January 2015

Population Dynamics: A Case Study Of The North Dakota Oil Boom

Jessica Leigh Jensen

POPULATION DYNAMICS: A CASE STUDY OF THE NORTH DAKOTA OIL BOOM

by

Jessica Leigh Jensen
Bachelor of Arts, University of North Dakota, 2015

A Thesis

Submitted to the Graduate Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master of Science in Applied Economics

Grand Forks, North Dakota
December
2015

This thesis, submitted by Jessica Jensen in partial fulfillment of the requirements for the Degree of Master of Science in Applied Economics from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

Dr. David Flynn

Dr. Patrick O'Neill

Dr. Xiao Wang

This thesis is being submitted by the appointed advisory committee as having met all of the requirements of the School of Graduate Studies at the University of North Dakota and is hereby approved.

Wayne Swisher
Dean of the School of Graduate Studies

December 15, 2015
Date

PERMISSION

Title Population Dynamics: A Case Study of the North Dakota Oil Boom

Department Economics

Degree Master of Science in Applied Economics

In presenting this thesis in partial fulfillment of the requirements for a graduate degree from the University of North Dakota, I agree that the library of this University shall make it freely available for inspection. I further agree that permission for extensive copying for scholarly purposes may be granted by the professor who supervised my thesis work or, in his absence, by the Chairperson of the department or the dean of the School of Graduate Studies. It is understood that any copying or publication or other use of this thesis or part thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to the University of North Dakota in any scholarly use which may be made of any material in my thesis.

Jessica Leigh Jensen
12/17/15

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

I would like to thank my parents, my advisory committee, and all of the other faculty members in the economics department that have taught me so much over the span of my education. Without the help, encouragement, and guidance of all of these people, I would never have been able to accomplish my goals.

ABSTRACT

This research examines the recent oil boom and the impacts it has had on North Dakota population dynamics, paying special attention to which demographic factors have had the largest influence on population growth. Research methodology includes the use of standard life tables, as well as cohort component population projections. Life tables include fertility rates, mortality rates, and migration rates. Results will lead to new and better population projections for North Dakota. The usefulness of a population projection is manifold, but perhaps the most obvious use is for planning purposes. It is essential for a community to have an idea about potential changes in size, diversity, and distribution occurring within their population. As previously unseen changes occur within a population, it becomes more difficult to obtain an accurate projection, which is why research and implementing new population techniques is important.

CHAPTER I

INTRODUCTION

The year 2007 marked the beginning of a historical change in North Dakota's oil producing economy. The use of innovative new hydrofracking and horizontal drilling techniques coupled with the high price of a barrel of oil, caused oil extraction in the Bakken region to increase rapidly. The surge in oil extraction brought with it largely increased revenues to the state. Currently, the North Dakota Treasury Office is operating around a $3 billion dollar budget surplus (North Dakota State Treasurer, 2015). But these revenues, however large, were not achieved without difficulty. Chaos enveloped the state as it was not equipped to deal with the rapid changes in population growth, home prices, housing shortages, increased criminal activity, infrastructure needs, etc. Stated in the North Dakota Tax Commissioner's 2012 report, 72% of North Dakotans agree or strongly agree with the notion that their state is taking appropriate measures of protection against the known volatility of the fossil fuel market (Fong, 2012). But this confidence could be seen as falsely optimistic and bred through misinformation because the extraction of mineral resources, although profitable, is not without major risks.

Rapid population increases are currently having a large impact on the state as a whole, but the concern of many is the impact that a potential and rapid population decrease would have. The majority of the increase that the labor force has seen in oil producing counties and surrounding areas is from an influx of migrants. These migrants are workers who most likely only reside in North Dakota temporarily, and are therefore expected to migrate out when the economic activity declines.

This thesis examines the impact of the oil boom on North Dakota population dynamics. Research methodology includes the use of standard life tables, life tables with assumptions about fertility rates, mortality rates, migration rates, as well as cohort component population projections. The results will lead to new and better population projections for North Dakota.

The usefulness of a population projection is manifold, but perhaps the most obvious use is for planning purposes. It is essential for a community to have an idea about potential changes in size, diversity, and distribution occurring within their population. As previously unseen changes occur within a population, it becomes more difficult to obtain an accurate projection, which is why research and implementing new population techniques is important (O'Neill, Balk, Brickman, & Ezra, 2001). The more accurate a population projection is, the more it leads to appropriate decision making with regard to city expansion and eventual decline.

Changes in a population are due to either a change in the rate of natural increase[1], or a change in net migration. When an economy experiences an exogenous shock as in the case of a rapid oil boom, in the short term, the change in net migration will become more prominent than any change in the rate of natural increase. This is due primarily to labor market demands. As can be seen in Figure 1 below, these rapid population increases are not permanent, and they follow a trend that can be mathematically modeled in correspondence with the life of the nonrenewable resource.

[1] Natural increase is defined as births minus deaths.

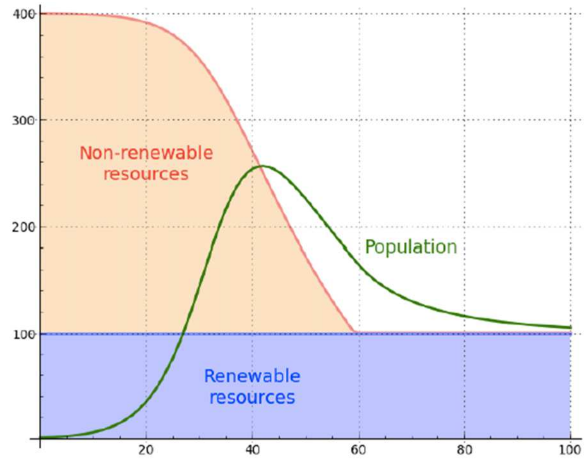

Figure 1. Model between non-renewable resource depletion and population change. (Lutus, 2014)

The challenge lies in predicting the peak point on the population curve. If it were possible to know the exact amount of the non-renewable resource, if the resource had a steady depletion rate independent of market fluctuations, and if labor demand/supply was predictable, then the peak might be possible to find. Due to large uncertainty regarding the size of the Bakken Shale and the volatility of the oil market, predicting the point of decline is complicated further[2]. For these reasons, the population projections in this thesis were completed with the standard underlying assumption that the applied rates will remain stable throughout the projection period.

The rest of the paper is organized as follows: First, we will review the literature, specifically focusing on the analysis of two previously completed population projections, previous population trends in North Dakota, a brief oil boom background, and an

[2] Due to the newness and uncertainty surrounding the type of extraction methods used, estimates vary from as much as 3.0 billion barrels to 24 billion barrels (Institute for Energy Research [IER], 2012). This is explained in more depth in the section "Oil Boom Background".

overview of techniques used in migration analysis. Second, the data and methodology is explained, specifically the calculation of survival rates using life tables, fertility rates, indirect migration rates, and direct migration rates. Third, we will look at the results of the population projection and the final projection tables. Last, we will conclude.

CHAPTER II

LITERATURE REVIEW

Previous Projections

Literature regarding population analysis in North Dakota is sparse and in general, demographic techniques can vary immensely in areas of complexity and best fit. By examining the methods utilized in previous population projections, and building upon them to better suite our purposes, more accurate projections can be made. The Cohort Component Method is one of the most commonly used projection techniques and literature regarding the use of the technique is widespread (Preston, Heuveline, & Guillot, 2001). This thesis completes an in-depth examination of two specific population projections, both of which utilized the Cohort Component Method.

The first of these projections was completed by the North Dakota State Data Center (NDSDC) at North Dakota State University. In 2002, NDSDC published a series of projections for North Dakota for the years 2005-2020. Much has changed in the state since the projections were published. This thesis revises their prior assumptions and uses new data to develop more accurate projections. The United States Census Bureau completed the second projection this thesis analyzes. Each year the US Census Bureau completes population projections at the national, state, and county level using the most recently released decennial census data. The last of these projections were completed in 2014. Through the examination of the methodology, this thesis shows that while these projections are often regarded as being highly accurate on a national level, they are not as well equipped to deal with North Dakota's unique circumstances and therefore the need for individualized methodology to the state is present. As such, this thesis uses different assumptions, data collection methods, and techniques than that of the US Census Bureau's nationwide projections.

NDSDC Projection Review

In 2002, there were three leading trends that influenced North Dakota's population growth: rural depopulation, out-migration of young adults and young families, and an increasing population of elderly (Rathge, Clemenson, & Danielson, 2002). Determining which of these previous trends are prevalent today, if any, will assist in the accuracy of a new population projection. The NDSDC projections brought up many concerns for the future of the state, some of which still apply. Worries of county viability in the face of rural depopulation, rising costs and decreased availability of goods and services, inadequate healthcare, inadequate education facilities, declining numbers of young couples starting families and forming roots, were some of the concerns listed in the paper (Rathge et al., 2002). Even though North Dakota is now facing the opposite problem in the major oil producing cities, too many people instead of too few, these problems are familiar. The rapid increase in population caused the costs of certain goods and services to rise steeply, it led to increased demand in healthcare and education facilities as well as other public service needs, and has drastically changed the demographic make-up of the state.

As stated previously, the NDSDC utilized the Cohort Component Method for their projections. For each county, they derived age-specific fertility rates for mothers between 15 and 44 years of age, and averaged any births given outside the age range into the top and bottom age cohorts. For mortality data, they used a single statewide death rate for all counties. The death rate was derived from a standard life table previously published in 1991 (Hamm & Azam, 1991). Migration rates were calculated using a residual technique, and were adjusted for any noted extremity. Due to the importance of migration in North Dakota currently, this thesis pays special attention to the calculation of migration, which cannot be said for the NDSDC projections. This is one major area where this thesis' methods differ from the methods the NDSDC implemented. Another major difference is in the calculation of mortality data. This thesis develops current life tables based on the most recently released data, while the NDSDC projections utilized mortality data that was derived for the year 1990, not the year 2000 in which their projection was centered.

US Census Bureau Projection Review

The United States Census Bureau uses the Cohort-Component Method of estimation in their population projections, as does this thesis (US Census Bureau, 2004). We utilize some of the same projection methodology as that used by the US Census Bureau, but also venture away from some. For example, the US Census Bureau's estimates are produced using a "top-down" approach in which they first estimate population at a national level, the county level, sum these estimates to the state level, and compare the national estimates to the aggregate of the state estimates (US Census Bureau, 2004). This system of checks and balances works well, but is of no use to us, because our interest only spans to that of North Dakota's estimates. However, a similar model could be used to check county estimates to the state estimate as a whole, if data were available.

Before the US Census Bureau estimates begin, the base population is altered to include changes that have been made since the last available census. These changes may include the CQR program[3], any legal boundary changes, and any changes to race categories. This step is also negligible in this paper's estimates as no legal entity has challenged population estimates through the CQR program, there have not been any legal boundary changes on the state level, and only sex and age are included in this thesis' estimations.

The US Census Bureau projections are noted as being highly accurate. Variation from the year 2000 to 2010 was 3.1 percent across all counties (Yowell & Devine, 2014). However, the percent difference between the population estimates and census counts for North Dakota was -3.09% (Yowell & Devine, 2014). This was the 3rd largest difference among all of the statewide estimates. This large variation between the Census counts and the US Census Bureau projections tells us two things: first, it provides an example of the difficulty faced in accurately projecting a state's population while the state is changing so rapidly, as is the case with North Dakota. Second, it indicates that the development of a North Dakota population projection requires specialized methods, and the altering of conventional techniques.

Although the US Census Bureau methodology works well at a national level, it is developed specifically to pay special attention to the demographic make-up of the areas it is projecting, especially to Hispanic origin. According to the 2010 Census counts, North Dakota's population was 90.0% white, with the remaining 10% being made up of 5.4% Native American, 2.0% Hispanic or Latino of any race, 1.2% Black or African, 1.0% Asian American, 0.2% Multiracial, 0.1% Pacific Islander, and 0.5% Other (US Census

[3] The Count Question Resolution Program is a way in which elected officials may challenge their jurisdiction's Census counts.

Bureau, 2010). These proportions are far less than what the United States experiences as a whole, and the state's homogenous nature allows for the separation of projection characteristics to be limited to age and sex, simplifying the projection methodology while still capturing all necessary information.

