studying economic development in Indigenous communities.

The use of nighttime light density as a measure of economic well-being allows researchers to generate a panel of well-being spanning over 20 years for communities large and small. In addition to the usefulness of this measure for economic research, conceptually, light may be a more palatable measure of well-being for many Indigenous cultures than GDP or the CWB index. Many Indigenous and non-Indigenous creation narratives embed light as a thing of value, potentially making it a measure with cross-cultural meaning beyond its ability to capture more standard economic measures of well-being (Levy, 1998; May, 1939; Miller, 2000; Rasmussen and Worster, 2009; Reid et al., 1996). Also, satellite nighttime light data are available for the whole world at a relatively fine level of detail and can be easily used to analyze any geographic unit of interest. For instance, to make comparisons to pre-existing Government of Canada generated statistics, we construct light density measures at the census subdivision level, which corresponds to government recognized political units such as cities, municipalities, or Indigenous reserves or government-recognized settlements. However, nighttime light data could also be used to study outcomes along Indigenous-defined geographies of interest, such as asserted land claims, traditional homelands, or historical treaty boundaries. The ability to use nighttime light data to transcend political, national and standard statistical boundaries has already proven to be advantageous for the study of economic development in the African context (Michalopoulos and Papaioannou, 2013, 2014).

In the next section, we discuss existing data sources for measures of the economic well-being of Indigenous communities. We then consider the distribution of communities within the nighttime light data, followed by a calculation of the elasticities of light data with respect to other outcome variables. We conclude with a discussion of further considerations when using nighttime light data in understanding Indigenous economic development.

2 Existing Well-Being Data and the Potential of Nighttime Light Data

Indigenous and Northern Affairs Canada (INAC) recognizes 618 First Nations, in addition to Inuit groups, associated with over 1,000 reserves and settlements throughout the country. Both reserves and Indigenous settlements are measured at the census subdivision (CSD) level, which is comparable to a municipality. Since many of these communities are small, publicly available data on housing, labour force participation, education and wages are only available for a subset of communities. The most comprehensive public collection of economic data for Indigenous communities is the Community Well-Being (CWB) database, derived from the Census of Population. The primary indicator of well-being in the CWB database is a composite index between 0 and 100 that reflects a community's overall well-being. This index, known as the Community Well-Being (CWB) Index, is similar to the United Nation's Human Development Index, as it takes into account education, housing, labour force participation, and income to provide a comprehensive measure of well-being.[6] The CWB Index is publicly available for all census subdivisions (CSD) in Canada that meet Statistics Canada public reporting criteria. For communities that meet slightly more stringent criteria, the individual component scores are also provided.[7] Along with the CWB index and relevant components, the data include population, type of census subdivision–First Nation, Inuit, or Non-Aboriginal[8]–and one can back out GDP per capita using the formula for the income component score.[9]

Although the CWB database is the most comprehensive community-level data on economic well-being in Indigenous communities, only 381 communities had data on GDP per capita in 2011 (AANDC, 2015), which is the most recent year for which these data are available. The composite CWB index yields a larger count of 602 Indigenous communities in the same year. However, of those communities, only 357 have consistent data from 1991 onwards. An additional drawback of these data is that they are not available annually;

[6]The CWB index can be downloaded from: https://www.aadnc-aandc.gc.ca/eng/1100100016579/1100100016580.

[7]Component scores are provided for income, education, housing, and labour force participation. They are available for communities with a population of at least 250, if the total number of unweighted individuals in the community with a component score was least 4, and the total number of weighted individuals with a component score was at least 10.

[8]We follow the terminology in the CWB database and use the term "non-Aboriginal" communities to refer to communities that are not associated with an Indigenous group.

[9]The income score is constructed using the following formula:

$$inc\_score = \left(\frac{\log(gdp\_pc) - \log(2,000)}{\log(40,000) - \log(2,000)} \right). \quad (1)$$

rather, they are available at five year intervals alongside the Census of Population.

The subset of communities included in the CWB database covers a substantial proportion of the on-reserve First Nation and Inuit population; however, it is a small fraction of the total number of Indigenous communities in Canada.[10] Moreover, the communities included in the sample are systematically selected. The threshold population size for being included in the CWB database is 65, while being included in the GDP sample requires a population of 250 people or 40 households (Indigenous and Northern Affairs Canada, 2010). Communities are also only included in either sample if they are completely enumerated. A reserve is deemed incompletely enumerated if it is not permitted to be enumerated or if enumeration is interrupted or of insufficient quality. Inclusion also requires a non-response rate to the census questions that was less than 25%. Since many questions relating to public policy, economic development, and Indigenous well-being focus on community-level outcomes,[11] a representative sample of these communities is required to understand the full extent of the policy under question. In particular, it is essential to have a complete distribution of community sizes to examine policies related to the revitalization of Indigenous communities, such as out-migration of traditional homelands. Many Indigenous value systems emphasize community-level priorities and objectives (Daes, 1995; Gomez, 2007; Kovach, 2010; Smith, 2012; United Nations, 2009); thus, excluding more than half of the communities from economic analysis may be particularly troublesome.

Given these constraints, nighttime light density data may be used as an alternative indicator of well-being for Indigenous communities. Nighttime light data have been used extensively in recent economic literature and have been shown to be good proxies for economic activity at various levels of aggregation: countries (Lessmann and Seidel, 2017; Pinkovskiy and Sala-I-Martin, 2016), ethnic homelands (Alesina, Michalopoulos, and Papaioannou, 2016; Michalopoulos and Papaioannou, 2013), sub- and supranational regions (Ghosh, Powell, Elvidge, Baugh, Sutton, and Anderson, 2010; Henderson, Storeygard, and Weil, 2012), and even at the pixel level (Bleakley and Lin, 2012). These data are gathered from satellites that orbit the earth up to 14 times per day and collect imagery of light density on Earth between 8:30 p.m. and 10 p.m. The raw images are processed by scientists at the National Oceanic and Atmospheric Administration's (NOAA) National Geophysical Data Centre (NGDC) to account for fluctuations in light density that occur from natural phenomena such as seasonal variation in sunlight.[12] All orbits are averaged

[10]For example, in 2011, the CWB database included well over 80 percent of the total on-reserve population, although nearly 40,000 people are still excluded from the data. The sample that contains only GDP excludes another 30,000 individuals.

