Employment Diversity on Tribal Nations in the Western U.S.: Quantifying Economic Resilience

EMPLOYMENT DIVERSITY ON TRIBAL NATIONS IN THE WESTERN U.S.: QUANTIFYING ECONOMIC RESILIENCE

by

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Abstract:

This thesis measures the impact of employment sector diversity on per capita income for tribal nations in the western U.S. over two, five-year summary time periods. Invoking definitions of economic resilience from economic geography literature to construct an OLS model, employment diversity is selected as the most feasible means of incorporating hypothesized indicators of resilience at the reservation spatial scale. By calculating three measures of employment diversity, the Hachman Index, the Herfindahl Index, and Shannon's Index, based on the North American Industry Classification System, this study measures the impact of employment diversity on per capita income both non-comparatively and with respect to the state the reservation primarily falls within. The model employed finds evidence that employment diversity metrics that measure non-comparative diversity (Shannon's Index, Herfindahl Index) have a positive and significant relationship with income, with higher diversity indicating higher real income levels. Performance of the non-comparative diversity measures is the strongest when included alongside the state comparative Hachman Index, which holds a negative, and slightly less significant, relationship with income. From these two alternating relationships, it is suggested that tribal nations benefit from diversifying employment on reservations but may not benefit from modeling that diversification after state industry employment spreads.

Chapter 1*: Introduction*

As sovereign nations that have historically and systemically suffered from seizure and fragmentation of their resources, American Indian reservations have faced significant and sustained challenges regarding economic development (Cornell & Kalt 2003). These same reservations also have faced increased risk to their economies based on their geography. As most large, populous reservations are in the arid, exurban western U.S., the volatility felt in temperatures and resource availability has implications for both traditional livelihoods and burgeoning industries. Currently, tribal nations are seeing disproportionate impacts from the COVID-19 pandemic, with the Navajo Nation at one point having the highest number of infections per capita in the U.S.. COVID-19 has temporarily shuttered crucial gaming and tourism operations on many reservations, compounding the negative economic impact experienced by tribal nations already struggling to combat transmission (Romero & Healy 2020). As the current pandemic has demonstrated the vulnerability faced by reservations, it also motivates an exploration into development efforts may mitigate impacts from future shocks.

Tribal nations in the U.S. have seen potential for economic development opportunities through settlements of Winters water rights, the Indian Gaming Regulatory Act (IGRA), and support systems for tribal nation building, such as the Harvard Project for American Indian Economic Development (see appendix B for the list of acronyms used throughout this thesis). As per the 1908 Winters doctrine (established through the Winters v. United States supreme court case), enough water to ensure a reservation could act as a homeland was "implicitly reserved" upon the date the reservation was established, meaning tribes are priority water users in most cases. Beyond the significance of water in maintaining environmental flows and sustaining culturally important practices, the settlement of water rights claims is motivated by the need for water as capital, a building block for development. Water can be used to sustain existing livelihoods, like agriculture, and support or inspire burgeoning ones, such as tourism or water marketing relationships with local municipalities. For tribal nations with few other development prospects, water provided by equitable Winters settlements is essential to both life on the reservation and for the growth of reservation economies. Alternatively, the IGRA's passage in 1988 opened a new gaming industry which was rapidly capitalized upon in 1990s, leading to marked increases in a variety economic metrics for reservations with gaming operations (Taylor et al. 2005; Akee, Spilde, & Taylor 2015; Conner & Taggart 2013).

The importance of Winters rights and the IGRA to reservation economies has been explored at length by econometric studies such as Deol & Colby (2018) and Young (2019). As climate change augments the circumstances of new Winters settlements, as well as the very landscape of reservations, recent literature has pushed to include innovative variables in considerations of reservation economic performance. These variables often represent the impact of historic policy such as the Dawes' Act (Leonard, Parker, & Anderson 2018) or Indian boarding school operation (Gregg 2018). These and other historic policies discussed within this thesis are contextualized through a timeline in figure 1.1. While a historic perspective has been beneficial in articulating the underlying factors affecting reservation economic development, better reservation data quality motivates new attempts to incorporate currently observable reservation characteristics, notably when taking inspiration from economic geography and development literature.

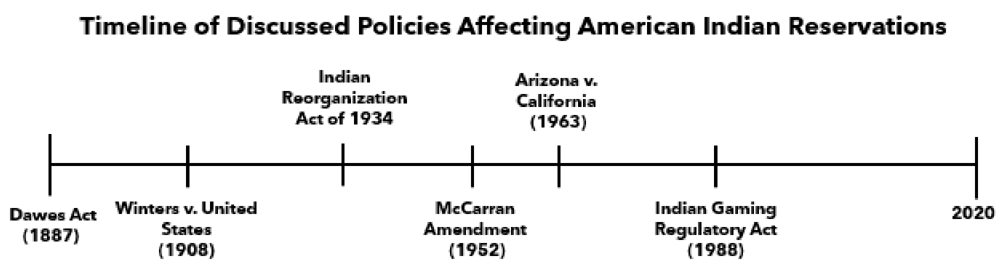

Figure 1.1: Timeline of Relevant Policies

Recent literature within various economic and social science fields has attempted to define the term *economic resilience* for businesses, industries, and communities, leading to a range of interpretations and proposed metrics (Rose 2017; Martin 2012; Martin & Sunley 2015). Rose (2017) documents the diverse, interdisciplinary spheres of influence on the definition, including the term resilience's origin in ecology and its iterations as applied to interweaving human and ecological systems. Economic geography specifically has focused on defining the term for regional economies, both urban and exurban. To paraphrase Martin & Sunley (2015)'s definition, regional economic resilience is the capacity of a regional economy to both resist and recover from a negative, external shock – either returning to its pre-shock equilibrium or its pre-shock growth path (Boschma 2014). Conclusions from Martin & Sunley (2015), Fieldsend (2013), and Boschma (2014) indicate that the diversity of employment (or the diversity of industries present) in a region strongly contributes to that region's shock resistance and therein economic resilience. Despite this consensus, few empirical studies utilizing employment diversity with consideration for regional economic resilience exist (Dinh et al. 2017).

To inform future-minded and climate conscious development decisions, this study quantifies an employment diversity measure and utilizes this measure in a log-linear model of reservation per capita income over two time periods, functioning as a theoretical indicator of economic resilience. I draw from U.S. Census American Community Survey (ACS) 5-year estimate data from 2012 and 2018 for 74 reservations in 8 western U.S. states, leading to 148 total observations (see figure 1.2 for study area). This time period does not allow the full timeline of an external shock to be observed, wherein the economic equilibrium pre-shock, during shock, and post-shock is recorded. However, the 2012 data includes 2008, which is inclusive of the Great Recession and its immediate post-shock period. For the purpose of this study, the 2012 data is considered a shock period, while the 2018 data is considered a recovery period. Specifications of the model account for three measures of employment diversity, Shannon's index, the Hachman index, and the Herfindahl index. The Hachman index provides a measure of diversity compared to the state in which the reservation falls (referred to as a comparative index), while the Shannon and Herfindahl indices measure diversity only regarding the spread of their own employment levels (referred to as noncomparative indices). Both noncomparative indices are found to have statistically significant relationships with income, such that reservations with higher levels of employment diversity also have higher income levels. The significance of these variables increases with the inclusion of the Hachman index, which itself is found to have a negative relationship within income in the model. Given the lack of empirical modeling of regional economic resilience and the components of resilient economies, this study serves to further a largely still narrative-driven literature, incorporating historic development factors specific to reservations that may impact current levels of income and economic prosperity.

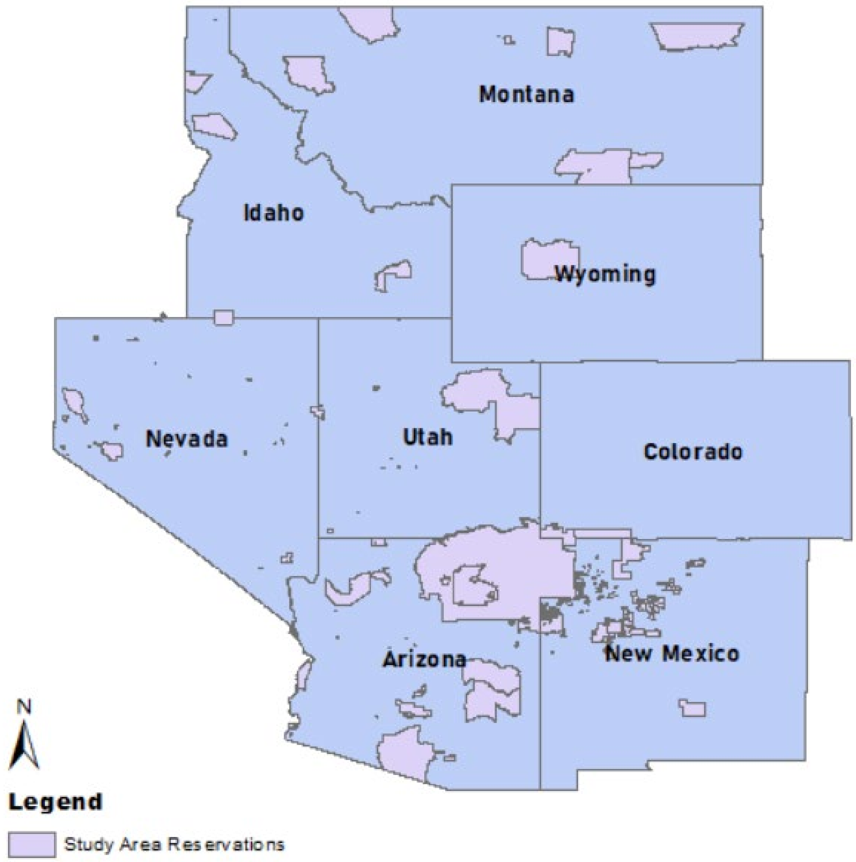

Figure 1.2: Study Area Reservations

The following chapters of this thesis begin with a literature review exploring the origins of the term economic resilience, defining resilience indicators of interest, and establishing links between economic development and reservation characteristics. The third chapter provides a conceptual model of economic resilience as proxied by employment diversity for reservations specified in this study. The fourth chapter includes a description of the dataset used as well as the methodology employed to calculate reservation employment diversity indices. The fifth chapter describes the models used in econometric estimation. The sixth chapter contains the model results and discussion, with several model iterations discussed to better represent the relationship between income and employment diversity. Finally, the seventh chapter concludes the paper, specifically reflecting on the alternating relationships with income the noncomparative indices and comparative index display.