The vital statistics methodology of the US Census Bureau's population estimates explain a modification to death records of those in the 70+ age range (US Census Bureau, 2004). Due to the unreliability of death data in this age range, they aggregate the population to a group of 70 to 99 and 100+, and apply life-table based death rates to these population categories. In the area of vital statistics, North Dakota is home to some of the nation's oldest people. A 2012 US Census Bureau report showed the top 10 states in the nation that have the greatest proportion of centenarians per population, and North Dakota was at the top of the list (Meyer, 2012). Therefore, it is logical to assume that the US life-table statistics may not fit North Dakota's elderly population as well as it fits others, and another methodology would better suit the state. This paper's methodology takes North Dakota's unique aging population into account, as is described in the methodology section.

Previous Population Trends

North Dakota's population grew a meager 0.5% from the years of 1990 to 2000, according to the 2000 Census (US Census Bureau, 2000). The State went from having the smallest relative growth of all 50 states, to having the top highest relative growth rate (Bureau of Economic Analysis [BEA], 2015). This sharp and unpredictable increase in growth makes projecting future population numbers difficult, because demographic trends can fluctuate rapidly from year to year. Additionally, changes in oil production, which is known to be volatile, can have large and rapid direct effects on the population of a state that has become increasingly dependent on oil activity.

A population pyramid is an effective way to visually represent the age and sex structure of a population. In Figures 2, 3, and 4 below, population pyramids for 1990, 2000, and 2010 are shown. The difference in shape between the three pyramids provides valuable insight into the changes of the demographic make-up that occurred between the years 2000 and 2010, using 1990 to 2000 as a frame of reference. In 2010 there was a substantial increase in the 20-24 age cohort, especially on the male side. From 2000 to 2010, the percent of males ages 10-14 (ages 20-24 in 2010 terms) increased by ~.9%. To put this increase into perspective, the change from 1990 to 2000 was only ~.2%. The only way to explain this type of increase is by migration. In the hypothetical absence of migration, the shape of the pyramid can only be changed from added births in the 0-4 age cohort, and deaths in every other cohort. Deaths cause a population decrease, so the increases that are seen in the population pyramids have to be attributed to an increase in net migration. The Appendix shows the percent changes in the 20-year span. For females, there was a large decrease of ~.6% in the 15-19 age cohort from the years of 2000 to 2010. The corresponding male change was a decrease of ~.4%. Again, because there was no rapid increase in mortality, this loss of population must be attributed to out-migration. These population pyramids not only show a changing age distribution, but they also show the changing sex distribution between males and females. Figures 5 and 6 below show the percent change in the male and female population from the years of 2000 to 2010 in side-by-side bar charts. The figures provide another perspective for the large changes in demographic composition.

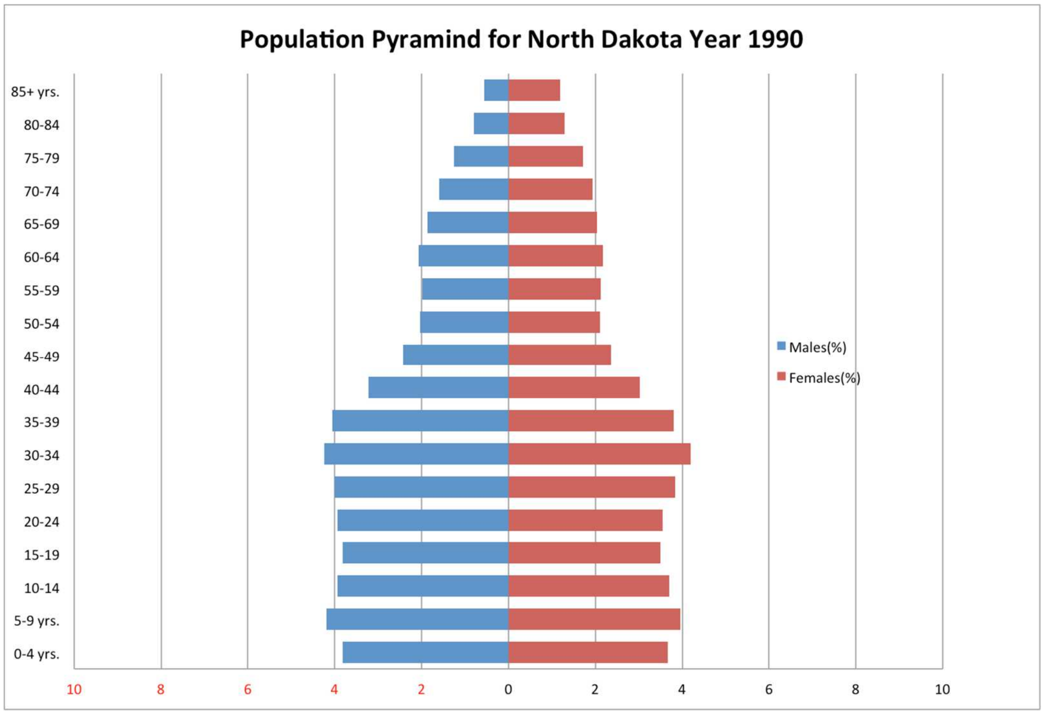

Figure 2. Population pyramid for North Dakota for the year 1990. Population data from the US Census Bureau (1990).

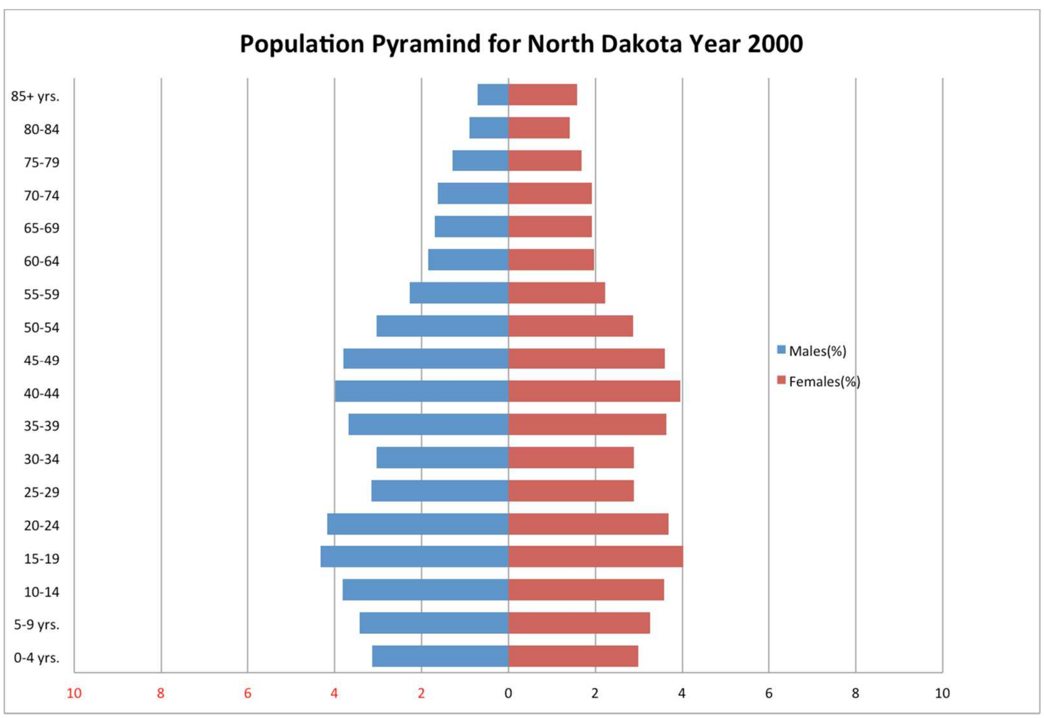

Figure 3. Population pyramid for North Dakota for the year 2000. Population data from US Census Bureau (2000).

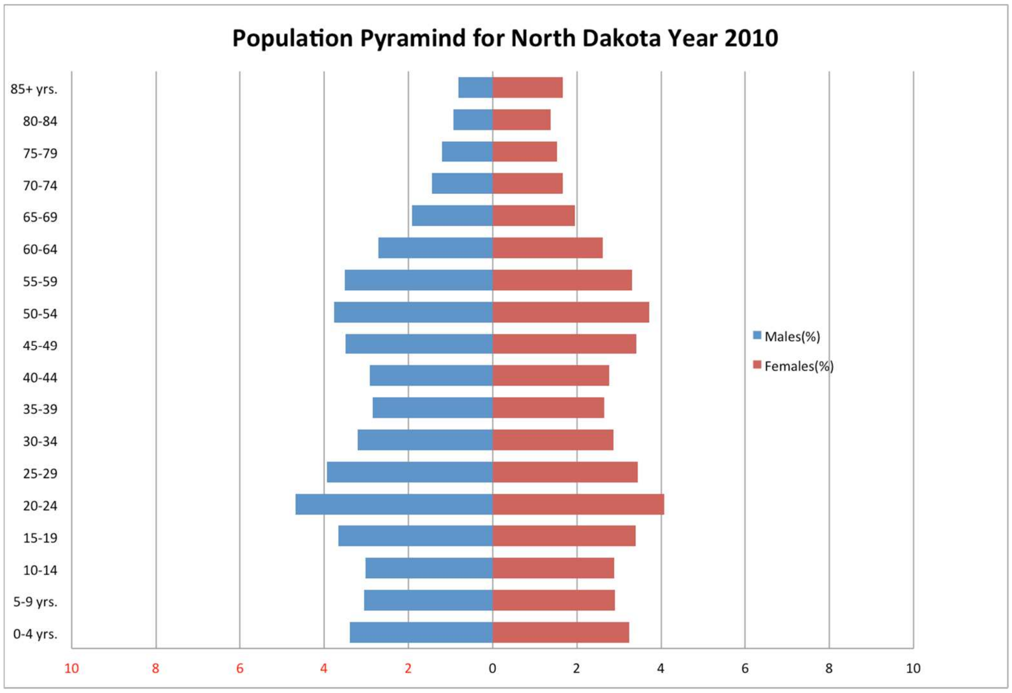

Figure 4. Population pyramid for North Dakota for the year 2010. Population data from US Census Bureau (2010).

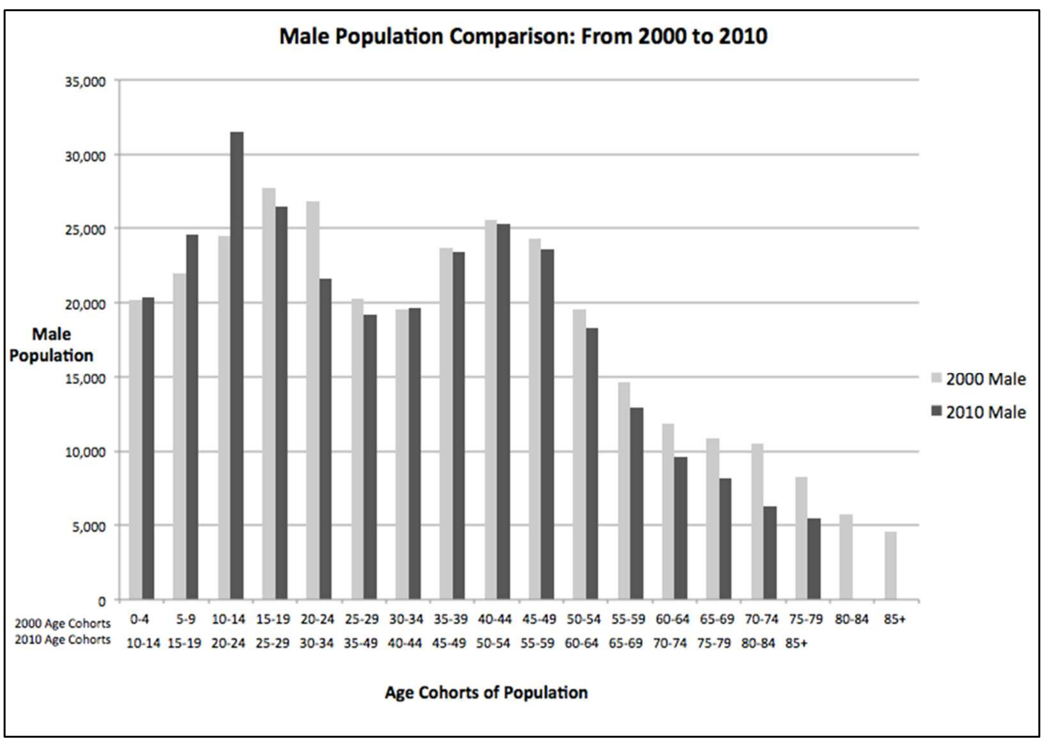

Figure 5. Side-by-side comparison of the change in North Dakota's male population between 2000 and 2010. Population data from US Census Bureau (2000), (2010).