[11]For examples, refer to Aragón (2015); Dippel (2014); Feir, Gillezeau, and Jones (2017).

[12]This seasonal adjustment is likely of most significance for Northern communities in our context.

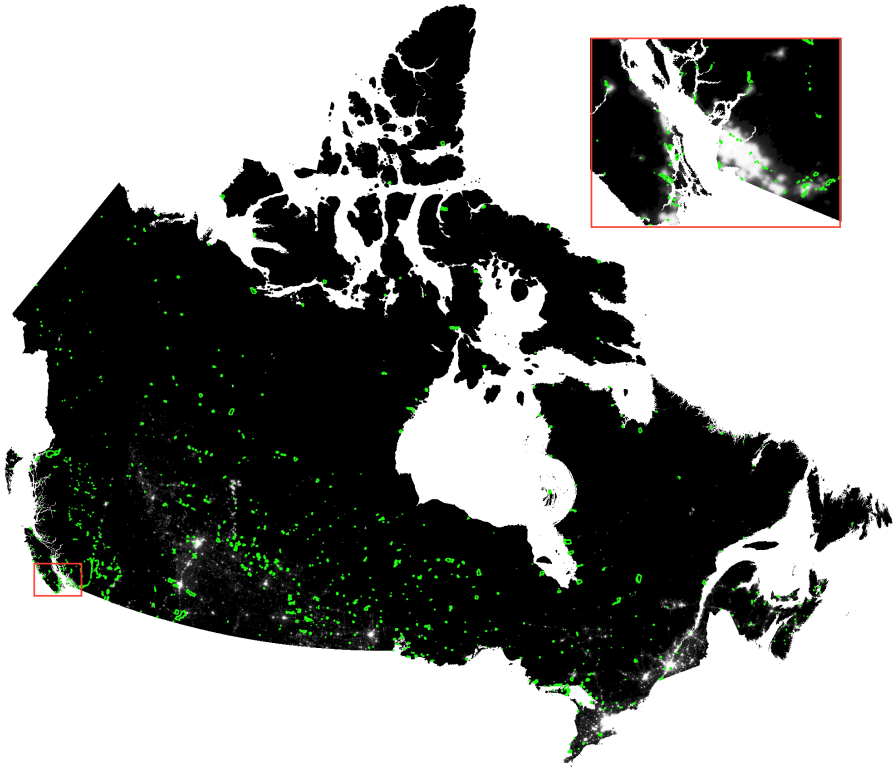

Figure 1: *This figure displays nighttime lights across Canada in 2011. Light areas represent locations with a high light density and dark locations have a low light density. CSD boundaries are in green. The data used in these figures is available from the National Geophysical Data Centre (NGDC).*

over valid nights to produce a satellite-year dataset (Henderson et al., 2012). In some years more than one satellite orbits Earth, in which case light density can be averaged over both satellites.

The nighttime light data are downloadable from the NGDC website in raster (bitmap image) form.[13] They are available at 30 arc second grids, which is equivalent to an area of approximately 1 square kilometre at the equator (Pinkovskiy and Sala-I-Martin, 2016). Each pixel of the raster is assigned a value between 0 (no light) and 63 (maximum light). They are available globally for every year between 1992 and 2013. If two satellites collected luminosity data in the same year, we take the logarithm of the average luminosity. Figure 1 displays the 2011 nighttime light density across Canada along with the geographic boundaries of Indigenous communities. It is easy to identify large economic centres in the south-east, along the border with the United States, and centres in the prairies by their luminosity.

[13]The data can be downloaded online from https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html.

The principal advantage of using nighttime light data in this context is that it can be constructed for all communities in Canada from publicly available information consistently from 1992 onward. Further, light data may be aggregated more naturally to geographic areas beyond those currently defined geographical units in existing survey data, like the census of population. This may allow Indigenous communities to draw boundaries of interest that they consider to be relevant units of study, rather than those defined by Statistics Canada. To make comparisons with the CWB index, we use the log of mean light density within census subdivision boundaries that Statistics Canada associates with an Indigenous settlement or reserve. As documented below, using light data avoids sample selection issues within government-based data resulting from political distrust among Indigenous communities. In what follows, we focus on communities below 6,500 people because the largest First Nations community for which we have a population estimate at the Census Sub-division level is 6,200 and we round up to the nearest 500. We have a total of 1,039 First Nations communities, 52 Inuit communities, and 3,585 non-First Nations communities in the night-light sample; 557 First Nations communities, 46 Inuit communities, and 2,154 non-Aboriginal in the CWB sample; and 340 First Nations communities, 41 Inuit communities, and 1,795 non-Aboriginal communities in the GDP sample.

3 The Distribution of Light Among Communities

Figure 2 displays the density of the natural logarithm of nighttime light density for all First Nations, Inuit, and non-Aboriginal communities with populations under 6,500 people as identified in the 2011 Census of the Population. The results of Figure 2 are striking: a substantial mass of First Nations and Inuit communities are in the dark. This is seen in the bimodal nature of the First Nation and Inuit light distribution: the first mass is at low levels of light density and the second mass is to the left of the median of the non-Aboriginal light density distribution. The low light density peak is not nearly as pronounced for non-Aboriginal communities and they have substantially more mass in the right tail of the distribution of light density. Inuit or northern communities are not driving the bimodal nature of the First Nations and Inuit light distribution.[14] Overall, the data paint a picture of a mass of First Nations and Inuit communities with low observable levels of economic activity and a larger mass that are still somewhat less well-off than their non-Aboriginal counterparts.[15]

[14]These results are unreported but available upon request.