Chapter 2*: Literature Review*

This chapter is divided into two sections. The first section outlines the terms *economic resilience* and *regional economic resilience,* focusing primarily on the body of literature from economic geography. It also reviews the few empirical studies that have quantified regional economic resilience as it has been defined in economic geography. It then discusses the applicability of the empirical studies in the context of reservations, where data is more limited. The second section discusses literature evaluating reservation economic development and the policies that have informed reservation socioeconomic conditions. It gives more attention to studies evaluating the impacts of Winters rights and the IGRA, as quantified water rights are included as a variable within this study's model and casino presence is included as a variable in alternative specifications seen in Appendices D and E.

2.1: Defining Economic Resilience, Employment Diversity, and Application to Tribal Nations

Resilience is a term used and defined by multiple disciplines, first stemming from ecology, it was then appropriated by and expanded upon in the context of human development, engineering, and urban planning literature, among others. Ecological resilience refers to a system's ability to return to its equilibrium, and potentially even improve on that equilibrium after an external shock, whether it undergoes significant fluctuation or not (Rose 2017). Building off various efforts to adapt the ecological definition to socio-economic conditions through inclusion of human and institutional elements, Rose (2017) offers two terms: static economic resilience and dynamic economic resilience. Static economic resilience is defined as "the ability of a system to maintain function when shocked," while dynamic economic resilience is defined as "the ability to hasten the speed of recovery from a shock." The shocks discussed may be economic or non-economic, though the latter arguably receives more scholarship than the former due to its intersection with economic studies of natural disaster recovery (Josephson, Shrank, & Marshall 2017).

Compared to the definition of economic resilience provided by Rose (2017), economic geography literature has further specified the term to be applied at the regional and local level (Martin 2012; Simmie & Martin 2015). Contrary to an equilibrium conception of economic resilience, Martin (2012) argues that a regional or local economy, such as a reservation economy, "need never be in equilibrium, yet can be characterized by an identifiable, and relatively stable, growth trend or path." Going on, Martin (2012) explains understanding resilience is dependent upon four interrelated dimensions: resistance (vulnerability of a regional economy to disturbances), recovery (speed and extent), re-orientation (in relation to jobs and income), and renewal (return to the growth path of the economy prior to the shock). Economic structure is thought to be a primary determinant of resilience, with a more greatly diversified industrial and employment 'portfolio' offering greater resistance to shocks (Martin 2012). Building from Martin (2012), Boschma (2014) defines economic resilience from an evolutionary perspective as, "the ability of regions to reconfigure their socio-economic and institutional structures to develop new growth paths," rather than sticking to one, singular growth path. Boschma (2014) also acknowledges the importance of diversity, claiming that the "recombination potential of a region" post-shock is enhanced by "a variety of skill-related industries that have little local input-output relationships with one another." Not only is the diversity of industries important in a regional economy, the independence of those industries is also crucial.

Empirical studies focusing on economic resilience at the business, industry, or consumer level are much more prolific than those focused on a local or regional economy. Economic resilience at these varying scales has been measured through methods such as the analysis of global input-output tables, individual transaction data, and survey responses (Hashiguchi, Yamano, & Webb 2017; Rose & Liao 2005). Martin & Sunley (2015) offer four primary methods for measuring economic resilience at the regional level: case studies, resilience indices, statistical time series models, and causal structural models. Case studies are arguably the most abundant of the listed methods. Cowell (2013) and Wang (2018) both provide case studies of urban areas over the late 20th century to present day, comparatively between Cleveland, Ohio and Buffalo, New York in the former case and in Beijing in the latter. Despite contrasting narratives of deindustrialization and industrialization, diversification is cited as a boon to shock resistance in both instances. Martin et al. (2016) examines UK regional resilience to recessions in two of the four previously mentioned resilience dimensions, resistance and recovery. Using change ratios in employment, resistance is measured by the level of employment contraction post-shock while recovery is measured directly, with regions then sorted into a matrix from most to least resilient. Fieldsend (2013) offers case studies of eight rural areas in Bulgaria, France, Hungary, and the UK, using the Strength, Weakness, Opportunity, Threat (SWOT) analysis technique substantiated on interviews, quantitative data, and previously conducted studies. Depopulation, high rates of migration, and an aging workforce are cited as chief vulnerabilities of the studied areas, while diversification of employment based on a broad mix of sectors is asserted as the primary determinant of economic adaptability. Due to the largely ex-urban nature of reservations, Fieldsend's (2013) area of study is arguably that most similar from an economic development standpoint to that of western U.S. reservation economies.

Existing regional statistical studies inclusive of the resilience indices and time-series models described by Martin & Sunley (2015) are still an emerging literature. Tan et al. (2017) utilizes principle component scores to construct a diversity index for resource-based cities in the Northeast Chinese provinces of Liaoning, Jilin, Heilongjiang, and the eastern Inner Mongolia. Tan et al's (2017) index sorts social and economic indicators into three categories like the four provided in Martin & Sunley (2015). Dinh et al. (2017) provides arguably the most comprehensive example of these methodologies, measuring resilience in the various regions of Australia during a time period of three different shocks: the Millennium drought, the Global Financial Crisis, and the boon to the domestic mining industry. The study utilizes both a diversity index, referred to as Community Economic Resilience (CER) and a time series model. CER is constructed through census derived indicators of 5 capital types (natural, social, human, financial, and structural) alongside an economic diversity score as measured by the Hachman index, which compares community-specific employment by sector with the national rate of employment in that sector, and an accessibility score as measured by the Accessibility and Remoteness Index for Australia. CER is found to improve when a community is in a post-shock period, and time-series models of median household income finds a positive long-term correlation with CER. Additionally, a higher economic diversity score is revealed to have a positive correlation with all capital types except for natural capital (Dinh et al. 2017).

Given that data quality at the reservation spatial scale is poorer and covers a smaller timeframe than non-tribal U.S. areas, analyzing regional economic resilience of reservations through the four resilience dimensions listed in Martin (2012) or even the two utilized in Martin & Sunley (2015) is difficult. The 2008 recession and Global Financial Crisis present a significant, relatively recent shock that could be used for study; however, the missingness within ACS reservation economic data prior to 2010 hinders the ability to establish the initial equilibrium or growth path of a reservation. As this baseline or trajectory is unobserved, recovery cannot be measured. Resistance, even in the absence of direct shock, can be more feasibly incorporated from an econometric perspective.

Employment diversity (sometimes referred to as industry diversity) has been consistently cited within resilience literature. Dinh et al. (2017)'s study includes it through the Hachman index, which functions alongside a constructed resilience index in the model. Furthermore, ACS reporting on reservation employment by sector using the North America Industry Classification System (NAICS) provides the necessary data to construct a measure of employment diversity through the Hachman index, as well as Shannon's index, and the Herfindahl index. As mentioned, the Hachman index is a specific measure of employment diversity that compares the level of regional employment in each industry to that of the national level of employment in that industry (Dinh et al. 2017; Hachman 1995). Dinh et al. (2017) finds a positive correlation between the Hachman index and regional income level. The Shannon and Herfindahl indices are more general measures of diversity, calculated without a reference region and with varying applications across disciplines. Shannon's index is typically used as a measure of biodiversity, whereas the Herfindahl index, or Simpson index as referred to in its ecological context, is used in economics literature as a measure of market concentration for firms. Applications of Shannon's index outside of ecology include Michler & Josephson (2017), which estimates the effect of crop diversity on poverty in Ethiopia, finding crop diversification to reduce the likelihood of household poverty. Michler & Josephson (2017) use the Herfindahl index alongside the Shannon index as robustness checks for one another. Similarly, both the Shannon and Herfindahl indices were selected for inclusion in this study due to their comparable, inverse results.

Reservation employment composition has been analyzed by Akee, Mykerezi, & Todd (2018), which compiles a list of tribal member employment based on the U.S. Census Longitudinal Business Database. The paper, which also uses the NAICS categorization system, finds high job counts in the Arts / Recreation / Tourism sector and the Public Administration sector for tribal members on most federally recognized U.S. reservations. Efforts to categorize and define employment composition on reservations are already useful qualitatively. By quantitatively defining and measuring diversity based on this employment composition, links to the larger concepts presented by economic resilience literature can be maintained and highlighted.

2.2: Economic Development on Reservations, Water Rights, and the IGRA

Reservation economies have been disadvantaged by the circumstances of reservation formation, and by the subsequent limiting and discriminatory policies imposed by the federal government (see appendix A for details focusing on Winters rights). In addition to historic difficulties, western U.S. tribal communities are also disproportionately vulnerable to climate change impacts due to the both their arid environments and their dependence on water and other natural resources for traditional livelihoods and cultural practices (Guatam, Chief, & Smith 2013). Aware of these vulnerabilities, recent econometric literature has attempted to evaluate reservation economies with consideration for the historic policy that has affected tribal reservations and their development.