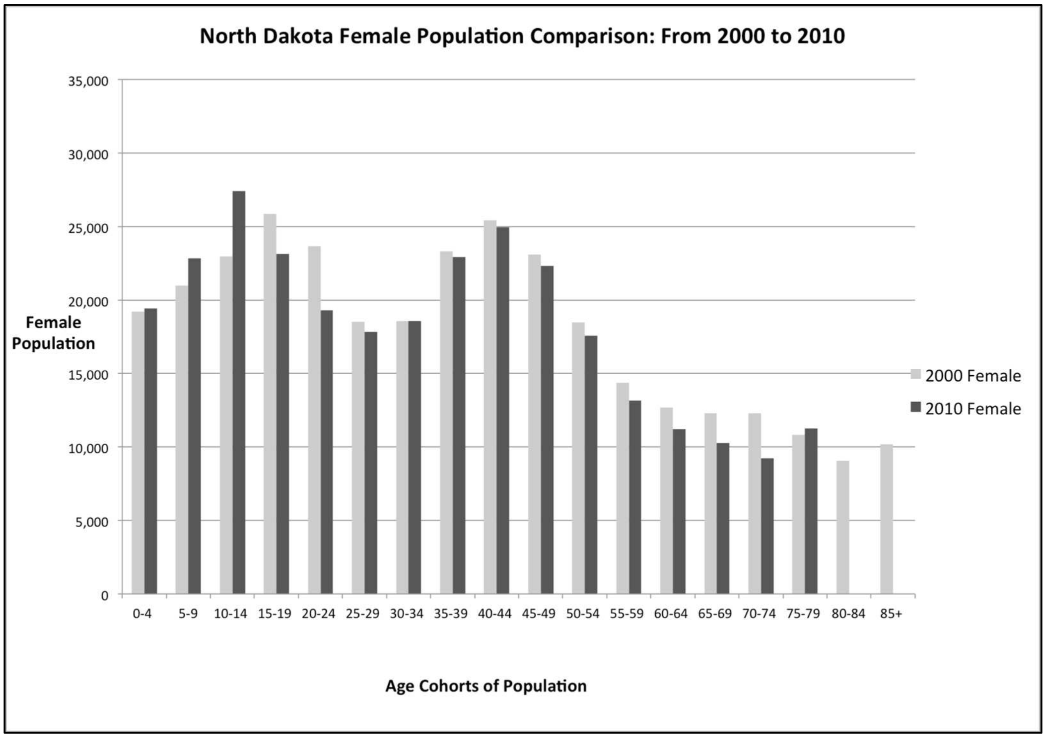

Figure 6. Side-by-side comparison of the change in North Dakota's female population between 2000 and 2010. Population data from US Census Bureau (2000), (2010).

Oil Boom Background

Located primarily in North Dakota, Montana, and Saskatchewan, and spanning over 200,000 square miles, the Bakken Formation is one of the largest continuous deposits of oil in the United States. A 2008 report by the United States Geological Survey estimated the shale to hold 3.0-4.3 billion barrels of oil, which would make it the largest oil find in US history (Institute for Energy Research [IER], 2012). These estimates are subject to growth as more exploration is done. Some more optimistic estimates go as high as predicting the existence of 24 billion barrels[4]. Ever since the discovery of techniques

[4] Estimates vary due to the relative newness of this type of extraction and exploration. Due to a widespread rumor that circulated the Internet around 2011 stating that there were actually 503 billion barrels present in the formation, public perception has become skewed. However, the US Geological Survey spoke out against this false information in an April 2008 press release in which they retracted their initial rough estimate that was given in 2006 stating that up to 500 billion barrels may be present in the formation. The 2006 study was a draft, had not been peer reviewed, and was later decreased to the more accurate 24 billion barrels. Any estimate cited as being grossly above this should be regarded as false.

that allow the fracking of the Bakken Formation, North Dakota has become the second largest oil producing state in the US, led only by Texas (IER, 2012). This type of oil extraction is known to be higher in cost[5] than traditional methods and being a relatively new method, its efficacy, sustainability, and long-term environmental impacts are unknown.

The method of extraction is called hydraulic fracturing, fracking or hydrofracking for short, and its purpose is to extract oil and natural gasses from shale rock. This is done by blasting millions of gallons of brine[6] at the shale rock formations at high pressures which releases the sought after resources from the shale rocks (Environmental Protection Agency [EPA], 2010). These fracking techniques have been relatively[7] efficient when it comes to the *initial* extraction of resources from the shale rock. But because shale oil behaves differently than conventional oil, fracking wells operate differently and are less cost effective. This is a major reason why fracking has only gained popularity in the last decade, because oil prices were high enough to cover the high cost associated with shale oil production. James Burkhard, the head of oil market research for IHS Energy, explained in an interview that the life of a fracking well is characterized by an initial burst of productivity followed by a steep decline (Tong, 2014). It can be compared to wringing out a sponge filled with water. The first time pressure is applied, a lot of liquid will come out, but subsequent attempts will produce less water. Because shale oil is trapped in rocks, and is not a pool of liquid, less oil is “wrung out” each time pressure is applied. According to Headwaters Economics, an independent nonpartisan research

[5] Costs are higher due to well productivity decreasing by almost half in the second year of production. This decreasing marginal production spawns the need for more wells to be built, raising infrastructure and labor costs, among others.
[6] Brine is a mixture of sand, water, and other unknown chemicals.
[7] When compared to conventional drilling, fracking is not as effective as it produces higher waste.

company, production from an unconventional Bakken well will decline as much as 45% in its second year (Headwaters Economics, 2011). There are multiple sources that warn against the diminishing marginal returns associated with shale oil, including Hughes (2014) and Loder (2013). The diminishing productivity has the potential to cause an artificially high demand for labor, land, and infrastructure. This "Red Queen Syndrome"[8] as it is referred to in the fields, is also known as the "Treadmill Effect" and was first introduced by Schnaiberg in 1980. When he came up with the theory he was attempting to find the root cause for the rapid increase in environmental degradation post World War II (Gould, Pellow, & Schnaiberg, 2004). His theory was that rapidly increasing amounts of available capital were being invested into new technologies that infiltrated the labor market and replaced employees while increasing profits. However, unlike the previously employed labor market, these new technologies were sunk capital once purchased so in order for firms to increase profits they had no choice but to increase production. This can be loosely applied to what is currently happening in North Dakota. To keep covering costs oil companies need to drill more wells and employ more people. The implications of which are that compared to conventional oil, more wells need to be drilled to keep up with production demand.

Intensive oil extraction drives the need for expensive enhancements to roads, water, sewer systems, as well as increases demand for public services such as police, firemen, emergency response teams, social services, and housing (Headwaters Economics, 2011). These demands lead to large gaps in the labor market, which is remedied by increasing wages in an attempt to attract workers. The workers, most of

[8] The name comes from the character of the Red Queen in "Through the Looking Glass" and the application comes from her statement to Alice that "It takes all the running that you can do, to keep in the same place" (Loder, 2013).

whom are young men with widely varying levels of education, move to the drill sites from all over the country, with the intent of making large sums of money but not necessarily becoming permanent residents. This was evidenced during the aftermath of North Dakota's last oil boom and subsequent bust, which occurred in the 1980s. Coinciding with a drastic drop in the price of a barrel of oil, the industry collapsed, the oil workers left, and the city developers were left with more property taxes on their infrastructure than they could afford to pay off. The developers were the next to leave, and the city of Williston then became responsible for around $25 million dollars of debt in lost infrastructure costs, and no tax base to pay it off (Weber, Geigle, & Barkdull, 2014). The oil workers and developers might not have a compelling reason to stay in North Dakota once the oil is gone, but what of the other migrants? Many other people have moved out west due to the increasing labor demand in other sectors, and it is hard to predict what these migrants will do if the boom turns to bust.

Migration Overview

Migration's role in the future population of North Dakota is disproportionally large when compared to the role of natural increase, and because of this, it must be paid special attention. The two figures seen below are based on the most recent set of county population estimates that the US Census Bureau has released. Figure 7 shows percent growth rates and Figure 8 shows what the primary source of the growth was due to. The majority of counties in North Dakota experiencing an increase in growth can attribute this to a net increase in migration. This net increase results from within state reallocation as well as out-of-state in-migration.

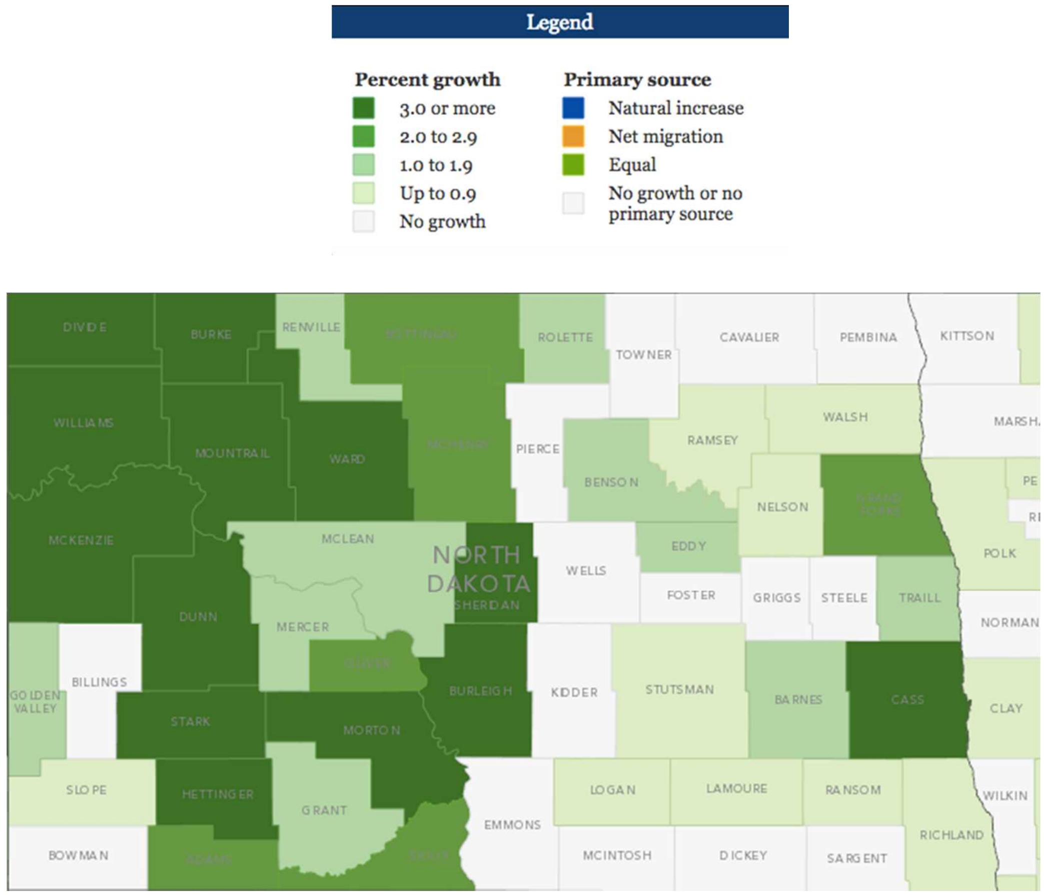

Figure 7. North Dakota percent growth rates per county for 2012-2013. Data from US Census Bureau (2014).