[15]The bimodal nature of the distribution is largely a feature of the inability of satellites to distinguish between the lowest levels of light. The notion that nighttime light density data are unable to differentiate

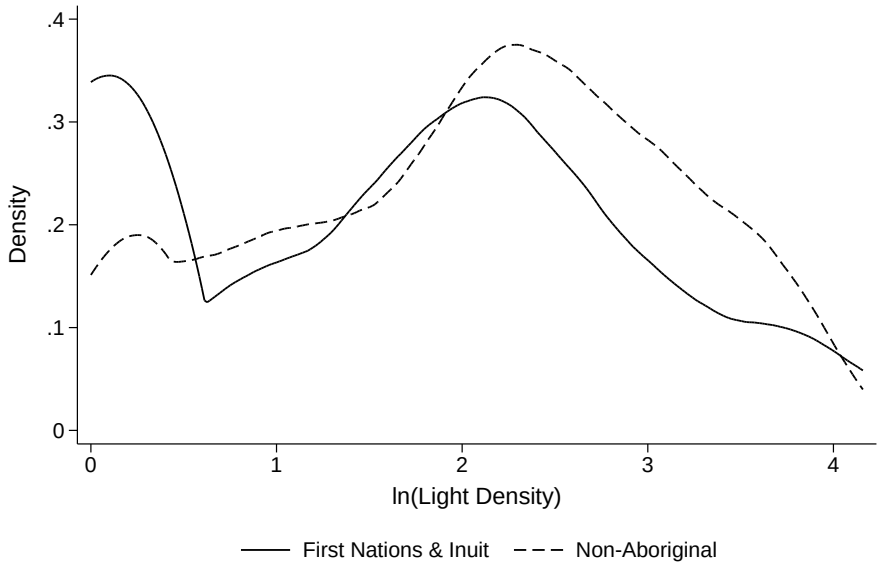

Figure 2: *This figure displays the distribution of the natural log of light density at night for First Nations and Inuit communities and non-Aboriginal Communities with a population under 6,500 individuals. Communities are defined by Census subdivisions in order to be comparable with the CWB index. The nighttime light data used in these figures is available from the National Geophysical Data Centre (NGDC). There are 1039 First Nations communities, 52 Inuit communities, and 3,585 non-Aboriginal communities included in this figure.*

In Figure 3, we display the distribution of the log of light density for First Nations, Inuit and non-Aboriginal communities, comparing the sample of communities included in the GDP sample, the larger CWB sample, and the nighttime light sample. It is clear that the CWB and GDP sub-samples look very different than the full light sample. In particular, restricting our analysis to only those communities in the CWB and GDP sample omits the lower mass of the light density. Given that policies are often meant to target the most impoverished communities or equalize funding across First Nations, Inuit and non-Aboriginal communities, this is a significant omission.

To further examine this sample selection, in Tables 1 and 2, we report summary statistics on population size and nighttime light density split by the sample that contains the community. Panel A of each table displays the summary statistics for all Indigenous communities in the nighttime light data. The population data are not available for all communities, so in panel B of each table we show the summary statistics for population

between light among very small communities has been noted in the literature (Chen and Nordhaus, 2011; Elvidge et al., 2017; Lessmann and Seidel, 2017), and it is important to recognize that as a result, nighttime light density may not be an appropriate indicator to use to study inequality between the smallest communities.

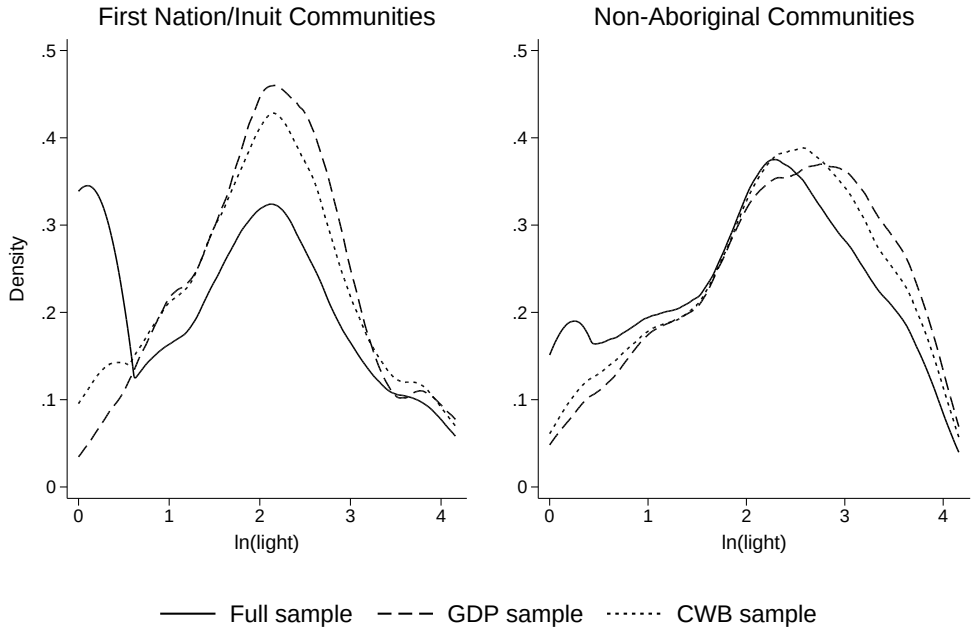

Figure 3: *This figure displays the distribution of the natural log of light density at night for First Nations and Inuit communities, comparing the distribution for sub-samples of communities based on the availability of GDP per capita and CWB information for communities under 6,500. Communities are defined by Census subdivisions in order to be comparable with the CWB index. The nighttime light data used in these figures is available from the National Geophysical Data Centre (NGDC). There is a total of 1039 First Nations communities, 52 Inuit communities, and 3,585 non-Aboriginal communities in the night-light sample; 557 First Nations communities, 46 Inuit communities, and 2,154 non-First Nations in the CWB sample; and 340 First nations communities, 41 Inuit communities, and 1,795 non-Aboriginal communities in the GDP sample.*