Winters water rights settlements and their economic impacts have received significant attention due to ongoing settlement processes. Named for the 1908 supreme court case *Winters V. United States*, Winters rights are federally reserved tribal water rights that take the priority date of the reservation's establishment. As reservation creation precedes almost all non-tribal prior appropriation claims, tribes are usually first priority water users with an entitlement quantifiable by the Practicably Irrigable Acreage (PIA) standard (Thorson et al. 2006). *Winters* rights quantification is necessary from a resource entitlement perspective and desirable due to the settlement process providing opportunity for infrastructure development.

Deol & Colby (2018) discuss Winters rights explicitly in estimating the economic performance of reservations on a portfolio of economic development indicators. Beyond water rights settlements, the study also takes casino operations and agricultural activity into consideration in order to investigate the interrelation between variables. Surveying 51 tribes across 2010 and 2015, Deol & Colby (2018) utilizes OLS and linear probability models of agricultural revenue, casino operations, and income, in which a water settlement dummy variable is included. Reservations with quantified water rights are found to have higher economic performance in both agricultural and casino operations. Agriculture is found to yield on average $47 million more in revenue for reservations with quantified water rights compared to those without. Casinos are found to be more likely to be operated on reservations with quantified water rights, though only marginally and with an unclear direction of causality. Quantification of Winters rights is also found to be more likely for reservations located closer to a major city, potentially due to increased water demand from non-tribal users. Despite the gains in revenue seen from agricultural and casino operations, income on reservations with quantified water rights is found to be lower than on reservations without quantified water rights. Deol & Colby (2018) and Young et al. (2019) support the narrative that tribes currently holding water rights for their land are, on average, less economically well-off than tribes which do not hold water rights, hence their pursuit of quantification. The significant, positive correlations with agricultural revenue and gaming operations seen by reservations with quantified water rights suggests that examination of the same reservations prior to quantification would reveal even lower comparative income.

Sanchez, Edwards, & Leonard (2019) estimate the likelihood of a tribe entering the settlement process in order to categorize the set of tribes that have already pursued settlements. The paper first uses a Cox Proportional Hazard Model to analyze the number of "years required to resolve Winters rights" claims and then employs a logistic regression to explore the factors affecting Winters rights quantification, its expected benefits, and the probability of a reservation pursuing adjudication. Analyzing the outcomes of 37 negotiated settlements, the likelihood of entering the adjudication process is found to increase when expected benefits of a settlement are greater. Greater perceived benefits are mainly driven by the severity of water scarcity on a reservation. Conversely, the likelihood of entering into an agreement is decreased when bargaining costs, such as the number of claimants and challenges to obtaining information on resource use, are high. When settlements are pursued, a positive correlation is found "between the number of bargaining parties involved in an adjudication and the time to finalize the adjudication," indicating the more desirable the water resource, the further prolonged the process (Sanchez, Edwards & Leonard 2019). The finding that water scarcity motivates the settlement process alongside the income trends seen in Young et al. (2019) and Deol & Colby (2018) indicate that tribes pursuing adjudication and with quantified settlements are arguably the most vulnerable to water scarcity. This conclusion particularly motivates the investigation of Winters rights in relation to economic development and indicates the importance of viewing the economic impact of Winters rights in a temporal dimension, wherein the maturity of rights matters. While Winters rights maturity is not included as a variable in this study, Winters rights ideally provide the resources necessary to sustain or expand agricultural practices or to pursue development of necessary infrastructure that could later lead to the support of other employment sectors. Therefore, Winters rights interaction with employment diversity is of interest.

The passage of the IGRA has led to the tremendous adoption of gaming industries on reservations, so much so that tribal casino operations now comprise a significant portion of tribal government revenue. Akee, Spilde, & Taylor (2015) evaluates the first 10 years of full California reservation casino operations after prolonged opposition to Class III tribal gaming development by the state government.[1] The paper details percent changes in several economic variables - such as income, poverty, and labor force participation - on California reservations in comparison to United States averages. Per capita income on reservations was found to increase by 43% over the 1990s compared to the 11% growth experienced by the US in the same time period. Akee, Spilde, & Taylor (2015) also investigate non-tribal spillover effects of casino operations due to California's smaller reservation sizes, reporting increases of median family and per capita income on census tracts greater than 20 miles from the casino location. Taylor et al. (2005), a previous paper with overlapping authorship, reports a 35% increase in real median household income for all reservations other than the Navajo Nation with gaming operations, compared to a 14% increase for reservations without gaming operations.

Other considerations of historic policy shaping current reservation economies include the requisite approval of tribal government structure by the federal government post-reservation creation, fractionation of reservation land by the Dawes' Act, forced inter-tribal coexistence, and Indian boarding school attendance and tenure. Akee, Randall, & Jorgensen (2015) find that the party of the U.S. President when a Tribe first adopted a written constitution is correlated with modern levels of reservation income and unemployment. The hypothesis that the political party of the U.S. president has an impact on a tribal nation's constitution is detailed as follows:

> "Republican Presidents such as Theodore Roosevelt envisioned US Federal programs as a means to dismember tribal institutions and to increase assimilation. Democratic

[1] The IGRA splits gaming into 3 classes. Class I and Class II gaming are regulated entirely by tribal governments, while Class III (Las Vegas-style) gaming is regulated by both state and tribal governments.

> Presidents, on the other hand, did not take such an extreme view in the administration of programs and imposition of political institutions."

Constitutions adopted under republican presidents favored a directly elected chief executive in a "presidential-type system," while constitutions under democratic presidents favored indirectly elected chief executives in a "parliamentary-type system." Using presidential party as a proxy for the type of constitution adopted, the models indicate that tribes operating under parliamentary-type systems hold higher per capita incomes and see higher labor force participation rates. Other historic factors concerning the federal government, such as the party of the U.S. Congress at the time the constitution was adopted, are found to be insignificant.

The impact of Dawes' Act reservation fractionation on economic indicators is explored in Leonard, Parker, & Anderson (2018). The study incorporates a reservation's percentage of agriculturally fertile, or prime, land into an OLS econometric model comparing incomes on reservations with those of their non-Tribal neighboring counties. Percentage of prime land is found to hold a non-linear U-shape relationship with income, with low prime land reporting higher incomes, mid prime land reporting low incomes, and high prime land again reporting higher incomes. Leonard, Parker, & Anderson (2018) argue that this is due to the greater levels of seizure and therein fractionation experienced by reservations held in trust with a higher percentage of prime land (reducing an initially high percentage of prime land to the now observed low percentage of prime land). The paper concludes by asserting that income differences between reservations and their neighboring counties is due to the lack of fully privatized land rights on reservations, which leads to additional obstacles in pursuing economic growth. Similar results have been found for Canada's First Nations population in Aragon (2015) and Aragon and Kessler (2018). All three of these papers contend that stronger property rights for indigenous peoples will reduce poverty on U.S. reservations and First Nation's reserve land. In the argument of Leonard, Parker & Anderson (2018), stronger property rights to land leads to greater autonomy over that land and the ability to leverage it for capital. Dipple (2014) considers the ramifications of reservation population composition, examining the impact of federal government imposed forced coexistence if multiple sub-tribal bands within a single reservation (such as the case of six of the seven bands of the Apache). The OLS models employed find that reservations that combined multiple sub-tribal bands upon formation are 30% poorer than reservations formed with only a single sub-tribal band. The significant, negative economic impacts seen from the circumstances of reservation creation and redefinition through Dawes' Act fractionation help emphasize the legacy of discriminatory policy that has continues to shape reservations' economic outcomes.

The effects of Indian boarding schools are discussed in Gregg (2018) and Feir (2016). In the U.S., reservations with the longest tenures of boarding school operations experience less poverty, greater educational attainment, and greater linguistic assimilation (Gregg 2018). Despite these positive correlations, Gregg (2018) believes that the first-generation costs of assimilatory practices outweigh the potential economic benefits. Indian boarding school (referred to as residential school) attendance in Canada is found to increase the likelihood of high school graduation and employment and decrease the likelihood of the boarding school attendant living in an indigenous community (Feir 2016). Like Gregg (2018), Feir (2016) finds this to ultimately be an economic detractor to indigenous communities and a signal of successful assimilation policy.

The multitude of statistical approaches in recent studies of economic outcomes for tribal nations indicates a great deal of necessary interest in this area of study. Current policy, such as the Winters doctrine and the IGRA, and historic policy are both taken into consideration in the performance of reservation economies, acknowledging both the conditions affecting reservation life currently and the conditions in which these homelands were created. In addition to academic interest in analyzing economic outcomes for reservations, economic development entities such as the Harvard Project for American Indian Economic Development and the Native Nations Institute, are involved with advancing sustainable development on reservations as a means of promoting renewed tribal nation building (Cornell & Kalt 2003). Through the incorporation of a strongly hypothesized metric of economic resilience, employment diversity, into an econometric model of reservation income, this paper bridges two distinct areas of study. Quantifying and measuring the impact of employment diversity through the lens of economic resilience provides a new economic development axis with which to analyze reservation economies. This effort also adds to the limited empirical studies of regional economic resilience stemming from the economic geography literature.

Chapter 3: *Conceptual Model of Economic Resilience for Reservations*

The purpose of this chapter is to qualitatively define regional economic resilience based on the literature reviewed in chapter 2. The conceptual model is largely derived from the resilience framework discussed in Martin (2012) and Martin & Sunley (2015), and the empirical application provided by Dinh et al. (2017). The model is informed by constraints specific to the reservation spatial scale and therefore defines economic resilience primarily in relation to a reservation economy's ability to resist, or minimize the impact of, an external shock.