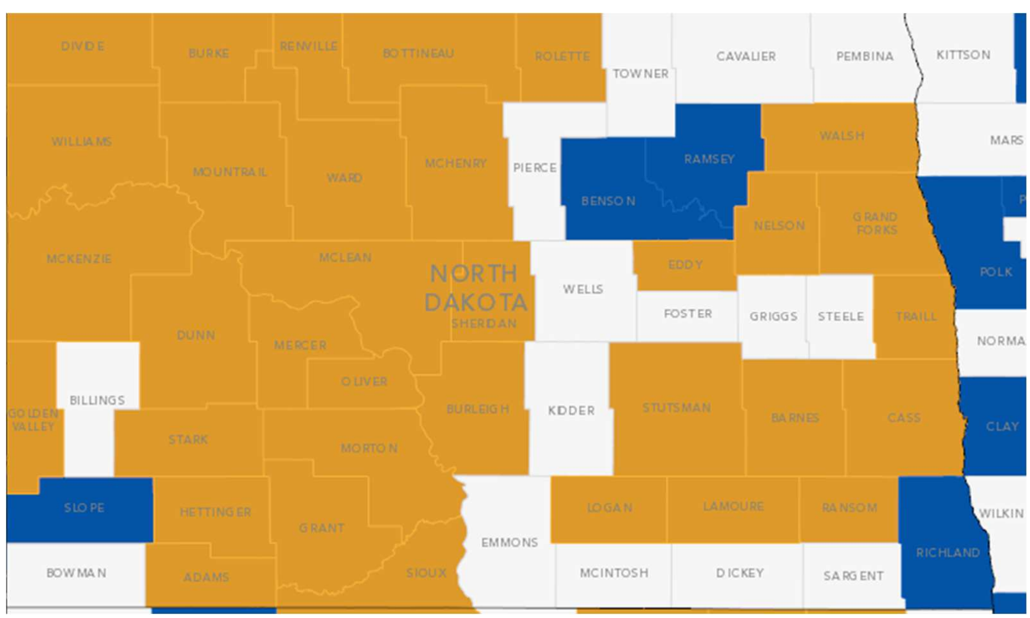

Figure 8. North Dakota primary source of growth per county for 2012-2013. Data from US Census Bureau (2014).

Figure 9 below shows a plot of North Dakota's net migration rate per year. The migration rates were derived from IRS exemption data, as is described in the methodology section. The figure shows a rapid upward trend in net migration, which would be expected during an oil boom. Unfortunately, data is not available for the 2013-2014 year. So we are not able to definitively know if the slight downward trend experienced in the 2012-2013 year was an anomaly, or if net migration has begun to reach a temporary equilibrium.

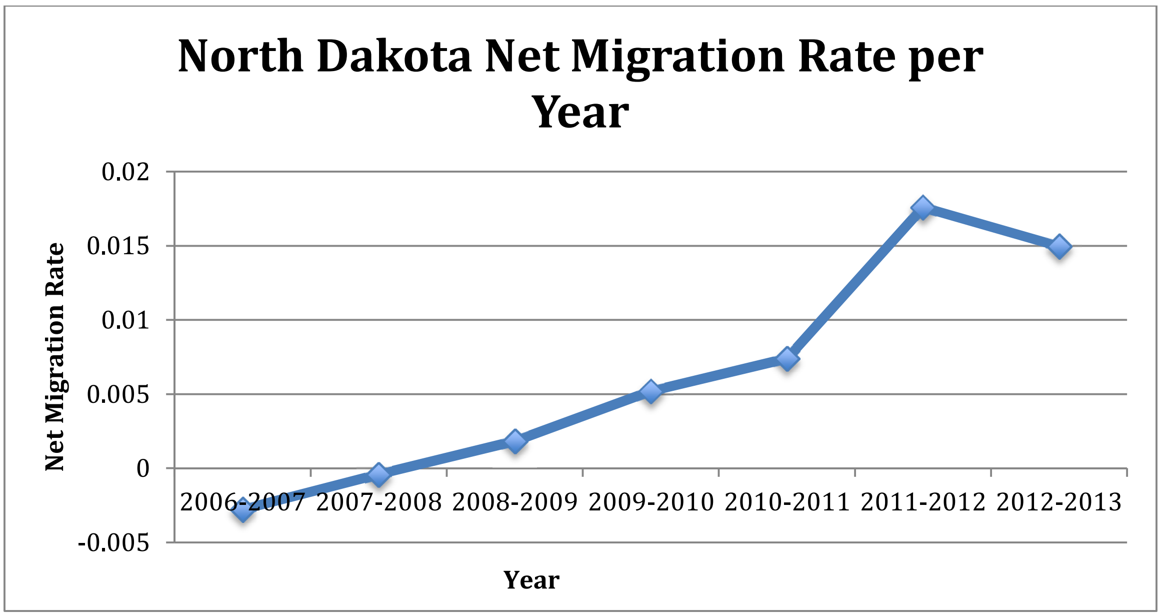

Figure 9. North Dakota's net migration rates per year. Migration data gathered from the Statistics of Income Division, International Revenue Service (2015).

Models of migration are built on the assumption that migration often occurs surrounding predictable life events such as moving for college, work, or retirement. On a large scale, the frequency of these life events is age specific, and therefore migration models are based on age (Willekens, 1999). As seen in Figure 10 below, there is a peak in migration associated with entrance into the labor force, and a second peak associated with retirement. Changes in migration are represented by an upward or downward shift in the in the level of the entire curve, but, under normal circumstances, the general shape of the curve does not change (Kale, Egan-Robertson, Palit, & Voss, 2005). The question then becomes, does an oil boom fall under the umbrella of a normal circumstance? Or will such an event not only change the levels of the migration curves, but also the shape of the distribution? Migration during an oil boom is unevenly distributed. The proportion of migrants that are young men increases more rapidly than other sections of the population.

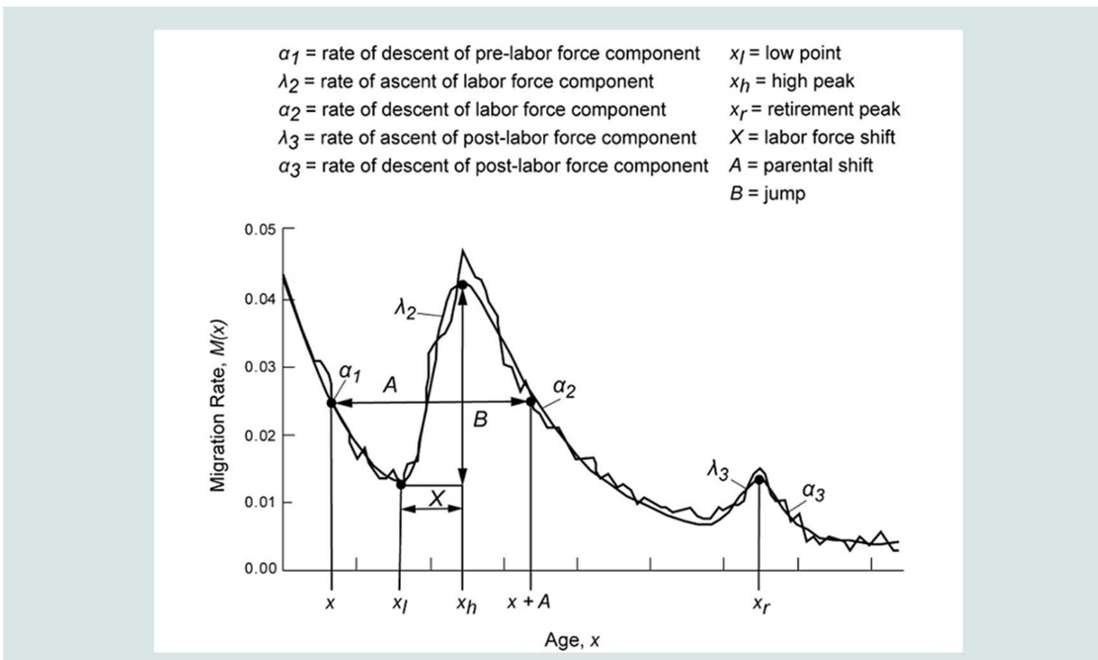

Figure 10. Migration peak schedule relative to age. Graphic from Preston et al., (2001).

In addition to this, prior to the oil boom, North Dakota's migration curve may very well have already presented with a different shape than that of the model. One of the leading trends that influenced North Dakota's past population demographics was an increasing proportion of elderly people, one of which is comparatively higher than that of other states. From the years of 1980 to 2000, the percent of the population base that was 65 or older increased from 12.3% to 14.7% (Rathge et al., 2002). In 2000, the national average was only 12.4% (Rathge et al., 2002). And as stated earlier in this thesis, as of 2012, North Dakota has the highest number of centenarians per population than any other state. It has been theorized that this increase in the elderly population would only become greater as the baby-boomer population aged and the elderly population continued moving back to their North Dakota home to be closer to family and friends. The result of which is historically higher than average migration rates of the elderly population.

Currently, the leading trend influencing North Dakota's population change is labor force migration. In 2005, Black, McKinnish, and Sanders examined the various impacts of the coal boom and bust that occurred in Appalachia in the 1970s and 1980s. They found that while there is not only an increase in the in-migration of the working-age men population, there is increased out-migration that is experienced by other age-groups in the population. Has the oil boom had any affect on the net migration of the elderly population? Anecdotal evidence from out west would say yes, it has had a great one, displacing families from their homes as they find themselves unable, or unwilling, to keep up with the rapid inflation. The inflation coupled along with rising crime rates, insufficient housing, infrastructure, medical care, schools, and insurmountable feelings regarding a decrease in general quality of life all influence a person's desire to stay. Changes in Medicare enrollment for the state may aid in developing a better understanding of the elderly population migration, past and present.

As with most consumer decisions, the decision to migrate can be viewed as a utility maximizing decision. The individual will choose a location based on the maximization of such things as local earnings, amenities, and the cost of moving. This model of migrant decision, called the Roy Model, formulates the basis of much migration research (Heckman & Honore, 1990). There is more that goes into the decision to move, such as distance from extended family, the utility of a spouse if the migrant has one, or the potential of finding a spouse in the new location. But the Roy Model provides a stable basis. Vachon (2015) builds on this model of utility maximization and develops a model of worker migration dependent on exogenous increases in earnings that are derived from demand shocks in the labor market. She concludes that the oil boom in North Dakota led to approximately a 2.6 percentage point increase in the net migration rate for oil producing counties in North Dakota (Vachon, 2015). However, the paper only examines permanent migration, and temporary migration might make up for a much larger portion of in-migrants. In any regard, a positive relationship does exist between areas with high levels of oil reserves and changes in net migration (Vachon, 2015)

CHAPTER III

DATA AND METHODOLOGY

Base population data for the state of North Dakota was obtained from both the 2000 and 2010 statewide census. These are often considered to be more reliable than the in between year estimations, even though these estimations are closer to the point of time of interest, the year of the oil boom. Both datasets were organized by 5-year age cohorts as well as by sex. North Dakota's birth data was gathered from the Center for Disease Control Vital Stats System. In the dataset, for the years 2000-2013 total births were divided up by the sex of the child as well as by the age of the mother. Initial mortality data was obtained from the Center for Disease Control using the Wonder platform. Total deaths were in 5-year age cohorts and separated by age and sex. Death and survival rates were calculated using a standard life table. Tax exemption data used in the calculation of migration rates was collected from the Statistics of Income Division in the International Revenue System for the years of 2006 through 2013. The data was provided in separate files of migration inflows and outflows for all of the 50 states, so North Dakota's data was pulled out and aggregated into a new data file. Medicare enrollment data for North Dakota was gathered from the Center for Medicare and Medicaid Services website for the years of 2009 through 2012, no other years were available. The data was provided for all of the 50 states, so North Dakota's data was pulled and aggregated into a new file.

Table 1: Sources for Variables

Variable	Source	Organization of Data
Base Population, P_x	US Census Bureau	5-year age cohorts, sex
Age-Specific Fertility Rate ($ASFR$) Derived from North Dakota Births, 2010	Center for Disease Control Vital Stats System	5-year age cohorts, sex of the child
Survival Rate (q_x) Derived from North Dakota Deaths 2009, 2010, 2011	Center for Disease Control, Wonder Platform	5-year age cohorts except infant mortality, sex
Net Migration Rate (NDM) Derived from Tax Exemption Data 2006-2013	Statistics of Income Division, IRS	Separated by state and year
Change in Migration for Elderly Population Derived From Medicare Enrollment, Years 2009-2012	Center for Medicare and Medicaid Services	Separated by enrollment status for all 50 states (A and/or B, A and B, A only, B only)

The model used in the population projection is The Cohort Component Method. It is a discrete-time model, and works by separating the population by age and sex into subgroups, which have varying exposure to fertility, mortality, and migration. In demographic terms, fertility refers to the number of live births that a woman has had, mortality refers to the number of deaths experienced by the population, and migration is the net effect of immigration minus emigration (Newell, 1988). The basic idea behind the Cohort Component Method can be explained by this simple equation:

$$P_{t+1} = P_t + Births - Deaths + Immigrants - Emigrants$$

where P_{t+1} is the population at time t+1, and P_t is the population at time t. The above equation shows the individual components of the future population change and provides the basis for our projection. Births minus deaths is referred to as natural increase, and immigrants minus emigrants is the net migration rate, which can be negative or positive depending on migration flows.