size for the available communities. Table 1 compares the CWB sample to the non-CWB sample, and Table 2 compares the GDP sample to the non-GDP sample. The tables emphasize that the CWB database excludes smaller communities. In fact, the average population of the communities excluded from the CWB database is approximately 550 people lower than the average of the included communities. This difference in population is partially reflected in a lower average light density among communities not included in the CWB database. The communities observed only in the lights sample have an average of about one standard deviation lower log light density compared to those included in the sample. A similar pattern holds when we compare the communities for which GDP data are available to those excluded from both the GDP data and the CWB database.

Table 1: Sample Selection in CWB Database

	In sample	Not in sample	Difference
Panel A: CWB Sample			
ln(Avg Light Density)	2.02	1.06	-0.95***
	(1.01)	(1.28)	
Has Population Data	1.00	0.94	-0.06***
	(0.00)	(0.24)	
Signed Modern Treaty	0.12	0.03	-0.09***
	(0.33)	(0.18)	
Dist to closest CMA	204.46	135.70	-68.76***
	(303.39)	(208.99)	
Dist to historical post	155.14	146.80	-8.34
	(208.83)	(171.73)	
Dist to railway station	323.04	245.53	-77.51***
	(426.54)	(347.47)	
Ruggedness Index	332.82	455.59	122.77***
	(270.31)	(318.16)	
Latitude	-103.77	-110.60	-6.83***
	(20.10)	(17.57)	
Longitude	52.73	51.87	-0.86**
	(5.36)	(4.04)	
Observations	602	489	1091
Panel B: CWB Sample with Population			
ln(Population)	5.98	2.11	-3.87***
	(1.00)	(2.05)	
Population	645.95	93.08	-552.87***
	(760.57)	(388.48)	
Observations	602	458	1060

Table 2: Sample Selection in GDP Database

	In sample	Not in sample	Difference
Panel A: GDP Sample			
ln(Avg Light Density)	2.14	1.30	-0.84***
	(0.91)	(1.28)	
Has Population Data	1.00	0.96	-0.04***
	(0.00)	(0.20)	
Signed Modern Treaty	0.17	0.04	-0.13***
	(0.38)	(0.19)	
Dist to closest CMA	244.55	135.60	-108.95***
	(347.43)	(202.58)	
Dist to historical post	161.05	146.22	-14.83
	(234.84)	(166.31)	
Dist to railway station	351.46	254.41	-97.05***
	(448.14)	(358.72)	
Ruggedness Index	315.31	426.77	111.45***
	(256.53)	(312.63)	
Latitude	-99.60	-110.71	-11.12***
	(19.83)	(17.86)	
Longitude	53.25	51.86	-1.39***
	(5.58)	(4.30)	
Observations	381	710	1091
Panel B: GDP Sample with Population			
ln(Population)	6.59	3.02	-3.57***
	(0.66)	(2.15)	
Population	936.61	109.93	-826.68***
	(826.10)	(321.36)	
Observations	381	679	1060

Notes: Mean values are reported with the standard errors in parenthesis. The total census population is rounded to the nearest 5. Communities are defined by Census subdivisions in order to be comparable with the CWB index. The nighttime light data used in these figures is available from the National Geophysical Data Centre (NGDC). Ruggedness is calculated using Global DEM files from the Harmonized World Soil Database v 1.2 (HWSD) from the Food and Agriculture Organization of the United Nations (Fischer et al., 2008). The CWB database, as well as GDP and population data, can be downloaded from: https://www.aadnc-aandc.gc.ca/eng/1100100016579/1100100016580. Significance stars: * 0.05 ** 0.01 *** 0.001.

Importantly, there are notable differences in other community characteristics between samples. On average, communities excluded from the CWB and GDP databases are slightly less geographically isolated, as indicated by being located closer to a census metropolitan area (CMA), to a railway station, or to a historical trading post, and are less likely to have signed a modern treaty with the federal government. There are also differences in the geographic characteristics between communities included in the CWB sample and those that are not. In particular, settlements not included in the CWB sample are more likely to be located on rugged terrain.[16]

There are also sample selection issues within the CWB database. In Table A1 of the appendix, we compare communities observed in the CWB sample, but not in the GDP sample. We find that communities in the GDP sample are systematically rated lower on the CWB index and higher in the light density index than those not included in the GDP sample. The CWB index is approximately half a standard deviation higher in the communities excluded from the GDP sample and about half a standard deviation lower in log light density. Again, there are differences in levels of modern and historical geographic isolation.

Figure 4 investigates the relationship between light density and population for First Nations, Inuit and non-Aboriginal communities in more detail.[17] This figure indicates that population size has similar impacts on nighttime light density for First Nations and Inuit and non-Aboriginal communities, but Figure 4 also shows that the gap in light density between First Nations and Inuit and non-Aboriginal communities is statistically significant for community sizes of approximately 20 to 50 people. This implies that differences in economic development may be occurring around this range, which other publicly available data would miss. While population size has been used as a measure of economic development when other data are not available (see for example Acemoglu et al. (2002)), this figure shows that light data are capturing something other than population. In addition, population sizes for First Nations and Inuit communities are not always available publicly as described above.