Regional economic resilience is thought to be comprised of several characteristics, as described in chapter 2 section 1. While not all characteristics are observable or directly related to traditional economic indicators, they do provide a pool of potential measures from which to pull from in available reservation data. As explained in Martin & Sunley (2015), resistance and recovery are the two dimensions in which resilience is measurable. A regional economy is understood to be in equilibrium without the presence of a shock, with each economic indicator displaying a general, observable growth path or average range of fluctuation. If a regional economy undergoes a negative, external shock, that shock has an impact on an economic indicator in equilibrium, such as income or unemployment. Resistance is what mitigates the impact from the shock. Recovery is the amount of time that it takes for the indicator to return to pre-shock levels. To measure economic resilience in these two dimensions, there should be an observable shock, an observable impact from that shock, and a recovery period. Figure 3.1 provides a visual representation of the shock, impact, recovery narrative presented throughout the resilience literature. The figure shows an external shock disrupting the equilibrium or growth path of a regional economy as perceived by a set of indicators (for example income, labor force participation, or poverty rate). The measurement of resistance is here referred to as *economy resistance capacity*. It is comprised of all the variables contributing to the economy's ability to mitigate the shock's initial impact on the indicators of interest, such as government efficacy or employment diversity. The measurement of recovery is referred to as *economy recovery capacity*. Economy recovery capacity includes all variables that affect the speed of indicator recovery, or the time it takes for an impacted indicator to return to its pre-shock levels. Distinguishing economy resistance capacity from economy recovery capacity may seem arbitrary, as they would likely be inclusive of the same types of variables, but the differences in what they measure are important. Indicator change is much more empirically accessible than recovery time, therefore variables thought to contribute to economy resistance capacity are also more easily measured. Martin & Sunley (2015) and Dinh et al. (2017) both measuring recovery as a temporal variable supports this assertion. Naturally, economy resistance capacity impacts economy recovery capacity, as the amount that an indicator changes from a shock is understood to impact the amount of time that elapses in the recovery period.

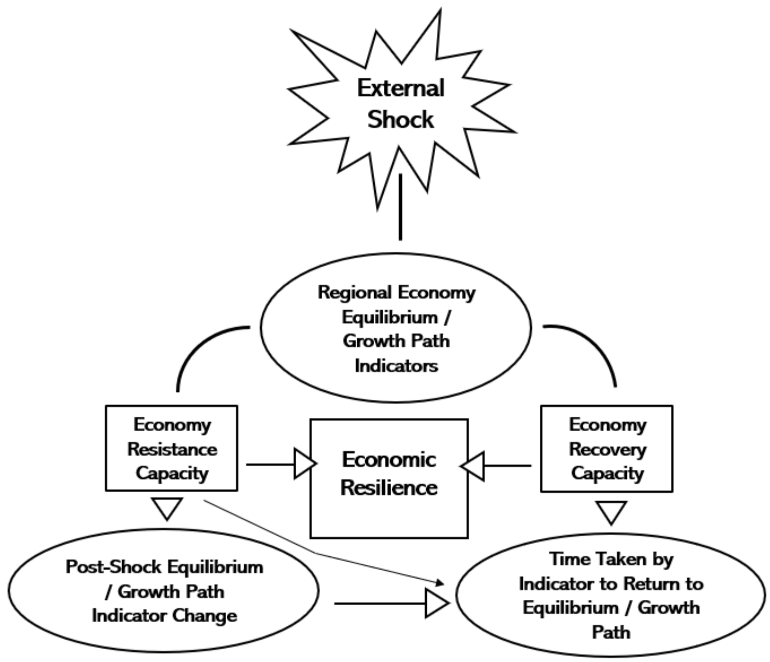

Figure 3.1: Effect of external shock on economy equilibrium

Based on the work by Martin & Sunley (2015) as well as Dinh et al. (2017), figure 3.2 provides a conceptual flowchart of potential factors influencing economic resilience, dividing resilience again into the dimensions of resistance and recovery. Here, employment diversity is substitutable with industrial diversity and is made up of employment percentage by sector, through arbitrary sectors A through E. Natural and human capital and geographic accessibility are included here as concepts derived from Dinh (2017)'s empirical modeling. Quantified water rights along with variables such as educational attainment would fall into the grouping. The geographic accessibility metric may be represented by commute time or the distance to the nearest city of 50,000 inhabitants or more. While mean commute time as reported by the ACS was initially chosen to represent the geographic accessibility of reservations, it was ultimately not included in the model due to several reservations reporting missing data over both time periods. As the observations are already limited due to missing data for other variables, commute time was omitted from the model in favor of retaining more observations. Here geographic accessibility is posited through the inclusion of state fixed effects, as states with a small number of geographically large reservations, such as Montana, may be argued to be more exurban and therefore less accessible than states with many geographically small reservations. The state fixed effects also function as a spatial control within the model. In the case of reservations, institutional strength may be represented by the efficacy of the tribal government but is somewhat complicated due to the federal government's trustee role for tribal nations (Thorson et al. 2006). Theoretical measurements of institutional strength may be derived from individual case studies of reservation governance, such as the Honoring Nations reports and case studies produced by the Harvard Project for American Indian Economic Development.[2] However, due to the limited and individualized nature of such case studies, extracting a singular representative variable for institutional strength to be used in an empirical model is difficult. Tribal constitution structure, whose adoption impacts were discussed by Akee, Randall, & Jorgensen (2015), could also represent institutional strength, due to its dictation of government operation. However, many tribal nations are in the midst of rewriting constitutions in efforts toward renewed nation building, and this complicates this variable's potential inclusion and therefore it is excluded in the empirical model. As mentioned, recovery is acknowledged in Martin & Sunley (2015) and Dinh et al. (2017) as being a directly observed time element. This dimension is not expanded upon here due to the limited time periods for which ACS data is available.

[2] Research Overview, retrieved from https://hpaied.org/publications-and-research

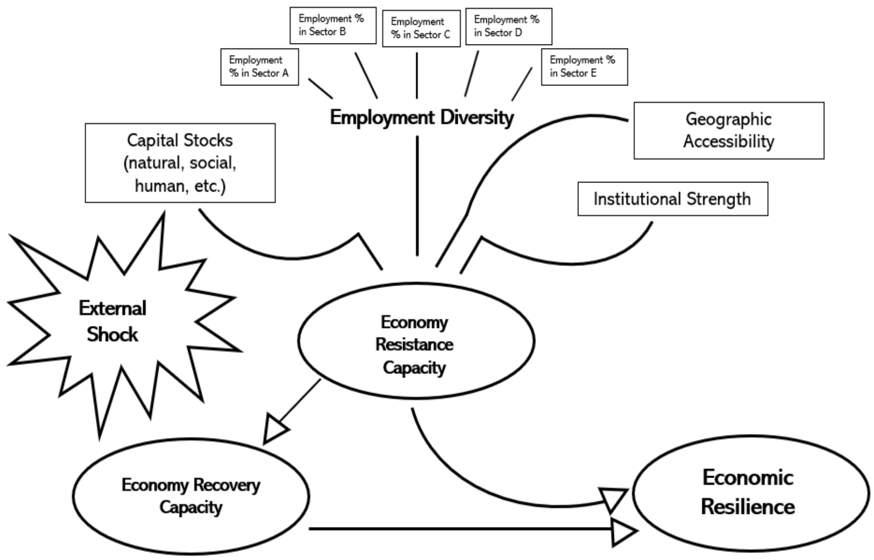

Figure 3.2: Economic Resilience Factors focuses on theorized factors of resistance

Consider a conceptual framework for an economy's resistance capacity and resilience based on figures 3.1 and 3.2:

$$Economy\ Resistance\ Capacity$$
$$= f(institutional\ strength, capital\ (resources)\ available, employment\ diversity, accessibility)$$

$$Resilience = f(Economy\ Resistance\ Capacity, Economy\ Recovery\ Capacity)$$

Due to temporal data constraints as well as difficulty in obtaining all metrics for all reservations (the observation of a shock, an indicator of economic equilibrium, and all factors influencing economy resistance capacity), the modeling in this study focuses on measurement of income as an indicator of an equilibria. Explanatory variables within the model include observable measures, feasibly related to economy resistance capacity, following from model iterations by Deol & Colby (2018) and Young (2019). Therefore, the proposed model draws from the observable characteristics of the flowchart and focuses mainly on the novel inclusion of employment diversity. It is described as follows:

$$Income = f(human\ capital, natural\ capital, employment\ diversity, accessibility, years\ past\ shock)$$

Based on this definition, table 3.1 details the sign and magnitude of the relationships between per capita income and the independent variables included in the empirical portion of the study.

Variable Name	Resistance Capacity Element	Expected Relationship with Per Capita Income
State Fixed Effects	Accessibility, Spatial Control	+/-
Hachman Index	Employment Diversity	+
Shannon's Index	Employment Diversity	+
Herfindahl Index	Employment Diversity	-
Employment Percentage	Human Capital	+
Percent of Reservation Population 25 and Older with a Bachelor's Degree	Human Capital	+
Population per Acre	Human Capital, Spatial Control	+
Quantified Water Rights	Natural Capital, Employment Diversity	-
Years is 2012	Years Past Shock	-

Table 3.1: Expectation of Variable Relationships with Income

Accessibility is thought to benefit economic performance, therefore population per acre is expected to have a positive relationship with income. State fixed effects, while signaling accessibility through location and differences in state government, are expected to have an ambiguous sign. Certain states may have reservations with specific patterns to their remoteness to non-tribal urban centers and therefore greater employment opportunities. Additionally, state governments can impact reservations through the delay of Winters settlements. The measures of employment diversity, Hachman, Shannon, and Herfindahl, are expected to have a positive, positive, and negative expected relationship with income, respectively. The alternating sign is due to Shannon's index and the Hachman index indicating higher diversity through larger index values and the Herfindahl index indicating higher diversity through smaller index values. The measures of human capital – employment rate, population per acre, and bachelor's degree attainment – are expected to have positive relationships with income. Quantified water rights, though intuitively thought to have a positive impact on income due to increased natural capital and potential employment diversification opportunities (such as water being apportioned to a resort golf course), is expected to have a negative impact due to the results of Doel & Colby (2018) and Young (2019). Finally, the number of years past shock, functioning as a recovery period, is expected to have a positive relationship with income (therefore, Year is 2012 holds a negative relationship). It should be noted that while income is interpreted as an economic performance metric and employment diversity is interpreted as a component of economic resilience, the direction of causality between employment diversity and income remains unclear.