The basics of the projections are as follows: We start with a base population, obtained from 2010 Census figures. Next we age that base population 5 years into the future by using survival rates obtained from a life table. Once the population is aged, births are added in by applying age-specific fertility rates to the number of women in a reproductive period. This will give us the number of expected births during the year which will be modified to fit into the 5 year period of the projection period. Lastly, migration is added in. Once the first 5 years are complete, the next 5 years will be projected.

Survival Rates

Death and survival rates were calculated using abridged, 5-year, cohort, period life tables, which can be seen in Tables 2 and 3. The life tables were calculated using 3-year averages of death statistics surrounding the 2010 Census. This was done to help control for irregularities in any specific year. In the life tables: x=the age of the individuals at the beginning of the interval, n=the width of the age-intervals, and a_x = the proportion of the interval lived by those that die. These values are derived from reference populations and are all set to 0.5 except for in the case of the 0-1 age cohort, where $a_{0-1} = 0.1$. The equations used in the construction of the life tables are commonly found in much of the existing literature regarding life table construction, including Preston et al., (2001), and Newell (1988).

Figure 11 below shows a graphic representation of a timeline for the specific age-intervals used in the life tables. Figure 11 shows that the intervals include the full years listed in the age range. For example, Interval 2, Age 1 through 4, would include the years 1, 2, 3, and 4 up until 5, but not including 5. The width of the age interval, n=4, is then made obvious. Interval 3, Age 5 through 9, would include the years 5, 6, 7, 8, and 9 up until 10, but not including 10.

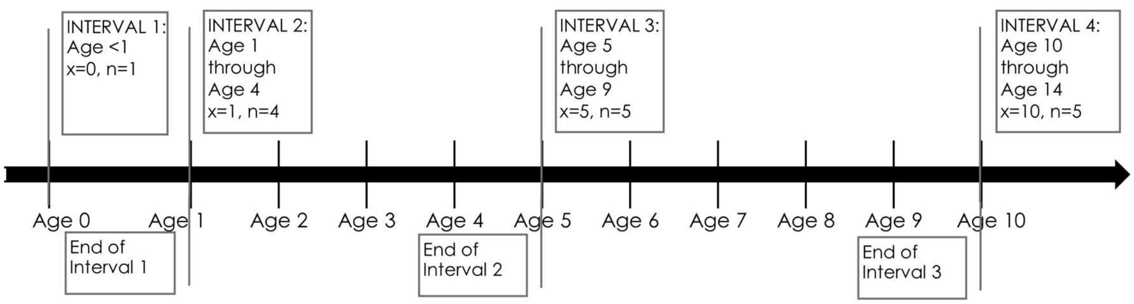

Figure 11. Graphic representation of age-interval timeline.

The first calculated column in the life table is the age specific death rate:

$$M_x = D_x / P_x \tag{1}$$

Where M_x is the age specific death rate, D_x is population Deaths at age x averaged over a 3-year period, and P_x is the Population age x at midyear. We then assume that $M_x = {}_n m_x$ where M_x measures the observed population values and ${}_n m_x$ refers to the life-table values. The probability of a person surviving an age interval dying in the current age interval is:

$${}_n q_x = \frac{n({}_n m_x)}{1 + n(1 - {}_n a_x)({}_n m_x)} \tag{2}$$

Where the subscript n refers to the width of the age-interval for the age-cohort that is being examined. For example females age 20-24 where n=5 and x=20 would be:

$${}_5 q_{20} = \frac{5({}_5 m_{20})}{1 + 5(1 - {}_5 a_{20})({}_5 m_{20})}$$

The probability of a person entering the age interval surviving the age interval is:

$${}_{n}p_{x} = 1 - {}_{n}q_{x} \tag{3}$$

i.e., the probability of survival during the age interval is 1 minus the probability of dying during the age interval. Person years lived between age x and x+n is:

$$l_{x+n} = {}_{n}p_{x} * l_{x} \tag{4}$$

with l_0= 100,000

The value of 100,000 is defined as the radix, and the numerical value of it is arbitrary. Changing the value will merely change the scale of the remaining life table columns, and it has no relation to the size of the population itself. The number of life table deaths is:

$${}_{n}d_{x} = l_{x} - l_{x+n} \tag{5}$$

i.e., life table deaths between age x and age x+n is equal to the difference between the number of survivors to age x and the number of survivors to age x+n. The number of person-years lived between x and x+n is:

$${}_{n}L_{x} = nl_{x+n} + {}_{n}a_{x}\,{}_{n}d_{x} \tag{6}$$

The sum of person-years lived after age x is:

$$T_{x} = \sum_{a=x}^{\infty} {}_{n}L_{a} \tag{7}$$

The average number of years a person at age x will live is:

$$e_{x} = \frac{T_{x}}{l_{x}} \tag{8}$$

i.e., the number of person-years that will be lived above the age at the beginning of the interval divided by the number of people that will live them.

Open-ended age intervals have to be dealt with differently than closed age intervals. This is especially important in a state like North Dakota where there are high numbers of elderly people entering into these intervals. A standard life table would commonly have 80+ as the last age interval, but for our purposes, two more age intervals were added, and 90+ is the open interval. In this interval, n=∞, therefore: $\infty q_x = 1.00$ $\infty p_x = 0.00$, and the equation for person years lived (6) becomes:

$$\infty L_x = l_x / \infty m_x \tag{9}$$

Data values for mortality are so small in North Dakota that it is not uncommon for data to be suppressed within specific age cohorts. This is especially true in younger age categories, such as those ages: 1-4, 5-9, and 10-14. Because of this data suppression, missing values were calculated by applying nation-wide age and sex specific death statistics to the total North Dakota deaths, which resulted in values that fit well within the data that was already known. This method resulted in a complete dataset with no missing values.

Table 2. Life Table for North Dakota Females, 2010

Age Interval	x	n	a_x	Female Population 2010	Female Deaths (2009, 2010, 2011)	M_x	q_x	p_x	l_x	d_x	L_x	T_x	e_x
<1	0	1	0.1	4,339	28	0.006530	0.0064918	0.993508	100000	649	99416	8241879	82.42
1-4	1	4	0.5	17,435	3	0.000191	0.0007645	0.999236	99351	76	397251	8142463	81.96
5-9	5	5	0.5	19,556	3	0.000136	0.0006816	0.999318	99275	68	496205	7745211	78.02
10-14	10	5	0.5	19,429	2	0.000103	0.0005146	0.999485	99207	51	495908	7249006	73.07
15-19	15	5	0.5	22,848	10	0.000438	0.0021860	0.997814	99156	217	495239	6753098	68.11
20-24	20	5	0.5	27,426	11	0.000389	0.0019427	0.998057	98939	192	494217	6257859	63.25
25-29	25	5	0.5	23,145	10	0.000446	0.0022298	0.997770	98747	220	493186	5763642	58.37
30-34	30	5	0.5	19,288	18	0.000916	0.0045692	0.995431	98527	450	491510	5270457	53.49
35-39	35	5	0.5	17,856	21	0.001157	0.0057703	0.994230	98077	566	488969	4778947	48.73
40-44	40	5	0.5	18,580	25	0.001346	0.0067051	0.993295	97511	654	485920	4289978	43.99
45-49	45	5	0.5	22,919	49	0.002138	0.0106330	0.989367	96857	1030	481711	3804058	39.27
50-54	50	5	0.5	24,971	66	0.002643	0.0131286	0.986871	95827	1258	475991	3322348	34.67
55-59	55	5	0.5	22,312	88	0.003944	0.0195278	0.980472	94569	1847	468229	2846357	30.10
60-64	60	5	0.5	17,573	113	0.006449	0.0317348	0.968265	92722	2943	456256	2378128	25.65
65-69	65	5	0.5	13,126	145	0.011072	0.0538697	0.946130	89780	4836	436808	1921873	21.41
70-74	70	5	0.5	11,210	199	0.017782	0.0851246	0.914875	84943	7231	406640	1485064	17.48
75-79	75	5	0.5	10,243	278	0.027173	0.1272226	0.872777	77713	9887	363846	1078424	13.88
80-84	80	5	0.5	9,234	427	0.046206	0.2071063	0.792894	67826	14047	304011	714578	10.54
85-89	85	5	0.5	6,483	536	0.082626	0.3424030	0.657597	53779	18414	222859	410567	7.63
90+	90		0.5	4,754	896	0.188403	1.0000000	0.000000	35365	35365	187708	187708	5.31

Table 3. Life Table for North Dakota Males, 2010

Age Interval	x	n	a_x	Male Population 2010	Male Deaths (2009, 2010, 2011)	M_x	q_x	p_x	l_x	d_x	L_x	T_x	e_x
<1	0	1	0.1	4,592	31	0.006751	0.0067101	0.993290	100000	671	99396	7689383	76.89
1-4	1	4	0.5	18229	5	0.000256	0.0010235	0.998977	99329	102	397113	7589987	76.41
5-9	5	5	0.5	20520	4	0.000195	0.0009742	0.999026	99227	97	495895	7192874	72.49
10-14	10	5	0.5	20361	4	0.000180	0.0009000	0.999100	99131	89	495430	6696979	67.56
15-19	15	5	0.5	24626	26	0.001056	0.0052651	0.994735	99041	521	493904	6201549	62.62
20-24	20	5	0.5	31530	36	0.001142	0.0056926	0.994307	98520	561	491198	5707645	57.93
25-29	25	5	0.5	26451	30	0.001134	0.0056548	0.994345	97959	554	488411	5216448	53.25
30-34	30	5	0.5	21601	34	0.001574	0.0078392	0.992161	97405	764	485117	4728037	48.54
35-39	35	5	0.5	19209	30	0.001544	0.0076924	0.992308	96642	743	481350	4242920	43.90
40-44	40	5	0.5	19617	56	0.002872	0.0142559	0.985744	95898	1367	476073	3761570	39.22
45-49	45	5	0.5	23461	92	0.003936	0.0194863	0.980514	94531	1842	468050	3285497	34.76
50-54	50	5	0.5	25306	128	0.005058	0.0249746	0.975025	92689	2315	457658	2817446	30.40
55-59	55	5	0.5	23634	173	0.007334	0.0360101	0.963990	90374	3254	443735	2359788	26.11
60-64	60	5	0.5	18300	207	0.011330	0.0550881	0.944912	87120	4799	423601	1916053	21.99
65-69	65	5	0.5	12902	227	0.017594	0.0842644	0.915736	82321	6937	394261	1492453	18.13
70-74	70	5	0.5	9635	255	0.026466	0.1241178	0.875882	75384	9356	353528	1098192	14.57
75-79	75	5	0.5	8125	363	0.044718	0.2011070	0.798893	66027	13279	296940	744664	11.28
80-84	80	5	0.5	6314	464	0.073487	0.3104094	0.689591	52749	16374	222810	447723	8.49
85-89	85	5	0.5	3700	442	0.119459	0.4599376	0.540062	36375	16730	140050	224914	6.18
90+	90		0.5	1,751	405	0.231487	1.0000000	0.000000	19645	19645	84864	84864	4.32

Fertility Rates

In demographic terms, fertility is defined as the number of live births divided by a measure of the population. It should be noted that this definition is different than the frequently used definition of fertility referring to a woman's ability to conceive a child, which is an individualized definition. Birth data was used to construct an Age Specific Fertility Rate (ASFR).

$$ASFR = \frac{Number\ of\ Live\ Births\ to\ Women\ Aged\ x}{Midyear\ Female\ Population\ Aged\ x} * 1000 \qquad (10)$$

For the age cohorts of 10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, and 50-54 the rate was calculated per 1000 women. The ASFR was used to calculate a 5-year fertility rate, which was then applied to the base population capable of giving birth (specific age-cohorts in the female population) which estimates the births that would occur in 5 years. The Baby Sex Ratio is the number of male babies per 100 female babies, and is as follows:

$$Baby\ Sex\ Ratio = \frac{\sum 2010\ Male\ Babies}{\sum 2010\ Female\ Babies} * 100 \qquad (11)$$

For 2010, The Baby Sex Ratio was approximately 104. This ratio is used to separate the total births into categories of male and female. The total number of babies born separated by sex then becomes the 2015 under 5 years of age cohort in the projection table. This method is not without it's limitations, because realistically it takes a male and female pair to conceive a child, and this method only takes the female population into account. The same method is then used for the next 5 years of the projection interval.