From this distributional analysis, it is clear that the communities excluded from typical GDP per capita or CWB analyses differ from communities in these limited samples. For nighttime light density data to be a useful measure, however, it is necessary that it serve as a functional proxy for economic outcomes of interest. While existing measures of well-being suffer from the drawbacks we discussed above, in Figure 5 we show that our light density measure correlates with the Community Well-Being Index. In the next

[16]Ruggedness is calculated using Global DEM files from the Harmonized World Soil Database v 1.2 (HWSD) from the Food and Agriculture Organization of the United Nations (Fischer et al., 2008). We overlay these files with reserve boundaries to compute the terrain ruggedness index of Riley et al. (1999).

[17]For the distribution of communities by population in graphical form refer to Figure A1.

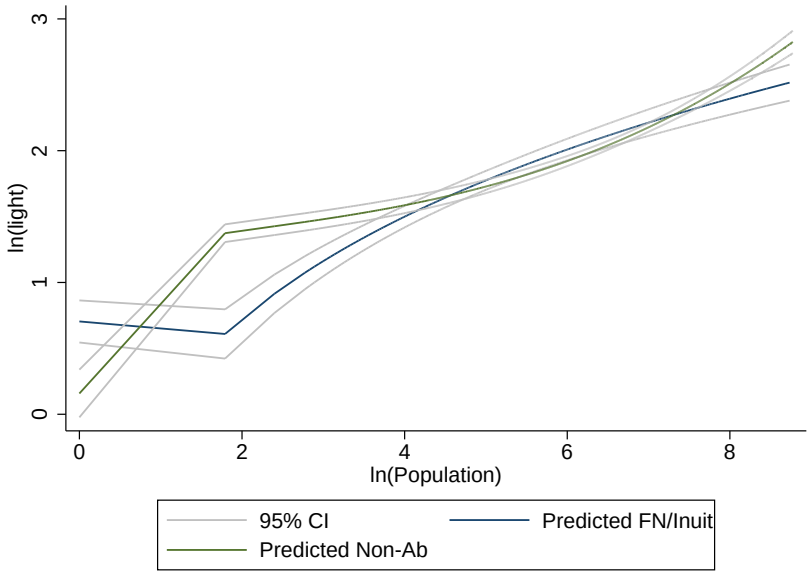

Figure 4: *This is a polynomial regression of ln(light density) on the log of population for First Nations and non-Aboriginal communities with a population of less than 6,500 with a 95% confidence interval displayed. The total census population is rounded to the nearest 5. Communities are defined by Census subdivisions in order to be comparable with the CWB index. The nighttime light data used in these figures is available from the National Geophysical Data Centre (NGDC)..*

section, we explicitly estimate the elasticities of the nighttime light data with publicly available measures of well-being at the community level.

4 Elasticities of Community Light Data and Other Outcomes

Table 3 displays the unconditional elasticities between community nighttime light density and standard composite measures from the CWB database, including education, housing, labour force participation, population, GDP per capita, and the CWB index itself for both First Nations and Inuit and non-Aboriginal communities. For both sets of communities, nighttime light density is positively correlated with all outcome variables and this correlation is strongly significant in all cases other than between nighttime light density and labour force participation. These estimated correlations between economic outcomes and nighttime light density are similar to those observed in other contexts (Donaldson and Storeygard, 2016). However, it is worthwhile to note that, in general, the correlations are stronger for non-Aboriginal communities.

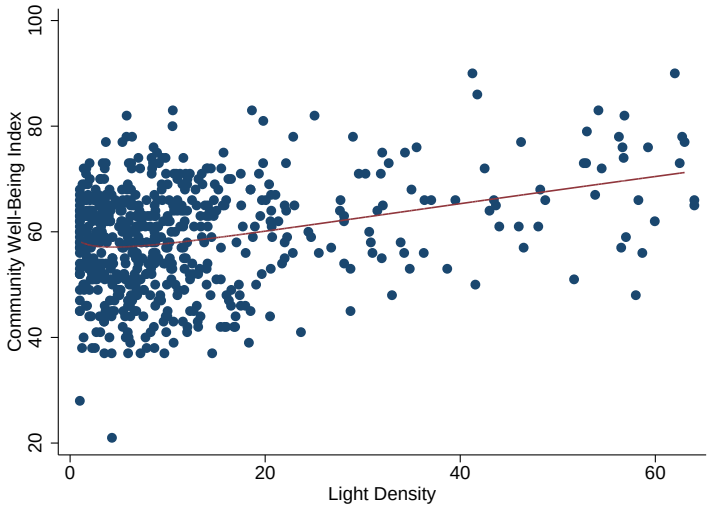

Figure 5: This figure plots the average light density per pixel for First Nations and Inuit census subdivisions against the CWB index in 2011. Communities are defined by Census subdivisions in order to be comparable with the CWB index. The nighttime light data used in these figures is available from the National Geophysical Data Centre (NGDC). The CWB database, as well as GDP and population data, can be downloaded from: https://www.aadnc-aandc.gc.ca/eng/1100100016579/1100100016580.