Chapter 4*: Study Area and Data*

The dataset described in this chapter is cross-sectional, with two observations for each of the 74 included reservations at two different time periods, 2008-2012 and 2014-2018, for a total of 148 observations. Not including spatial fixed effects, there are eight independent variables of interest that are listed in table 3.1. There is one dependent variable of interest: the natural log of per capita income. The data was primarily compiled from two ACS data tables,five- Selected Economic Characteristics and Education Attainment (U.S. Census Bureau 2020). Shannon's index and the Herfindahl index were calculated using the industry variables, as defined by the North American Industry Classification System (NAICS) within the economic characteristics table. The Hachman index for each of the eight states in the study was calculated using the same industry divisions from the Selected Economic Characteristics table generated at the state level. Additional reservation characteristics were collected through supplemental online research and utilization of the U.S. census reservation shapefiles within ArcGIS software (U.S. Census Bureau 2019).

4.1 Study Area

The study area comprises American Indian Reservations and ,Off-Reservation Trust Land in the western states of Arizona, Utah, New Mexico, Colorado, Nevada, Idaho, Montana, and Wyoming. These states were chosen due to their larger[3], treaty-granted reservations and similarly arid climates, which inform water rights claims. While there is a total of 89 federally recognized reservations within these states, only 74 were used in this study due to missing data in one or both time periods, or a low enough reported labor force to concentrate employment entirely in one sector.[4] Categorized by state, the dataset includes 18 reservations in Arizona, 2 in Colorado, 4 in Idaho, 8 in Montana, 24 in Nevada, 19 in New Mexico, 3 in Utah, and 1 in Wyoming. For reservations that fall within multiple state boundaries, the reservation is assigned

[3] Reservations in the designated western states are generally geographically larger and more populous than reservations in non-western states. The treaty system granted larger swaths of land in West to tribes, whereas reservations created by the Indian Appropriations Act in other parts of the U.S. led to systemically smaller reservations.

[4] For example, in 2012 the Kootenai Reservation is reported as having 5 people in its labor force. Those 5 people are all employed in the public administration sector, leading to the public administration sector having 100% of the reported reservation employment.

to the state that contains most of the reservation's area. To represent the spatial and political differences between the states – particularly acknowledging the impact that states can have on water rights quantification – 7 state fixed effects are created: *Arizona (AZ), Colorado (CO), Idaho (ID), Nevada (NV), New Mexico (NM), Utah (UT)*. Note that here, Wyoming is the base case and excluded.[5]

Regarding spatial designation within the ACS data, the used ACS tables are inclusive of all American Indian Areas, Alaskan Native Areas, and Hawaiian Homelands. The Alaskan Native Areas, Hawaiian Homelands, and the American Indian Areas in the non-designated Western states were culled from the dataset. Additionally, all American Indian Areas in the designated Western states that are not categorized as federal reservations were culled. Lastly, the remaining reservations were further culled based on the previously described criteria. Again, the final number of reservations included is 74, totaling 148 observations between the two time periods.

4.2 ACS and Economic and Educational Attainment

The ACS data was obtained through the U.S. Census's online data portal data.census.gov, with the five-year data tables Selected Economic Characteristics (table DP03) and Educational Attainment (table S1501) downloaded at two time periods (U.S. Census Bureau 2020). The 2012 five-year estimates, which range from 2008-2012, were appended to the 2018 five-year estimates, which cover 2014-2018. The five-year estimates were chosen as they are more accurate for smaller populations due to the data averaging over a longer time period as compared with the one or three-year estimates (Torrieri et al. 2014). The DP03 five-year estimates were also downloaded at the state spatial scale, for the industry variables to be used in the calculation of each reservation's Hachman index. To distinguish between the two time periods a binary variable, Year is 2012 (YR2012) was created. If the ACS year the observation appeared in is from the 2012 data, then it takes a value of 1, otherwise it takes a value of 0.

From the ACS DP03 table, variables of interest include the reservation's employment rate, distribution of industry employment, and income levels. ACS categorization of employment

[5] Off-reservation trust land may be in a different state than the reservation itself. As ACS reporting groups reservation and off-reservation trust land data together, as one observation, out-of-state off-reservation trust land also takes the state designation of the reservation.

rate does not differentiate between full-time or part-time work, it derives the employment status of a respondent through 7 questions and measures employment and labor force participation based on that criteria.[6] The ACS distinguishes between year-round and seasonal work, though variables based on this question are not included in the DP03 table. Of the income measures included, per capita income was chosen as the dependent variable due to it being reported for all reservations in the dataset. The ACS adjusts its five-year income measures for the most recent year in the five-year estimate table, therefore the 2012 income measures are reported at the 2012 real income level, and the 2018 income measures are reported at the 2018 real income level. Per capita income is coded in the model as PERCAPINC and is given a natural log transformation to enable the estimation of log-linear models, therefore the natural log of PERCAPINC is included as the dependent variable in all model specifications and coded as LNPERCAP. The other variable directly included in the model from the DP03 table is reservation employment rate, coded as EMPLYPERC. The DP03 table was also downloaded at the state spatial scale for the 8 states in the study area in order to calculate the Hachman index for each reservation. As state level data is only of interest regarding industry employment percentages, no other state level data was used in the empirical portion of this thesis. From the S1501 table, only one variable is used, the percentage of bachelor's or higher level degree attainment for the population 25 and over. This variable is coded within the dataset as BOHIGH (bachelor's degree or higher).

4.3 Industry Diversity Calculation

The measures of job sector diversity by industry were derived from the NAICS categorized industry variables obtained in table DP03 at the reservation and state spatial scales. Identification of the respondent's industry of employment is based on several ACS questions prompting the respondents to describe their place of employment, occupation, and job (Torrieri et al. 2014). From these questions and an additional question asking if the respondent works within the wholesale or retail trade industries, the respondent's occupation is coded within one of 13 categories. The categories are:

- Agriculture, forestry, fishing, hunting, and mining (AG)

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[6] The ACS has been known to report higher levels of employment than other American population surveys, such as the Current Population Survey. See Local Area Unemployment Statistics provided by the Bureau of Labor Statistics.

- Construction (CON)
- Manufacturing (MAN)
- Wholesale trade (WT)
- Retail trade (RT)
- Transportation and warehousing, and utilities (TRANS)
- Information (INF)
- Finance, insurance, real estate, rental, and leasing (FIN)
- Professional, scientific, management, administrative, and waste management services (PROF)
- Educational services, healthcare, and social assistance (ED)
- Arts, entertainment, recreation, accommodation and food service (REC)
- Other services except public administration (OTH)
- Public administration. (PUB)

Each of these categories reports a percentage of the employed population working in that industry of employment. As the NAICS categories attempt to fully encompass an incredibly diverse number of occupations, this categorization does not necessarily indicate high levels of similarity between occupations that may fall within the same category. Additionally, while the Bureau of Labor Statistics reports average wage data for the NAICS categories, wage data is not included due to this study's focus only on the diversity of industry employment.

Job sector diversity is calculated based on an analysis of the industry employment percentages present in the DP03 table. The presence of the industry on or near the reservation or the comparative revenue generated from that sector is not accounted for. Therefore, the sectoral diversity score essentially represents the diversity of industries of employment for the reservation population. The employment diversity of a reservation is calculated by three different diversity indices, Shannon's index and the Herfindahl index, which only reference the reservation's industry employment proportions, and the Hachman index, which measures the reservation's industry employment proportions against those of the state the reservation is primarily located within. Shannon's index and the Herfindahl index are similar measures and are both explored due to their alternating signs providing a mutual robustness check. Shannon's index is commonly used in biology as a measure of species richness, calculating a biodiversity score based on the relative abundance of the number of species in a habitat. It is applied here with industries substituting for species, and is estimated by:

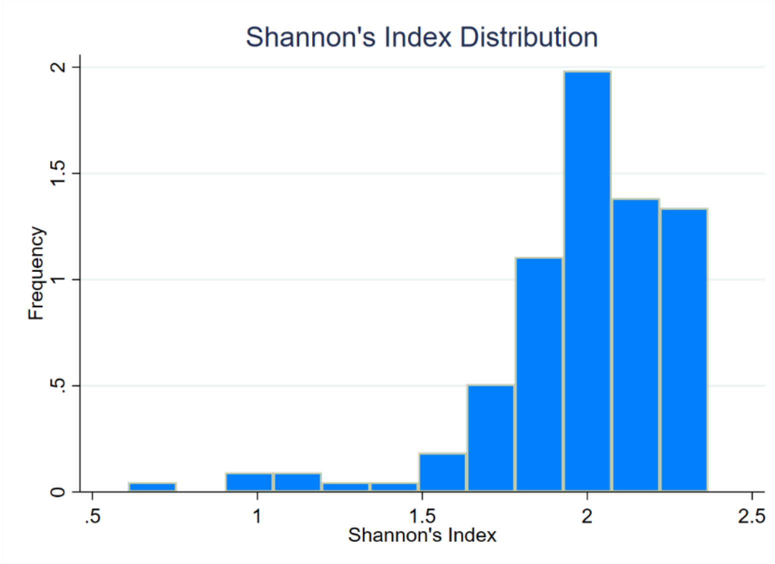
$$H = -p \sum_{i=1}^{S} ln\ (p) \qquad (1)$$

Here *S*, can be interpreted as the number of industries offering employment to a reservation community, though these industries are not necessarily located on reservation land (based on the NAICS categories, *S* would be 13). *P* is the proportion of employment observed in each industry, *i.* The summation of the p_i operation for all industries results in the sectoral diversity score for that reservation. The employment diversity score can range from 0, in which the entire employment of the reservation would be concentrated in one sector, to 2.564949357, in which employment proportion would be evenly spread across all 13 sectors. To this author's knowledge, the application of Shannon's index for use in measuring employment diversity is unique. Shannon's index is coded in the data as *SHAN*.