Table 4: Calculated Age-Specific Fertility Rates for North Dakota Women, 2010

Age Interval of Mother	Aggregated Live Births	Midyear Female Population	ASFR	One Year Fertility Rates	Five Year Fertility Rates	Projected Babies in 5-Years
10-14 years	7	19,429	0.360	0.0003	0.002	35
15-19 years	659	22,848	28.843	0.029	0.144	3295
20-24 years	2155	27,426	78.575	0.079	0.393	10775
25-29 years	3298	23,145	142.493	0.142	0.712	16490
30-34 years	2119	19,288	109.861	0.110	0.549	10595
35-39 years	726	17,856	40.659	0.041	0.203	3630
40-44 years	129	18,580	6.943	0.007	0.035	645
45-49 years	11	22,919	0.480	0.0004	0.002	55
50-54 years	0	24,971	0	0	0	0
						Total
						45520

Data Source: Center for Disease Control Vital Stats System

Migration

Migration analysis was done using both direct and indirect methods. With migration being one of the harder aspects of the population equation to model, the more analysis that is done, the better fit the projection will be. In populations with high life expectancy and low fertility, mortality and fertility rates are easier to predict, and a miscalculation will not have as drastic of an effect on a projection as a miscalculation in migration would (Kale et al., 2005). In contrast to this, a miscalculation in migration could have far greater consequences to model accuracy (Greenwood, 2005).

Indirect Methods

Migration was computed indirectly using forward and reverse survival rate methods and averaging the results from the two. Both methods have their limitations, but direct measures are also not without difficulties. The forward method assumes that all migration is taking place at the end of the period, and that all deaths during the period are to non-migrants (Kale et al., 2005). However, this is not completely accurate, as deaths do occur within the migrant population, especially in dangerous job conditions, such as those that oilrig workers often experience. The reverse method assumes that deaths occur after people migrate, which results in a larger number of net migrants. The forward method was computed by multiplying the 2000 census population by the previously derived survival rates and subtracting the 2010 census population from this. This was done for each 5-year age interval with the 2010 census population age intervals 10 years into the future from the 2000 census population intervals. The forward method is as follows:

$$m = p^t_{x+t} - e, where \quad (12)$$

$$e = s * p^0_x \quad (13)$$

where m= net migration of persons age x+t, e = the expected population absent any migration, which is the equivalent of the survival rate, s, multiplied by persons of age x at the time of the first census, and p^t_{x+t} = persons of age x+t at the time of the second census taken 10 years later.

The reverse method is as follows:

$$m = \frac{p^t_{x+t}}{s} - p^0_x \quad (14)$$

Because there was a large change in migration beginning with the oil boom in 2007, these migration numbers are not assumed to be evenly distributed between years. The analysis of IRS data, as described below, shows a rather large change in net migration rates after the year 2006 up to present years.

Direct Methods

Migration was computed using data from the Internal Revenue System, specifically the Statistics of Income Division (SOI). The IRS database has detailed accounts of changes in tax exemptions from year to year, which approximate the number of individuals. This data is based on the year-to-year address changes that are reported on an individual's tax returns during two consecutive years (Pierce, 2015). Prior to 2011, migration data was only based on a partial year of data (the income tax returns filed before September), and did not include information regarding the age of the taxpayer. It is estimated that around 4% of the population files their taxes after the September deadline, therefore their absence in the migration data contributes to a potential bias of the data (Pierce, 2015). Also contributing to potential inaccuracy is if the taxpayer is maintaining a dual residence, filing taxes in one location but primarily residing in another. This may be a problem especially relevant to North Dakota, as all migrant workers may not establish residency in North Dakota and may instead travel back and forth between their work site and home site.

It is essential to remember that not everyone files taxes and therefore this data is not able to capture every member of the migrant population with complete accuracy. Those that are not required to submit Federal Tax Returns such as the poor or elderly, will not be represented in the data (Gross, 2006). A net migration rate was calculated using the same methodology as used in the US Census Bureau's population projection. Net migration is calculated by subtracting the number of out-migrant exemptions from the number of in-migrant exemptions and dividing by the number of non-migrant exemptions plus the out-migrant exemptions (US Census Bureau, 2014).

$$NDM = \frac{In\ Migrants - Out\ Migrants}{Non-Migrants + Out\ Migrants} \tag{15}$$

Table 5: Calculation of North Dakota Net Migration Rates, Total Population, 2006-2013

	In-Migrants (Exemptions)	Non-Migrants	Out-Migrants	In Migrants -Out Migrants	Non Migrants +Out Migrants	Net Migration Rate
2012-2013	34,705	549,746	26,085	8,620	575,831	0.015
2011-2012	31,739	539,483	21,866	9,873	561,349	0.018
2010-2011	23,261	537,412	19,145	4,116	556,557	0.007
2009-2010	20,333	534,299	17,468	2,865	551,767	0.005
2008-2009	19,562	533,895	18,549	1,013	552,444	0.002
2007-2008	18,029	530,106	18,260	-231	548,366	-0.0004
2006-2007	17,599	517,666	19,093	-1,494	536,759	-0.003

Data Source: Statistics of Income Division, IRS

Migration flows in some areas of the labor market can be disproportionate between men and women, and because of this, it may be difficult to disaggregate net migration by sex (Newell, 1988). This is likely the case in North Dakota, because there are more male migrant workers than female. The aggregated net migration rates were disaggregated by total age and sex using a technique developed by Kale et al. (2005). First, the total numbers of migrants were divided into male and female categories using observed sex ratios. These sex ratios are much different than the average country ratios because the majority of migrant workers are male. In 2014, the US Census Bureau estimated an average sex ratio in North Dakota of 105 males to 100 females, while the national average was reported as being 97 males to 100 females (Cicha, 2015). The difference is even larger in the age range of 20-24 year olds where there are approximately 118 males for every 100 females in the state. Also contributing to the "flipped" sex ratio is the fact that the older generations of North Dakotans, those in the 65+ age bracket, have been experiencing higher than average out-migration levels, and this age bracket is more densely female, as males tend to die at earlier ages (Cicha, 2015).

As Figure 12 below shows, the majority of the counties in the state in 2010 had a higher percent male than female, and this uneven sex distribution has become more prominent.

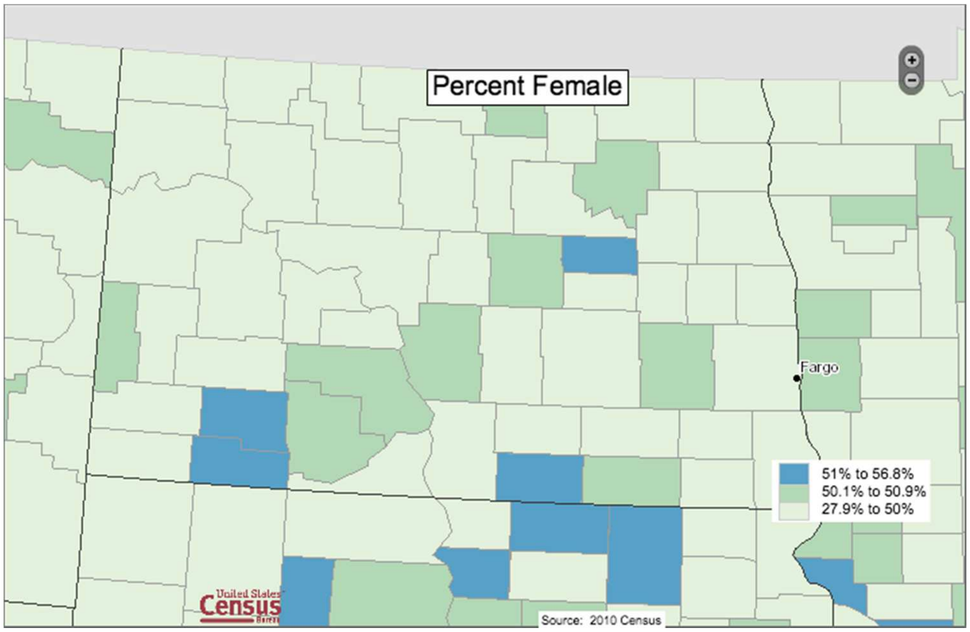

Figure 12. Geographic representation of North Dakota's skewed sex ratio. Data from US Census Bureau, (2010).

A first look at the migration data shows negative net migration in the 2006-2007 year as well as the 2007-2008 year. In the 2008-2009 year net migration becomes positive and shows an increase in every consecutive year after that. When an economy experiences an up-swing or down-swing, there is a time lag between the event and the reaction of the population affected (Kale et al., 2005). So it is not surprising to see that the change in net migration took a 2-year period to move from negative to positive. Overall there is a trend of increased net migration that is approximately 1.9% every 5 years. This number was calculated through a combination of the indirect and direct methods described above.

CHAPTER IV

RESULTS

The overall projection results for the years 2015 and 2020 are shown in Table 6 below. The population estimates are slightly lower than what has been predicted by the US Census Bureau, but follow the same general trend of rapid increase and the population breaking 800,000 sometime around the year 2017-2018 year. Tables 7 and 8 show more detailed projection results.

Table 6. Projection Results for Total Population

	Total Population			
Age Interval	2000	2010	2015	2020
1-4 years	39,400	44,595	49,404	49,477
5 to 9 years	42,982	40,076	48,540	53,856
10 to 14 years	47,464	39,790	43,626	52,921
15 to 19 years	53,618	47,474	43,281	47,418
20 to 24 years	50,503	58,956	51,528	47,038
25 to 29 years	38,792	49,596	63,963	55,994
30 to 34 years	38,095	40,889	53,750	69,345
35 to 39 years	46,991	37,065	44,238	58,245
40 to 44 years	51,013	38,197	40,087	47,749
45 to 49 years	47,436	46,380	41,092	43,070
50 to 54 years	37,995	50,277	49,701	43,971
55 to 59 years	28,926	45,946	53,553	52,715
60 to 64 years	24,507	35,873	48,355	55,888
65 to 69 years	23,142	26,028	36,951	49,092
70 to 74 years	22,759	20,845	25,954	36,081
75 to 79 years	19,085	18,368	19,853	23,676
80 to 84 years	14,766	15,548	15,920	16,138
85 to 89 years	9,455	10,183	11,360	10,515
90 years and over	5,271	6,505	8,805	9,365
Total	642,200	672,591	749,959	822,553

Table 7. Projection Results for North Dakota Female Population

Age Intervals	2010 Base Population[1]	2010 Survival Rates[2]	Age Intervals	2015 Aged Population[3]	2015 Survivors[5]	2015 Survivors +Migrants[6]	2020 Aged Population	2020 Survivors	2020 Survivors +Migrants
0-1 years	4,339	0.993508	0-4 years	22,314[4]	22,233	24,236	22,314	22,233	24,248
1-4 years	17,435	0.999236	5 to 9 years	21,774	21,759	23,720	24,236	24,220	26,415
5 to 9 years	19,556	0.999318	10 to 14 years	19,556	19,546	21,307	23,720	23,708	25,857
10 to 14 years	19,429	0.999485	15 to 19 years	19,429	19,387	21,133	21,307	21,261	23,188
15 to 19 years	22,848	0.997814	20 to 24 years	22,848	22,804	24,858	21,133	21,092	23,004
20 to 24 years	27,426	0.998057	25 to 29 years	27,426	27,365	29,831	24,858	24,803	27,051
25 to 29 years	23,145	0.997770	30 to 34 years	23,145	23,039	25,115	29,831	29,694	32,386
30 to 34 years	19,288	0.995431	35 to 39 years	19,288	19,177	20,905	25,115	24,970	27,234
35 to 39 years	17,856	0.994230	40 to 44 years	17,856	17,736	19,334	20,905	20,765	22,647
40 to 44 years	18,580	0.993295	45 to 49 years	18,580	18,382	20,039	19,334	19,129	20,863
45 to 49 years	22,919	0.989367	50 to 54 years	22,919	22,618	24,656	20,039	19,776	21,568
50 to 54 years	24,971	0.986871	55 to 59 years	24,971	24,483	26,690	24,656	24,175	26,366
55 to 59 years	22,312	0.980472	60 to 64 years	22,312	21,604	23,551	26,690	25,843	28,185
60 to 64 years	17,573	0.968265	65 to 69 years	17,573	16,626	18,125	23,551	22,282	24,302
65 to 69 years	13,126	0.946130	70 to 74 years	13,126	12,009	13,091	18,125	16,582	18,085
70 to 74 years	11,210	0.914875	75 to 79 years	11,210	9,784	10,665	13,091	11,425	12,461
75 to 79 years	10,243	0.872777	80 to 84 years	10,243	8,122	8,853	10,665	8,457	9,223
80 to 84 years	9,234	0.792894	85 to 89 years	9,234	6,072	6,619	8,853	5,822	6,350
85 to 89 years	6,483	0.657597	90+ years	11,237	5,137	5,600	12,219	5,587	6,093
90+ years	4,754	0.457192							
Total	332,727			355,041	337,883	368,329	390,643	371,822	405,525

1: From US Census Bureau 2: From Table 2, Column p_x 3: Base population aged 5 years into the future 4: Projected births, Table 4 5: Those that survive the 5-year period 6: Those that survived the 5-years period plus the net migrant population, becomes 2015 Base Population.