We repeat this exercise in Table 4 where we present our elasticity estimates conditional on population size. For non-First Nations and Inuit communities, we continue to see a positive correlation between education, housing, population, and GDP per capita and light density. As in the unconditional correlations, the correlations remain positive for First Nations and Inuit communities. As such, we should feel confident in employing nighttime light density data as a general proxy for economic development in more rural regions of Canada for First Nations, Inuit, and non-Aboriginal communities.[18] It is worth considering the reasons why we might observe a lower correlation between the CWB and its sub-components for Aboriginal and non-Aboriginal communities. One possibility is that measurement error in the self-reported CWB database is larger among Aboriginal communities than non-Aboriginal communities. Given the fraught history between Aboriginal communities and the federal government in Canada, it is plausible there is significant discomfort with full disclosure of income and other personal information to the federal government among First Nations and Inuit communities (Smith, 2012; Walter and Andersen, 2013). In this case, light data may be a more accurate measurement of

[18]If we estimate elasticities separately for Inuit and First Nations communities we find that the correlations are larger in magnitude for the Inuit, but estimated with significantly more noise. These results are unreported but available upon request.

well-being than the CWB, even for communities for which both are available. On the other hand, it may be possible that economic development and light emissions are fundamentally different between First Nations, Inuit, and non-Aboriginal communities because of the types of development or economic activity occurring in these communities. For example, if for a given level of income, non-Aboriginal communities choose housing that is substantially larger and emits more light than Aboriginal communities, then we would see a different relationship between income and light but no difference in well-being.

5 Discussion and Future Work

It is our hope that this work will encourage scholars in economics and elsewhere in the social sciences studying economic and quality-of-life outcomes for Indigenous communities to turn to nighttime light density data as an important data source. It is clear that light density is a strong proxy not just for GDP per capita in Indigenous communities, but also for a broader composite of indicators encompassed by the Community Well-Being Index. Most importantly, for scholars working with publicly available data on First Nations or Inuit communities, we have demonstrated that there is a substantial sample selection problem with the CWB and GDP per capita samples. Going forward, scholars will need to tackle this approach econometrically, perhaps through a Heckman selection model, or through the use of alternative data sources, like the nighttime light density data.

We decided to write this piece while studying the long-term impacts of the near-extermination of the bison in the Great Plains (Feir et al., 2017). Light data was particularly valuable as the bison roamed across many low population regions that are excluded from traditional economic well-being databases. Authors looking to study the long-run impacts of historical shocks or geography on Indigenous outcomes should view light density as a reasonable present-day outcome. Another potential use of these data is in the evaluation of government programs targeted to First Nations and Inuit communities in the areas of housing, infrastructure, and other forms of economic development that could be reflected in these figures.

Just as income, education, and labour force participation are not perfect measures of well-being or economic activity, nighttime light data are not without limitations. For example, the economic assumption underlying the use of light density to proxy for economic activity is that lighting is a normal good (Donaldson and Storeygard, 2016). Although this may seem natural to assume, this point may merit additional consideration in the Indigenous context. For instance, if a community's shared values lead them to resist forms of economic activity that generate light pollution—i.e., activities that may obscure the stars—or activities that may damage the natural state of their traditional territories—

e.g., dams, wind farms, or certain types of natural resource exploration—then a lack of light density or measured income does not serve as a proxy for dysfunction and therefore does not necessarily signal a poor quality of life. Alternatively, if Indigenous community members are more likely to engage in traditional activities, like hunting and fishing, or are involved in mining, which may require those involved to be away from their communities, then nighttime light density will underestimate the economic well-being in these communities. Thus, any findings using light or other existing measures of well-being, like the CWB index, should take these points into account.

Finally, when researchers are considering any form of publicly available data regarding Aboriginal peoples in Canada, whether the CWB database or data derived from satellites, there needs to be an awareness that this data, and therefore the research, does not clearly fall under the principles of OCAP (Ownership, Control, Access, and Possession) put forward by the First Nations Information Governance Centre (Schnarch, 2004). Given this, researchers should exercise additional reflection about the potential benefits and harms of their research for the communities included in their analysis. While the use of nighttime light data may increase the potential for culturally relevant economic research, the broader goals of reconciliation and engagement must always be kept in mind.

References

AANDC (2015, April). The community well-being index: Well-being in First Nations communities, 1981-2011. Technical Report R3-170/2-2014E, Strategic Research Directorate Aboriginal Affairs and Northern Development Canada, Ottawa. https://www.aadnc-aandc.gc.ca/eng/1345816651029/1345816742083.

Acemoglu, D., S. Johnson, and J. A. Robinson (2002). Reversal of fortune: Geography and institutions in the making of the modern world income distribution. *The Quarterly Journal of Economics 117*(4), 1231–1294.

Alesina, A., S. Michalopoulos, and E. Papaioannou (2016). Ethnic inequality. *Journal of Political Economy 124*(2), 428–488.

Aragón, F. M. (2015). Do better property rights improve local income?: Evidence from First Nations' treaties. *Journal of Development Economics 116*, 43–56.

Bleakley, H. and J. Lin (2012). Portage and path dependence. *The Quarterly Journal of Economics 127*(2), 587–644.

Chen, X. and W. D. Nordhaus (2011). Using luminosity data as a proxy for economic statistics. *Proceedings of the National Academy of Sciences 108*(21), 8589–8594.

Cooke, M. (2005, January). The First Nations community well-being index (cwb): A conceptual review. Technical Report R2-400/2005E-PDF, Strategic Research and Analysis Directorate Indian and Northern Affairs Canada, Ottawa.

Daes, E.-I. (1995, l). Draft principles and guidelines for the protection of the heritage of Indigenous peoples. Technical Report UN Doc. E/CN.4/Sub.2/1995/26, Special Rapporteur for the Sub-Commission on the Promotion and Protection of Human Rights.

Dippel, C. (2014). Forced coexistence and economic development: Evidence from Native American reservations. *Econometrica 82*(6), 2131–2165.

Donaldson, D. and A. Storeygard (2016). The view from above: Applications of satellite data in economics. *Journal of Economic Perspectives 30*(4), 171–198.

Elvidge, C. D., K. E. Baugh, E. A. Kihn, H. W. Kroehl, E. R. Davis, and C. W. Davis (2017). Relation between satellite observed visible-near infrared emissions, population, economic activity and electric power consumption. *International Journal of Remote Sensing 18*(6), 1373–1379.