The Herfindahl index offers a similar measurement of diversity more commonly seen in economics literature, particularly in the calculation of firm concentration within an industry. It estimates diversity through the function:

$$H = \sum_{i=1}^{S} p^2 \qquad (2)$$

with the variable representations *s, p*, and *i* within (2) remaining consistent from their interpretation in Shannon's index. The Herfindahl index ranges between 1 and approximately 0, with 1 being the least diverse outcome and 0.07687693 being the most diverse given 13 sectors. The Herfindahl index is coded in the dataset as *HERF*. While the range of both the Herfindahl index and Shannon's index are small, Shannon's index sees a wider distribution of values with a higher magnitude. Because of this, Shannon's index is expected to have a smaller magnitude coefficient compared to the Herfindahl index within the model specification. Both Shannon's index and the Herfindahl index show significant clustering around their 'more diverse' value ranges. This clustering can be seen in figures 4.1a and 4.1b. The log of both Shannon's index and the Herfindahl Index were taken to explore potential changes in distribution. However, similar spreads were found after the log transformation.



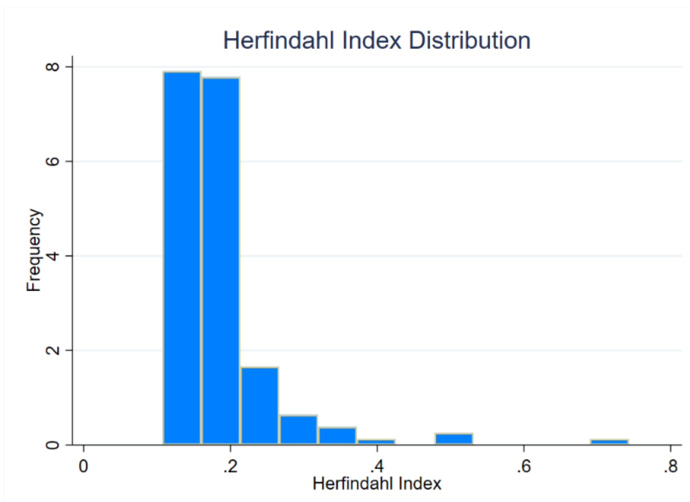


Figure 4.1a and 4.1b: Distribution of the Shannon Index and Distribution of the Herfindahl Index

Certain reservations had systematically missing data for the employment category variables and therefore neither a Shannon nor a Herfindahl score could be calculated. These reservations were removed for the econometric analysis and are not included in the 148-observation count.

The third included diversity index, the Hachman index, is a comparative measure of sectoral diversity. The Hachman index compares a given region's employment proportions across observed sectors to the proportions of a reference area, usually at the national level, measuring the similarity between the region of interest and the reference area. The calculation of the Hachman index for each of the reservations included in the study, here the regions of interest, is performed with the state the reservation primarily falls within as the reference area. Like Shannon's index and the Herfindahl index, the Hachman index is calculated across the 13 sectors of employment reported in the ACS as defined by the Bureau of Labor Statistics. The Hachman index is bounded between 0 and 1, here a value of 1 indicates a regional economy that is perfectly similar to the reference economy, whereas a value of 0 indicates a completely dissimilar regional economy from the reference economy. The formula for the Hachman index is as follows:

$$H_{RES} = 1/(\sum_{j=1}^{n}((p_{RESj}/p_{STATEj}) * P_{RESj})) \quad (3)$$

Again, P represents the proportion of employment in sector j, both at the state and reservation level. The reservation proportion of employment in sector j is divided by the state proportion of employment in sector j, resulting in a location quotient for each industry. The location quotient is then multiplied by the reservation proportion of employment in sector j again to normalize the industry share. This calculation is repeated and summed across each of the 13 sectors, with the reciprocal of the summation resulting in the Hachman index for the reservation in question. While the Hachman index does mainly quantify the likeness between the region of interest and the reference area, if the region of interest is similarly diverse to the reference area but does not have the same areas of concentration, it will still report a score closer to 1. In this way, the Hachman index only penalizes reservations with different areas of concentration than the reference area if they are also, in general, less diversely distributed (Hachman 1995; Shaleen 2016). Table 4.1 reports the average Hachman indices for 2012 and 2018 by state for the 74 included reservations. The Hachman index is coded as HACH within the model.

State	**Number of Reservations in State**	**2012 Average Hachman Index**	**2018 Hachman Index**
Arizona	18	0.483501856	0.512053548
Colorado	2	0.634055658	0.549200477
Idaho	4	0.611382063	0.673929709
Montana	8	0.707734667	0.707734667
Nevada	24	0.365723482	0.368661777
New Mexico	19	0.683286849	0.741028531
Utah	3	0.276923449	0.427101531

Wyoming	1	0.96492	0.961669

Table 4.1: Average Reservation Hachman Indices by State and Year

4.4 Additional Reservation Characteristics

Additional reservation characteristics were gathered from online sources and were cross referenced with previous reviews of western U.S. reservation characteristics provided by Deol & Colby (2018) and Young (2019). The status of a tribe's water rights is taken from the Congressional Research Service's report on Indian Water Rights Settlements (Stern 2020). Updated in May of 2020, the document includes information on tribes with enacted water rights settlements and those with appointed negotiation teams. The only tribe that gained a water right settlement between the first and second time period was the Blackfeet Indian Reservation. If a tribe has an enacted water right settlement the binary variable, *WTRRGHT* takes a value of 1. Otherwise, it takes a value of 0. Figure 4.2 provides a map that distinguishes reservations with quantified water rights from those without quantified water rights.

As reservation size and population density is also of interest, reservation population per acre is calculated and included in the dataset. Reservation size is measured in ArcMap, using the U.S. Tiger/Line 2019 shapefiles for reservations. In shapefile documents downloaded from the US Tiger/Line Database, area is initially coded as meters squared, and the total area of a given reservation is split between two measurements, land area and water area. Those values are added together to obtain the total meters squared of the reservation. While these values can conflict with listed acreage given by tribal governments, they are internally consistent and therefore are preferable to obtaining acreage amounts from separate sources for each reservation. In cross-referencing the area listed in the shapefiles with individually reported reservations, the disparity between the two values follows no discernable pattern. The additive water and land amounts were then converted from meters squared to acres. The acreage amount was then divided by the civilian non-institutionalized population, a variable listed within the DP03 table. The population per acreage variable is coded as POPPACRE.

The summary statistics for all variables detailed within this section and included in the empirical model specifications detailed in chapters 5 and 6 are listed in table 4.2.

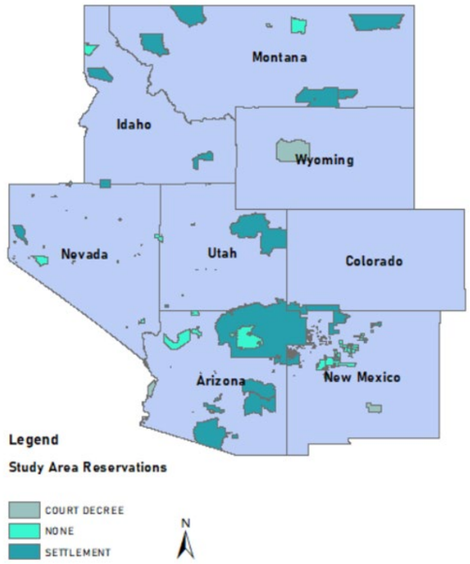


Figure 4.2: Water Rights Status of Study Area Reservations

VARIABLE	ALIAS	Description	OBS	MEAN	STD. DEV.	Min	Max
Per Capita Income*	PERCAPINC	Continuous variable; per capita income of reservation	148	17465.88	5931.061	8672.495	35887
Natural Log of Per Capita Income*	LOGPERCAP	Continuous variable; log of per capita income	148	9.714973	.322411	9.0679112	10.48813
Year is 2012	YEAR2012	Binary variable; takes a value of 1 if the year the data was observed in was 2012 and a 0 otherwise	148				
Employment Percentage	EMPLYPERC	Continuous variable; percent of	148	45.734	9.305673	20.4	75.9

		population living on reservation 16 and older and employed					
Bachelor's Degree Attainment or Higher	BOHIGH	Continuous variable; percent of reservation population aged 25 and older with a bachelor's degree	148	10.332	6.926094	0	28.5
Water Rights Status	WTRRGHT	Binary variable; takes a value of 1 if a reservation has settled Winter's rights, otherwise takes a 0	148	.5466667	.4994852	0	1
Population Per Acre	POPPACRE	Continuous variable; noninstitutionalized civilian population divided by the number of acres within the reservation	148	.3726512	1.526441	.0007154	13.1
Hachman Index	HACH	Continuous variable; comparative state diversity index described in section 4.2	148	.558234	.2170046	.0353467	.9616689
Shannon's Index	SHAN	Continuous variable; diversity index described in section 4.2	148	1.985742	.2817927	.6086012	2.366711
Herfindahl Index	HERF	Continuous variable; diversity index described in section 4.2	148	.1847925	.0776118	.107533	.742891

State Fixed Effects (Arizona, Colorado, Idaho, Nevada, New Mexico, Utah, Wyoming	AZ, CO, ID, NV, NM, UT, WY	Binary variables; takes a value of 1 if reservation is in a specified state, other takes a 0, Montana is the base case

**Income measures given in 2018 constant year dollars*

Table 4.2: Summary Statistics

Chapter 5*: Empirical Model*

With the basis of the conceptual model outlined in chapter 3, an empirical model specification is constructed based on the variables described in chapter 4. This model intends to measure the relationship between employment diversity, as measured by Shannon's index, the Hachman index, and the Herfindahl index, and per capita income. The models employed are multivariate log-linear ordinary least squares (OLS) specifications, with the natural log of per capita income taken in order to interpret the independent variable relationships with income in terms of percentages. As mentioned in chapter 3, while diversity and income have an expected positive relationship, the direction of causality between employment diversity and income is unclear. It may be that employment diversifies due to unobserved factors external to the reservation, naturally leading to a higher percentage of the workforce employed in higher paying positions. Employment diversification may also be spurred by internal reservation characteristics, such as the quantification of water rights. As discussed in chapter 2, this could plausibly lead to job creation – most likely in the AG or REC sectors. Alternatively, higher income may indicate a greater level of capital within or around the reservation that could incentivize employers of various industries to locate on or around the reservation and hire reservation residents, thereby increasing the level of employment diversity on the reservation.