Table 8. Projection Results for North Dakota Male Population

Age Intervals	2010 Base Population[1]	2010 Survival Rates[2]	Age Intervals	2015 Aged Population[3]	2015 Survivors[5]	2015 Survivors +Migrants[6]	2020 Aged Populatio n	2020 Survivors	2020 Population +Migrants
0-1 years	4,592	0.993290	0-4 years	23,206[4]	23,116	25,167	23,206	23,116	25,229
1-4 years	18,229	0.998977	5 to 9 years	22,821	22,798	24,820	25,167	25,143	27,440
5 to 9 years	20,520	0.999026	10 to 14 years	20,520	20,500	22,319	24,820	24,798	27,064
10 to 14 years	20,361	0.999100	15 to 19 years	20,361	20,343	22,147	22,319	22,201	24,230
15 to 19 years	24,626	0.994735	20 to 24 years	24,626	24,496	26,670	22,147	22,021	24,034
20 to 24 years	31,530	0.994307	25 to 29 years	31,530	31,351	34,132	26,670	26,519	28,942
25 to 29 years	26,451	0.994345	30 to 34 years	26,451	26,301	28,635	34,132	33,864	36,959
30 to 34 years	21,601	0.992161	35 to 39 years	21,601	21,432	23,333	28,635	28,415	31,011
35 to 39 years	19,209	0.992308	40 to 44 years	19,209	19,061	20,752	23,333	23,000	25,102
40 to 44 years	19,617	0.985744	45 to 49 years	19,617	19,337	21,053	20,752	20,348	22,208
45 to 49 years	23,461	0.980514	50 to 54 years	23,461	23,004	25,045	21,053	20,527	22,403
50 to 54 years	25,306	0.975025	55 to 59 years	25,306	24,674	26,863	25,045	24,143	26,349
55 to 59 years	23,634	0.963990	60 to 64 years	23,634	22,783	24,804	26,863	25,383	27,703
60 to 64 years	18,300	0.944912	65 to 69 years	18,300	17,292	18,826	24,804	22,714	24,790
65 to 69 years	12,902	0.915736	70 to 74 years	12,902	11,815	12,863	18,826	16,489	17,996
70 to 74 years	9,635	0.875882	75 to 79 years	9,635	8,439	9,188	12,863	10,276	11,215
75 to 79 years	8,125	0.798893	80 to 84 years	8,125	6,491	7,067	9,188	6,336	6,915
80 to 84 years	6,314	0.689591	85 to 89 years	6,314	4,354	4,740	7,067	3,817	4,165
85 to 89 years	3,700	0.540062	90+ years	5,451	2,944	3,205	7,945	2,998	3,272
90+ years	1,751	0.377317							
Total	339,864			363,070	350531	381,630	404,836	382,109	417,029

1: From US Census Bureau 2: From Table 3, Column p_x 3: Base population aged 5 years into the future 4: Projected births, Table 4 5: Those that survive the 5-year period 6: Those that survived the 5-years period plus the net migrant population, becomes 2015 Base Population.

These results show an increase in every age interval in the population. This increase is mostly due to an increase in net migration. The increase in migration was leveled out at ~1.9% per year interval. This rate is less than what Vachon (2015) predicted, which was an increase of ~2.6%. The difference is most likely due to the fact that our rate was a statewide rate while Vachon (2015) developed a rate that was only for oil producing counties. Therefore, intuitively it makes sense that our percent increase is less than what Vachon (2015) found. The percent increase in net migration is held constant throughout the prediction period because it cannot continue to increase indefinitely, at some point it will stabilize as the demand for jobs begins to slowly decrease. This is reported to have already begun in 2015 when the economy experienced a drastic drop in the price of a barrel of oil, and the price dipped below the cutoff for profitability.

Along with the increase in population, there is a continued change in the demographic make-up of the population. This can be seen in Figure 13 below. Figure 13 is a population pyramid based on the projection results from this thesis. In order to see the large changes that are expected to occur in the demographic make-up of the state, it can be compared to Figure 14, which is a population pyramid of the 2020 projections that NDSDC had completed, before the occurrence of the oil boom. The shapes of the two pyramids are vastly different, which can be attributed to the changes in the make-up of the population due to the influx in migration.

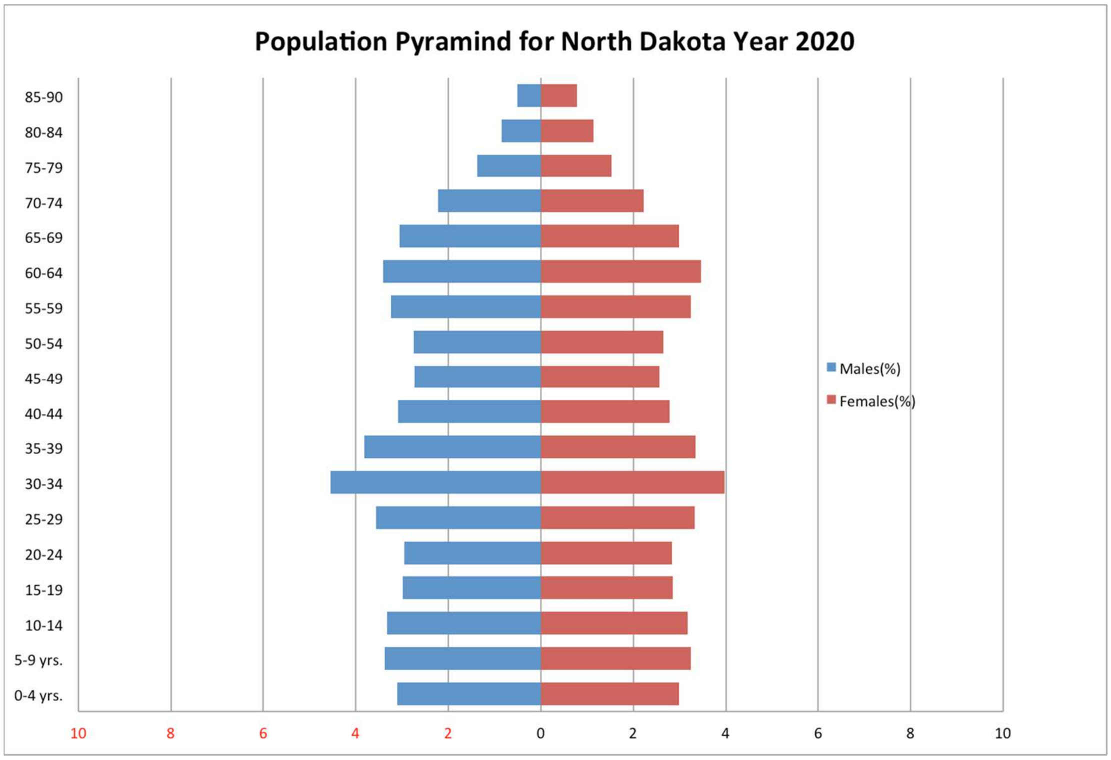

Figure 13. North Dakota population pyramid for year 2020.

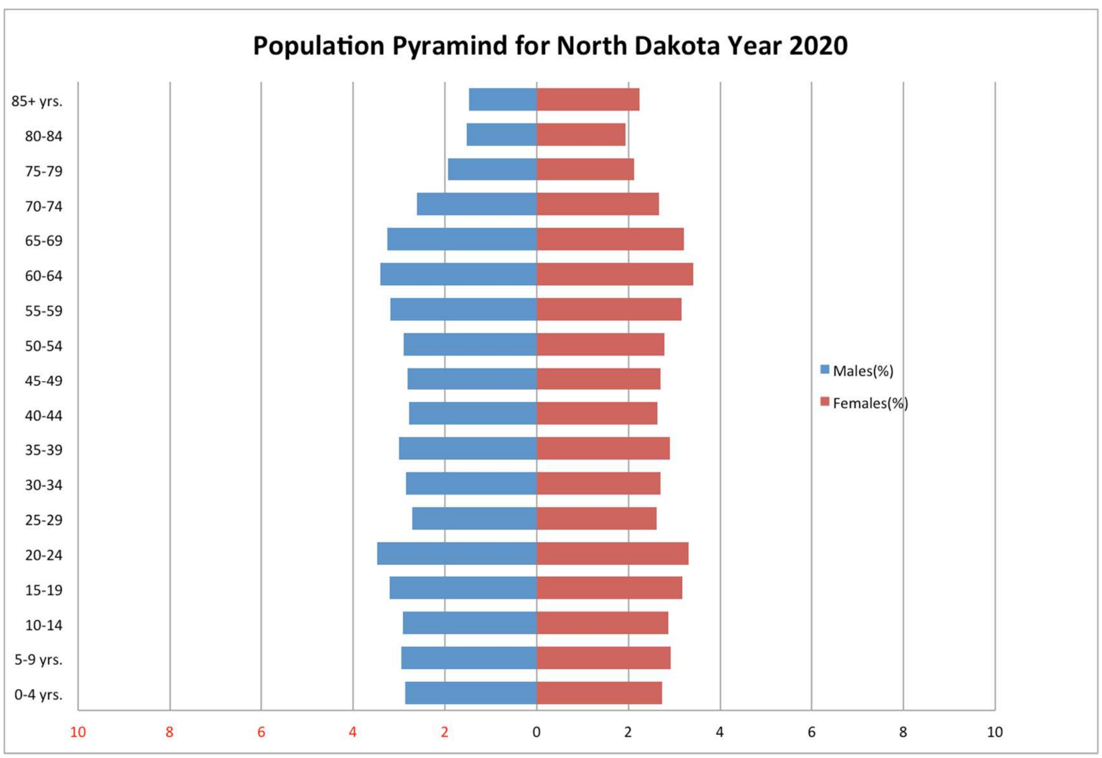

Figure 14. North Dakota population pyramid for year 2020 according to NDSDC projection results. Data from Rathge et al., (2002).

Some questions that should be posed when examining a population's structure are as follows: 1) What is the age distribution implying? 2) What is the average lifespan of the population, so that a future prognosis can be made? 3) What is the distribution of males and females? 4) What are the economic and social implications of this structure? (North, 2014). The population pyramids can help to answer some of these questions. The main factors driving the projection results are an increase in the young working age male cohort due to migration, an out migration of the elderly, and an uneven sex ratio. The pyramid tells us that 1) the changing age distribution is centered on the initial influx of the 20-24 year old male labor force population that occurred when the oil boom started. 10 years later when the population has aged to 30-34, there is a bulge present in the pyramid. 2) As seen in the lifetables, the average life expectancy for a North Dakota male is around 77 years and 82 years for a North Dakota female, while life expectancy is not yet decreasing, the elderly population is being affected by out-migration. 3) The distribution of males and females is greatly uneven. There are fewer females on average, and large disparities in certain age-cohorts. 4) The social and economic implications are large, and are therefore discussed in the next section.

Policy Implications

Now that the results of the population growth have been summarized, it is important to discuss some implications. It is the belief of some that forecasts of economic scenarios grossly underestimate the impact of population increases. Population growth can act as a quasi-independent variable, which can either directly or indirectly affect many economic factors. To mention a few, there are financial factors such as "inflation (through supply push and demand pull theories), pension funds, national debt, interest rates" as well as factors like "raw material prices (including basic necessities such as land and water), energy prices, government fiscal policy (including budget breakdowns), unemployment levels, boom/bust cycles, and aggregate demand" (North, 2014). When dealing with intensive oil extraction specifically, it drives the need for expensive enhancements to roads, water, sewer systems, as well as increased demand for public services such as police, fire protection, emergency response teams, social services, and housing (Headwaters Economics, 2011).