Feir, D., R. Gillezeau, and M. E. C. Jones (2017). The slaughter of the bison and reversal of fortunes on the Great Plains. *University of Victoria Working Paper, DDP 1702*.

Feir, D. and R. L. Hancock (2016). Answering the call: A guide to reconciliation for quantitative social scientists. *Canadian Public Policy 42*(3), 350–365.

Fischer, G., H. van Velthuizen, M. Shah, and F. Nachtergaele (2008). Global agro-ecological zones assessment for agriculture (gaez 2008).

Ghosh, T., R. L. Powell, C. D. Elvidge, K. E. Baugh, P. C. Sutton, and S. Anderson (2010). Shedding light on the global distribution of economic activity. *The Open Geography Journal 3*, 148–161.

Gomez, N. (2007). Healing hidden wounds. *Cultural Survival Quarterly 31*(3), 3–15.

Henderson, J. V., A. Storeygard, and D. N. Weil (2012). Measuring economic growth from outer space. *American Economic Review 102*(2), 994–1028.

Indigenous and Northern Affairs Canada (2010, September). The community well-being (cwb) index: Methodological details. Technical report, Strategic Research Directorate, Ottawa. http://www.aadnc-aandc.gc.ca/eng/1100100016585/1100100016598.

Kovach, M. E. (2010). *Indigenous methodologies: Characteristics, conversations, and contexts*. University of Toronto Press.

Lessmann, C. and A. Seidel (2017). Regional inequality, convergence, and its determinants – A view from outer space. *European Economic Review 92*, 110–132.

Levy, J. E. (1998). *In the Beginning: The Navajo Genesis*. University of California Press.

May, H. G. (1939). The creation of light in genesis 1:3-5. *Journal of Biblical Literature 58*(3), 203–211.

Michalopoulos, S. and E. Papaioannou (2013). Pre-colonial ethnic institutions and contemporary African development. *Econometrica 81*(1), 113–152.

Michalopoulos, S. and E. Papaioannou (2014). National institutions and subnational development in Africa. *Quarterly Journal of Economics 129*(1), 151–213.

Miller, J. (2000). *Tsimshian Culture: A Light Through the Ages*. University of Nebraska Press.

O'Sullivan, E. (2011, September). The community well-being index (cwb): Measuring well-being in First Nations and Non-Aboriginal communities, 1981-2006. Technical Report R3-170/2-2012E-PDF, Strategic Research Directorate Aboriginal Affairs and Northern Development Canada, Ottawa.

Pinkovskiy, M. and X. Sala-I-Martin (2016). Lights, camera... income! Illuminating the national accounts-household surveys debate. *The Quarterly Journal of Economics 131*(2), 579–631.

Quinless, J. (2017). *Decolonizing bodies: A First Nations perspective on the determinants of urban Indigenous health and wellness in Canada*. Ph. D. thesis, University of Victoria.

Rasmussen, K. and W. Worster (2009). *Inuit Folk-tales*. Adventures in new lands. IPI Press.

Reid, B., W. Reid, and R. Bringhurst (1996). *The Raven Steals the Light*. University of Washington Press.

Riley, S. J., S. D. DeGloria, and R. Elliot (1999). A terrain ruggedness index that quantifies topographic heterogeneity. *Intermountain Journal of Sciences 5*(4), 23–27.

Schnarch, B. (2004). Ownership, control, access, and possession (ocap) or self-determination applied to research: A critical analysis of contemporary First Nations research and some options for First Nations communities. *International Journal of Indigenous Health 1*(1), 80.

Smith, L. T. (2012). *Decolonizing Methodologies: Research and Indigenous Peoples*. Otago University Press.

The Truth and Reconciliation Comission of Canada (2015). *Summary of the Final Report of the Truth and Reconciliation Commission of Canada*. McGill-Queen's University Press.

United Nations (2009). *State of the world's indigenous peoples*, Volume 9. United Nations Publications.

Walter, M. and C. Andersen (2013). *Indigenous statistics: A quantitative research methodology*. Left Coast Press.

Table 3: Elasticities of Light with Respect Other Well-being Measures

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Non-Aboriginal Communities						
ln Education	1.055***					
	(0.124)					
ln Housing		3.983***				
		(0.837)				
ln Labour Force			2.211***			
			(0.238)			
ln Population				0.266***		
				(0.008)		
ln GDP per Capita					0.885***	
					(0.120)	
ln CWB						3.428***
						(0.313)
Observations	1795	1795	1795	3585	1795	2154
Adjusted R^2	0.038	0.037	0.045	0.173	0.033	0.064
Panel B: First Nations and Inuit Communities						
ln Education	0.622***					
	(0.124)					
ln Housing		1.305***				
		(0.182)				
ln Labour Force			0.277			
			(0.326)			
ln Population				0.233***		
				(0.014)		
ln GDP per Capita					0.235**	
					(0.106)	
ln CWB						1.087***
						(0.213)
Observations	381	381	381	1060	381	602
Adjusted R^2	0.066	0.112	-0.001	0.216	0.011	0.036

Notes: The left hand column labels the natural log of the respective indexes. The dependent variable is the natural log of average annual nighttime light density as described in the data section. Communities are defined by Census subdivisions in order to be comparable with the CWB index. The nighttime light data used in these figures is available from the National Geophysical Data Centre (NGDC). The CWB database, as well as GDP and population data, can be downloaded from: https://www.aadnc-aandc.gc.ca/eng/1100100016579/1100100016580. Standard errors are contained in the parentheses. Significance stars: $^{*}p < 0.10,^{**} p < 0.05,^{***} p < 0.01$

Table 4: Elasticities of Light with Respect to Well-Being Measures Conditional on Population Size and Population Density