As there are several potential narratives of causation, it is of interest to closely examine the changes in per capita income alongside the changes in employment diversity indices for the two time periods. To explore this fully, a first difference approach would seem ideal, as it would directly capture the change between the two datasets. Though a first difference model was initially employed, due to the data encompassing only two time periods, with a few number of independent variables, the model's robustness is severely inhibited and reports only EMPLYPERC as a significant variable with a small magnitude coefficient. A Wald Chi-Square test was performed in which the null hypothesis was not rejected, indicating the model did not statistically explain the data. For these reasons, the first difference model was not pursued further. See appendix C for the full first difference model results.

Despite the insignificance of the first difference model, an investigation of the changes observed between the two time periods is warranted. Table 5.1 summarizes the average percent change between the 2012 and 2018 data for income and the diversity indices. All four variables show positive changes. Per capita income increases by approximately 3.679%. Shannon's index increases by approximately 1.9%, while the Herfindahl index decreases by approximately 5.1%. As described in chapter 4, a lower Herfindahl index indicates a more diverse distribution of employment across sectors. Therefore, a negative percent change in the Herfindahl index aligns with the positive percent change seen in Shannon's index. The Hachman index, like the other diversity indices, also increases between the two time periods, growing approximately 4.5%.

	Per Capita Income	**Hachman Index**	**Shannon's Index**	**Herfindahl Index**
2012 to 2018 Percent Change on Reservations	3.679%	4.476%	1.906%	-5.103%

Table 5.1: 2012 to 2018 Percent Change for Income and Diversity Index Variables

The OLS model specifications differ in the primary independent variables of interest. The Hachman index is the only measure of employment diversity within the first specification. The independent diversity measures, the Shannon and Herfindahl indices, are individually introduced in specifications 2 and 3 alongside the Hachman index. Inclusion of both a comparative diversity measure and a noncomparative diversity measure helps to disentangle the impact of state level influence on the diversity metric within the model. Additionally, implementing two different measures of noncomparative employment diversity allows the results to be checked for consistency, ensuring anomalies in either measure do not account for the significance or insignificance of the results. With these alternative specifications in mind, the empirical model is defined as follows:

$$\begin{aligned} ln(Per\ Capita\ Income)_{it} \\ = \beta_0 + \beta_{1it}YEAR2012 + \beta_{2it}EMPLYPERC + \beta_{3it}BOHIGH + \beta_{5it}WTTRGHT \\ + \beta_{6it} + \beta_{7it}POPPACRE + \beta_{8it}DIVERSITYINDEX + \varepsilon_{it} \end{aligned}$$

The subscripts *i* and *t* refer to the reservation being observed and the time period of the observation, i.e. reservation *i* being observed time period *t*. The *i* subscript refers to the 74 reservations included in the study, while the *t* subscript refers to the two time periods of reservation observations, resulting in 148 total observations. Table 5.2 summarizes the four different specifications of the model above.

	Model Specification 1	**Model Specification 2**	**Model Specification 3**
Measure of Employment Diversity	Hachman Index	Hachman Index and Shannon Index	Hachman Index and Herfindahl Index

Table 5.2: Model Specifications

The Year is 2012 (YEAR2012) binary variable is included to represent distance from the shock, referenced as Years Past Shock in chapter 3's theoretical model description. While this does not perfectly encapsulate a post-shock indicator, the observations from 2018 represent a period of comparative economic stability, while the 2012 observations include data from the Great Recession of 2007-2008 and its recovery period. Percent Employment (EMPLYPERC) is included as a signal of human capital, as well as being linked directly with income. Percent of Reservation Population 25 and Older with a Bachelor's Degree or Higher (BOHIGH) also is representative of human capital. Population per Acre (POPPACRE) is a normalized population measure, meant to capture the human capital level with respect to the size of the reservation. Additionally, reservations with a particularly low POPPACRE may signal more remote reservation employment opportunities, though certainty of this secondary use likely requires further spatial analysis. Water Rights Status (WTRRGT) is included as a signal of natural capital and an alternative indicator of employment diversity. Finally, DIVERSITYINDEX refers to the Hachman index (HACH) and either Shannon's index (SHAN) or the Herfindahl Index (HERF), depending on the model specification. State-level fixed effects, with the base case of Wyoming, are included for 7 of the states in which study area reservations are located. State-level fixed effects (CO, AZ, ID, NM, NV, UT, WY) are again hypothesized to impact reservation income as state governments are involved in both tribal water rights settlements and the regulation of casino operations as well as posing spatial differences. While California is not included in this study, Akee, Randall & Jorgenson's (2015) assessment of California's late start to Class III gaming operations provides a salient example of how a state government can impact the economic development of reservations within state boundaries.

Other variables were included in alternative iterations of the model, with their regression results reported in appendix D. The Shannon and Herfindahl indices were interacted with percent employment to test the intuition that high levels of employment alongside high level of employment diversity would hold a higher magnitude relationship with income, following the intuition that the impact of employment diversity could feasibly be negligible if the level of employment on the reservation was too low. Mean commute time in minutes and casino presence are two variables that were both included in initial specifications of the models. Both variables were insignificant in all specification in which they were included, with casino presence depressing the significance of the state fixed effects. Additionally, models were run on the 2012 and 2018 data separately, without the Hachman index, and without water right's status.

Chapter 6: Results & Discussion

6.1 Results

The initial results of the three OLS model specifications detailed in chapter 5 are summarized in table 6.1. The coefficients for each model are listed with their robust standard errors directly below.

VARIABLES	(1) Hach	(2) Hach Shan	(3) Hach Herf
YR2012	-0.0237	-0.0219	-0.0223
	(0.0342)	(0.0337)	(0.0339)
EMPLYPERC	0.0138***	0.0133***	0.0135***
	(0.00233)	(0.00232)	(0.00237)
BOHIGH	0.0317***	0.0314***	0.0323***
	(0.00381)	(0.00335)	(0.00335)
WTRRGHT	-0.0549	-0.0582	-0.0571
	(0.0407)	(0.0405)	(0.0405)
POPPACRE	-0.0201	-0.0220	-0.0216
	(0.0157)	(0.0156)	(0.0155)
HACH	-0.0325	-0.264*	-0.236
	(0.138)	(0.154)	(0.147)
SHAN		0.206*	
		(0.108)	
HERF			-0.671**
			(0.313)
AZ	-0.0231	-0.0704	-0.0623
	(0.0808)	(0.0824)	(0.0828)
COL	-0.109*	-0.167***	-0.167***
	(0.0612)	(0.0631)	(0.0626)
IDA	0.0840	0.0305	0.0423
	(0.0513)	(0.0590)	(0.0566)
MON	-0.289***	-0.303***	-0.306***
	(0.0626)	(0.0600)	(0.0618)
NEV	0.163*	0.0955	0.0957
	(0.0900)	(0.0928)	(0.0933)
NM	-0.142**	-0.165***	-0.169***
	(0.0601)	(0.0608)	(0.0618)
UT	0.0532	-0.0517	-0.0406
	(0.0950)	(0.0967)	(0.0959)
Constant	8.847***	8.641***	9.134***

	(0.199)	(0.210)	(0.247)
Observations	148	148	148
R-squared	0.629	0.644	0.644

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Table 6.1 OLS Model Results

The three model specifications presented in table 6.1 will be referred to as 6.1 model 1, 6.1 model 2, and 6.1 model 3. The model shows consistency in variable coefficients and robustness across all 3 specifications. The R-squared values for all three model specifications are consistent, ranging from 62.9 – 64.4%. The reported R-squared value are higher than similar specifications reported in Deol & Colby (2018) (using 178 observations in OLS models of reservation income, Deol & Colby (2018) found R-squared values between 11-12%). EMPLYPERC and BOHIGH are all significant at the 5% level across all 3 specifications, both reporting a positive relationship with income. The Hachman index is significant only in 6.1 Model 2 at the 10% level, unexpectedly taking a negative sign. The Shannon and Herfindahl Indices are significant at the 5% and 10% levels, respectively, they follow their expected signs. State fixed effects that are found to be significant only for Colorado, New Mexico, and Montana, which all also have a negative sign. POPPACRE and WTRRGHT are both negative and insignificant across all specifications.