Due to the inherent uncertainty in forecasting, economic planning in general is a difficult task. Add in a rapidly growing population and changing age-structure, and this planning becomes even more difficult. Due to complexity of policy decisions, this paper only provides a starting point for policy implications, in which the next step would be a much more comprehensive analysis. The potential policy implications of this thesis' results will be organized into three main sectors: the public sector, private sector, and non-profit sector. Examples will be given for each, as well as a very broad overview.

The demand for public goods such as medical facilities, schools, and law enforcement will likely remain high during the projection period. Law enforcement is especially pertinent, because North Dakota has experienced continually increasing crime rates in both violent crimes and property crimes since the beginning of the oil boom (Weltz, 2014 It would be expected that crime rates would increase as the population base increases, but the noted increases are larger than what can be attributed to balanced population growth because some demographic cohorts may be more likely to commit certain crimes than others, and this could be an influencing factor. The projection results suggest that there is a correlation between the increase in the young male population and the increase in crime. As noted earlier, the changing sex ratio has lead to a large gender imbalance in North Dakota. The data also suggests that males are more likely than females to commit violent crimes. Decisions in the public sector regarding law enforcement will then not only have to account for increased crime due to an increased population, but also a change in types of crimes committed.

Hospitals can have a large presence in the non-profit sector, and are certainly affected by changing population. The increase in population will lead to an increase in demand for medical facilities, and the change in population composition will likely lead to a change in the types of services needed as well. For example, young males working in dangerous jobs require different types of medical care than that of geriatric patients, who are sometimes displaced when housing prices increase.

In the private sector, small businesses play an essential role in the sustainability of a community. The Bureau of Labor Statistics published an article that was focused on employment and wage changes in oil-producing counties in the Bakken Formation. According to this article, from the years of 2007-2011 employment more than doubled in Williams County, ND, known as the central location of shale drilling (Ferree & Smith, 2013). Statewide the corresponding increase was 35.9%, and of that, 68.5% of the increase could be attributed to the industries of mining, quarrying, oil extraction, gas extraction, transportation, warehousing, and construction (Ferree & Smith, 2013). The influence that the increase in oil drilling has had spans further than just these industries that are categorized as being directly related to oil, because most every local business feels the affect of the change in population and the economic changes in the community. The implications of these statistics are large, because they signify that even small changes in the oil industry have the potential to cause big changes in the North Dakota labor market. As the demand for workers related to jobs in the oil industry increase, and wages become more competitive, it becomes increasingly more difficult for smaller business to compete for employees. As businesses raise wages, the price of goods increases, which leads to regionalized inflation. Some businesses likely can't compete in this environment and are forced to close, which in turn can lead to shortages in essential goods.

CHAPTER V

CONCLUSION

Population projections are completed with the assumption that current demographic rates will continue into the future, and without that assumption, the projection loses much of its interpretive power. However, it is nearly impossible to determine how long the current oil boom will last in North Dakota. Estimates regarding the size of the Bakken Shale vary immensely among estimators, and that is only one of many uncertainties in the volatile oil producing market. An improvement could be made to this population model if information was released regarding the oil extracting limit of the Bakken Shale.

North Dakota is currently in a vulnerable state with regard to an unforeseen future, and the further examination and improvement of demographic techniques and analysis will only benefit it. The monetary benefits provided from oil revenue need to be carefully allocated, and some of which should be allocated to studying the economic consequences of such a rapid and explosive expansion. As new data becomes available, a well-fitting population model needs to be adjusted to include the new information. In that sense, a population model is never completely finished and should be regarded as such.

APPENDIX

Table 1: Percent Change in North Dakota Male and Female Population, Years 1990 through 2010

	1990		2000		2010	
	Males(%)	Females(%)	Males(%)	Females(%)	Males(%)	Females(%)
0-4 yrs.	3.822	3.668	3.143	2.992	3.393	3.237
5-9 yrs.	4.183	3.962	3.425	3.268	3.051	2.908
10-14 yrs.	3.939	3.703	3.815	3.576	3.027	2.889
15-19 yrs.	3.815	3.491	4.323	4.026	3.661	3.397
20-24 yrs	3.943	3.551	4.178	3.686	4.688	4.078
25-29 yrs	4.010	3.842	3.156	2.884	3.933	3.441
30-34 yrs.	4.237	4.195	3.042	2.890	3.212	2.868
35-39 yrs.	4.050	3.798	3.685	3.632	2.856	2.655
40-44 yrs.	3.228	3.016	3.983	3.961	2.917	2.762
45-49 yrs.	2.430	2.366	3.792	3.595	3.488	3.408
50-54 yrs.	2.029	2.112	3.040	2.876	3.762	3.713
55-59 yrs.	1.989	2.123	2.273	2.231	3.514	3.317
60-64 yrs.	2.070	2.175	1.845	1.971	2.721	2.613
65-69 yrs.	1.866	2.040	1.691	1.912	1.918	1.952
70-74 yrs.	1.599	1.937	1.631	1.913	1.433	1.667
75-79 yrs.	1.249	1.724	1.287	1.685	1.208	1.523
80-84 yrs.	0.791	1.288	0.890	1.409	0.939	1.373
85+ yrs.	0.564	1.195	0.711	1.582	0.810	1.671

Data Source: US Census Bureau (1990), (2000), (2010)

REFERENCES

Black, Dan and McKinnish, Terra and Sanders, Seth. (2005). The Economic Impact of the Coal Boom and Bust. *The Economic Journal, 115,* 449-476.

Bureau of Economic Analysis. (2015). *Broad Growth Across States in 2014*. Retrieved from https://www.bea.gov/newsreleases/regional/gdp_state/gsp_newsrelease.htm

Center for Disease Control and Prevention, National Center for Health Statistics. (2014). *Birth Data Files, 2006-2013.* [Data file] CDC Vital Statistics System Online Database. Available from http://www.cdc.gov/nchs/nvss.htm

Centers for Disease Control and Prevention, National Center for Health Statistics. (2015). *Multiple Cause of Death 1999-2013*. [Data file]. CDC WONDER Online Database. Accessed at http://wonder.cdc.gov/mcd-icd10.html

Center for Medicare & Medicaid Services. (2014). *Medicare Enrollment Data By State and Age, 2009-2012*. [Multiple data files]. Available from https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/MedicareEnrpts/index.html

Cicha, Joe. (2015). *Growing North Dakota by the Numbers*. North Dakota Census Office.

Environmental Protection Agency. (2010). *Hydraulic Fracturing Research Study*. Science in Action.

Ferree, P., & Smith, P. (2013). Employment and Wage Changes in Oil-Producing Counties in the Bakken Formation, 2007-2011. *Beyond the Numbers: Regional Economies*, *2.*

Fong, Cory. (2012). *North Dakota State and Local Taxes: An Overview and Comparative Guide.* Office of State Tax Commissioner.

Gould, K., Pellow, D., & Schnaiberg, A. (2004). Interrogating The Treadmill Of Production: Everything You Wanted To Know About The Treadmill But Were Afraid To Ask. *Organization & Environment, 17*, 296-316.

Greenwood, Michael J. (2005). Modeling Migration*. Encyclopedia of Social Measurement, 2*.

Gross, Emily. (2006). *US Population Migration Data: Strengths and Limitations.* Statistics of Income Division, Internal Revenue Service.

Hamm, Rita R. and Syed Azam. (1991). *North Dakota Life Tables 1960, 1970, 1980, 1990.* North Dakota Center Report No. 17. Department of Agricultural Economics. North Dakota State University, Fargo, ND.

Headwater Economics. (2011). *Fossil Fuel Extraction and Western Economies*. Bozeman, MT. Published online at http://headwaterseconomics.org/energy/oil-gas/maximizing-benefits

Headwaters Economics: Independent Nonpartisan Research. (2012). *Unconventional Oil and North Dakota Communities: State Fiscal Policy Unprepared for Impacts of Energy Development.*

Heckman, James J. and Honore, Bo E. (1990). The Empirical Content of the Roy Model. *Econometrica, 58(5)*, 1121-1149.

Hughes, David. (2014). *Drilling Deeper: A Reality Check on US Government Forecasts for a Lasting Tight Oil & Shale Gas Boom.* Post Carbon Institute.

Institute For Energy Research. (2012). *The Bakken Facts*.

Kale, Balkrishana and Egan-Robertson, David and Palit, Charles D. and Voss, Paul R. (2005). The Migration Component in a Population Projections Model. *ASA Social Statistics Section*, 1970-1976.

Loder, A. (2013). U.S. Shale-Oil Boom May Not Last as Fracking Wells Lack Staying Power.

Lutus, Paul. (2014). *Peak People*. Retrieved from http://arachnoid.com/peak_people/

Meyer, Julie. (2012). *Centenarians: 2010, 2010 Special Census Reports.* United States Census Bureau: US Department of Commerce.

Newell, Colin. (1988). *Methods and Models in Demography.* New York, NY: The Guilford Press.

North, Christopher. (2014). Economic Implications of Growing Populations and Changing Demographic Structures. *KIOES Opinions, 3*.

North Dakota State Treasurer. (2015). *North Dakota Daily Operating Balance.*

O'Neill, Brian C. and Balk, Deborah and Brickman, Melanie and Ezra, Markos. (2001). A Guide to Global Population Projections. *Demographic Research 4(8),* 203-288.

Pierce, Kevin. (2015). *SOI Migration Data: A New Approach.* Statistics of Income Division. International Revenue Service.

Preston, Samuel H. and Heuveline, Patrick and Guillot, Michael. (2001). *Demography: Measuring and Modeling Population Processes*. Oxford, UK: Blackwell Publishers.

Rathge, Richard and Clemenson, Mandy and Danielson, Ramona. (2002). *North Dakota Population Projections: 2005 to 2020.* North Dakota State Data Center.

Statistics of Income Division, Internal Revenue System. (2015). *State To State Migration Flows, Inflows and Outflows, 2006-2013.* [Multiple data files]. Available from https://www.irs.gov/uac/SOI-Tax-Stats-Migration-Data

Tong, Scott. (2014). *The Problem with Fracking.* Marketplace Sustainability. http://www.marketplace.org/2014/11/24/sustainability/problem-fracking

United States Census Bureau. (1990). *US Census Bureau, Census 1990.* [Data file]. Available from http://www.census.gov/main/www/cen1990.html?cssp=SERP

United States Census Bureau. (2000). *US Census Bureau, Census 2000.* [Data File]. Available from http://www.census.gov/population/age/data/decennial.html

United States Census Bureau. (2004). *Methodology Summary, Interim Population Projections for States by Age and Sex: 2004 to 2030.* Population Projections Branch, Population Division.

United States Census Bureau. (2010). *US Census Bureau, Census 2010.* [Data File]. Available from http://www.census.gov/population/age/data/decennial.html

United States Census Bureau. (2010). [Geographical representation of North Dakota's Skewed Sex Ratio]. *Census Data Mapper, 2010 Census Data.* Retrieved from http://datamapper.geo.census.gov/map.html

United States Census Bureau. (2014). *Methodology for the United States Population Estimates: Vintage 2014*.

United States Census Bureau. (2014). [Illustration of geographic distribution of North Dakota percent growth rates and primary sources of growth]. *Population Estimates, County Totals: Vintage 2013.* Retrieved from http://storymaps.esri.com/stories/2014/census-county-population-change/

Vachon, Mallory C. (2015). *The Impact of Local Labor Market Conditions on Migration: Evidence From the Bakken Oil Boom.* (Unpublished Doctoral Dissertation). Syracuse University, Syracuse, NY.

Weber, Brett and Geigle, Julia and Barkdull, Carenlee. (2014). Rural North Dakota's Oil Boom and its Impact on Social Services. *Social Work, 59(1).*

Weltz, Colleen. (2014). *Crime in North Dakota.* Office of Attorney General, Bureau of Criminal Investigation.

Willekens, Frans J. (1991). Probability Models of Migration: Complete and Incomplete Data. *SA Journal of Demography 7(1).*

Yowell, Tiffany and Devine, Jason. (2014). *Evaluating Current and Alternative Methods to Produce 2010 County Population Estimates.* Working Paper No. 100, Population Division, US Census Bureau.