	(1)	(2)	(3)	(4)	(5)
ln Education	0.405***				
	(0.073)				
(Non-Ab==1)*ln Education	-0.127				
	(0.098)				
ln Housing		0.868***			
		(0.156)			
(Non-Ab==1)*ln Housing		0.118			
		(0.286)			
ln Labour Force			0.203		
			(0.224)		
(Non-Ab==1)*ln Labour Force			1.238***		
			(0.250)		
ln GDP per Captia				0.189***	
				(0.062)	
(Non-Ab==1)*ln GDP per Cap				-0.006	
				(0.085)	
ln CWB					0.997***
					(0.157)
(Non-Ab==1)*ln CWB					0.416*
					(0.214)
Non-Aboriginal Indicator	X	X	X	X	X
Population Fixed Effects	X	X	X	X	X
ln (Population per Sq Km)	X	X	X	X	X
Observations	2175	2175	2175	2175	2755
Adjusted R^2	0.770	0.773	0.780	0.766	0.716

Notes: The left hand column labels the natural log of the respective indices, the indices interacted with a non-Aboriginal dummy variable, and a series of 10 population group dummy variables with an equal number of communities in each group. The dependent variable is the natural log of average annual nighttime light density. Communities are defined by Census subdivisions in order to be comparable with the CWB index. The nighttime light data used in these figures is available from the National Geophysical Data Centre (NGDC). The CWB database, as well as GDP and population data, can be downloaded from: https://www.aadnc-aandc.gc.ca/eng/1100100016579/1100100016580. Standard errors are contained in the parentheses. Significance stars: $^{*}p < 0.10,^{**} p < 0.05,^{***} p < 0.01$

A Additional Tables and Figures

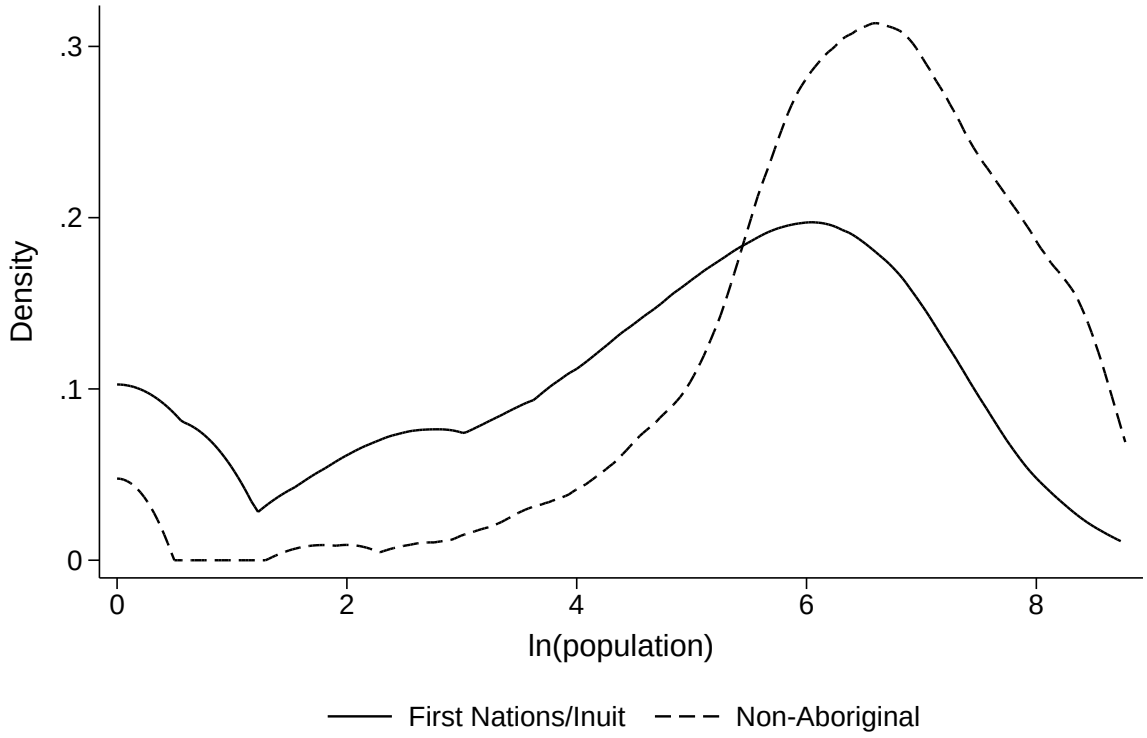

Figure A1: This figure plots the distribution of the natural log of population for First Nations communities and for non-First Nation communities. The sample is limited to communities with a population of less than 6,500.

Table A1: Summary Statistics: Sample Selection in the CWB Database

	In GDP sample	Not in GDP sample	Difference
ln(Avg Light Density)	2.14	1.81	-0.33***
	(0.91)	(1.14)	
CWB Index	57.43	61.45	4.02***
	(10.63)	(9.03)	
ln(Population)	6.59	4.91	-1.68***
	(0.66)	(0.39)	
Population	936.61	144.86	-791.76***
	(826.10)	(54.46)	
Signed Modern Treaty	0.17	0.05	-0.13***
	(0.38)	(0.21)	
Dist to closest CMA	244.55	135.36	-109.19***
	(347.43)	(188.08)	
Dist to historical post	161.05	144.94	-16.10
	(234.84)	(154.00)	
Dist to railway station	351.46	274.05	-77.41*
	(448.14)	(382.52)	
Ruggedness Index	315.31	362.99	47.68*
	(256.53)	(290.69)	
Latitude	-99.60	-110.96	-11.37***
	(19.83)	(18.51)	
Longitude	53.25	51.84	-1.41**
	(5.58)	(4.84)	
Observations	381	221	602

Notes: Mean values are reported with the standard errors in parenthesis. The total census population is rounded to the nearest 5. Significance stars: * 0.05 ** 0.01 *** 0.001