By adjusting the coefficients to accommodate the log-linear specification of the model, the effects of the significant variables on per capita income can be expressed in percent changes. In 6.1 model 1, a 1% increase in the employment percent leads to a 1.38% increase in income, with the other two specifications reporting marginally lower increases. These results are significant at 1% level. For BOHIGH, a 1% increase yields a 3.17% increase in income in model 1, again with similar results reported in similar specifications. The Hachman index coefficient's impact on income in accordance with a 1% increase in its value ranges from -3.25% to -26.4%, with -26.4% in model 2 being the only significantly reported coefficient. In the case of the Shannon's index in model 2, a 1 unit increase would lead to a 20.6% increase in income. For the Herfindahl index in model 3, a 1 unit increase would result in a 67.1% decrease in income. Again, as discussed in chapters 4 and 5 the negative relationship is expected, as higher Herfindahl index values indicate less diversity of employment for the reservation population. The high degrees of magnitude seen in both the Herfindahl and Shannon indices' coefficients reflect their small range of values. A unit of an increase change in either index would be dramatic in either case, therefore more reasonable changes might be expected to be at the level of a tenth of a percent (2.06% increase in income for every 0.1 of a unit increase in the Shannon's index, and a 6.71% decrease in income for every 0.1 of a unit increase in the Herfindahl index). Though the magnitude of the Herfindahl index is larger, the coefficients of both the Shannon and Herfindahl reflect by far the largest magnitudes among the variables included within the model. The dummy variables, except for state fixed effects, are all insignificant within the model specifications. Even, YR2012 which was hypothesized to hold a significant, negative relationship with income due to the shock period it is thought to encompass, is insignificant across all three specifications, though it holds the expected sign.

To analyze the three cases in which state fixed effects were significant, the coefficients for Colorado, Montana, and New Mexico, were adjusted using the Halverson & Palmquist (1980) method for interpreting dummy variables in log-linear models. Reporting the adjusted coefficients for these variables in models 2 and 3, the effect of a reservation being located in Colorado results in a 15.3% decrease in per capita income, reservation location in Montana results in a decrease in per capita income ranging from -26.14% (model 2) to -26.36% (model 3), finally the effect of reservation location in New Mexico results in a per capita income decrease ranging from 15.2% (model 2) to 15.55% . As evident, all three states report negative effects on income. While Colorado and Montana both have a relatively small number of reservations, with 2 and 8 respectively, New Mexico has 19, which is considerable larger. Due to the low reservation counts in Colorado's case, the variable does not represent a state effect, but rather the individualized effect of a reservation (or 2) when compared with the Wyoming base case. Despite the significance of only three of the seven included state fixed effects, the model specifications with state fixed effects were chosen due to their higher R-Squared values and to maintain a spatial control beyond population per acre.

6.2: Diagnostics and Robustness Checks

In order to test for high levels of multicollinearity, the Variance Inflation Factor (VIF) for each of the variables was measured alongside regressions of the independent variables with suspected collinear relationships. The VIF measures and the independent variable regressions provide similar results, so only the VIF measures are reported in table 6.1. Of note, there was no significant linear relationship found between the diversity measures and quantified water rights. Five state fixed effects report a VIF greater than four, the general cutoff for a high level of multicollinearity. The state fixed effects are likely colinear with the Hachman index, due to its inclusion of state industry levels in its calculations. The states with high VIF scores are Nevada, Arizona, New Mexico, Montana, and Idaho. Because of the multicollinearity resulting from the inclusion of state fixed effects, and because most state fixed effects held high VIF scores, model iterations without state fixed effects were also investigated.

	Model Specification 1 (HACH ONLY) – VIF	**Model Specification 2 (HACH SHAN) – VIF**	**Model Specification 3 (HACH HERF) – VIF**
YR2012	1.01	1.01	1.01
EMPLYPERC	1.25	1.27	1.26
BOHIGH	1.86	1.86	1.87
WTRRGHT	1.34	1.34	1.34
POPPACRE	1.10	1.11	1.10
HACH	2.25	3.89	3.53
SHAN	-	2.20	-
HERF	-	-	1.79
AZ	17.29	17.56	17.48
COL	3.11	3.17	3.16
ID	4.01	4.08	4.05
MON	8.67	8.68	8.69
NV	20.62	21.24	21.24
NM	15.58	15.65	15.67
UT	3.38	3.56	3.53

Table 6.2: Multicollinearity Test

In order to assess the presence of heteroskedasticity in the model, both a Breusch-Pagan Test and White’s Test were performed on the model specifications. In both tests the null hypothesis is that there is no heteroskedasticity in the model, As seen in table 6.3, in both cases, the Breusch-Pagan Test found evidence to not reject the null hypothesis of homoskedasticity, as did White's Test. Despite both the Breusch-Pagan test and White's Test not rejecting the null hypothesis of no heteroskedasticity, the standard errors were adjusted to White's Robust Standard Errors and are reflected in the results in table 6.2.

Model	**Breusch-Pagan Test P-Value**	**White's Test P-Value**	**Results**
Model 1 (HACH ONLY)	0.9074	0.9092	Breusch-Pagan: Do not reject null White's: Do not reject null
Model 2 (HACH SHAN)	0.8959	0.5291	Breusch-Pagan: Do not reject null White's: Do not reject null
Model 3 (HACH HERF)	0.8728	0.8663	Breusch-Pagan: Do not reject null White's: Do not reject null

Table 6.3: Heteroskedasticity Tests

In order to address the high VIF scores reported for the state fixed effects, models were estimated without state fixed effects with a focus given to the impact on the diversity index coefficients. The full regression tables for these iterations are available in appendix D.1. Table 6.4 provides a summary of the differences between the two model iterations. Dropping the state fixed effects from the model, Shannon's index and the Hachman and Herfindahl indices all increase in significance and magnitude. All three variables are significant at the tenth of a percent level in the D.1 specifications. The Hachman index nearly doubles in magnitude, with a

1 unit increase now indicating decreases in income ranging from 30.8% to 62.2%. A 1 unit increase in Shannon's index now indicates a 36.2% increase in per capita income, and a 1 unit increase in the Herfindahl index now indicates a 115.1% decrease in income. In all D.1 model specifications, the diversity indices held the highest magnitude impacts on income, again due to their small range leading. Despite the greater level of significance in the diversity indices, these models were not chosen as the primary models over the specifications that include state fixed effects due to a desire to maintain spatial controls within the model. As mentioned within chapter 3, state fixed effects may signal differences in reservation accessibility or as mentioned in chapter 4, affect decisions such as Winter's rights quantification.

	6.1 Model 1	**6.1 Model 2**	**6.1 Model 3**	**D.1 Model 1**	**D.1 Model 2**	**D.1 Model 3**
Hachman Index	-0.0325	-0.264*	-0.236	-0.308***	-0.622***	-0.572***
Shannon Index	-	0.206*	-	-	0.362***	-
Herfindahl Index	-	-	-0.669**	-	-	-1.151***

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$,

Table 6.4: Comparison of Hachman Coefficients with Shannon and Herfindahl Coefficients Across Model Iterations

Alternative model specifications were estimated in order to check the robustness of the coefficient estimates and the variability of model results. As the 2012 and 2018 data periods were posited to represent shock and recovery periods, respectively in chapter 3, models were run with each of the time periods separately to investigate the claim further. YR2012 was removed and the three specifications were run on each time period's 74 observations. The 2012 data reports higher levels of significance for the diversity indices as compared to the primary model, while the 2018 does not report any significant diversity index variables. The full regression results for these iterations are available in appendix D.2A and D.2B.

To explore the impact of Shannon's index and the Herfindahl index without the presence of the Hachman index, additional model specifications were run in which either SHAN or HERF was the only diversity measure included. In both instances, SHAN and HERF were insignificant, indicating that the inclusion of both the comparative Hachman Index alongside the noncomparative indices allows for greater explanatory power within those diversity metrics. As the Hachman Index controls for differing levels of employment sector concentration between states (i.e. Nevada has a slightly higher percentage of REC employment than the other states) and the similarity of reservations to their state concentrations, the Shannon and Herfindahl indices represent the level of reservation employment diversity separate from considerations of state employment diversity. The full regression results for these specifications are available in appendix D.3. Additional model specifications in appendix D include model specifications without water rights and model specifications with casino presence on reservation indicated by a dummy variable (appendix D.4, appendix D.5). Model specifications in which the Herfindahl and Shannon indices are interacted with employment were also explored in appendix D.6. Appendix E reports estimated results from a previous iteration of this thesis that use 2017 ACS 5-year estimates instead of 2018 ACS 5-year estimates and does not include the Hachman index, it should be noted that appendix E's income measures are in current year dollars rather than constant 2017 year dollars.

6.3 Discussion

Of the diversity index coefficients, the results in 6.1 models 2 and 6.1 model 3 are of the most interest due to inclusion of both the Hachman index and one of the two non-comparative diversity indices. Notably, when included on its own in 6.1 model 1, with the presence of state fixed effects, the Hachman index coefficient is not significant. Similarly, in models referenced in appendix D, when the Herfindahl index and Shannon's index are included as the only diversity index measure within specifications their coefficients are also insignificant (though they do take their expected sign). The impact of the Hachman index being negative is an unexpected result, as conventionally an area having a more similar spread of industry employment to its comparison area (whether at the state or national level) is thought to be indicative of greater economic development (Shaleen 2016). However, reservations have experienced unique circumstances in their formation and are typically exurban. Given that reservations are a qualitatively different spatial scale than other non-reservation regional economies in the U.S., a negative Hachman index coefficient, particularly when coupled with the fact that both the Herfindahl and Shannon indices take their expected sign, may signal that reservations do not see the same positive effects on income from trying to model their employment spread after the state in which they fall within. This interpretation implies that reservations are best served by striving for diverse levels of employment, but that the importance of employment diversity lessens as employment percentage grows higher. Reservations, in addition to being exurban, often have undeveloped land and natural areas serving as wildlife habitat, as there has been less access to capital for the types of economic activities occurring on non-reservation areas. They sometimes offer unique outdoor recreation settings, as well as opportunities for visitors to learn about indigenous culture and history and to purchase arts and crafts. The dis-similarity with the overall state mix of employment, indicated by the econometric findings, may be an economic advantage. This potential advantage should also be considered alongside the limited access to capital reservations may have when pursuing development.

The inclusion of either Shannon's index or the Herfindahl index reinforces this interpretation. When one of the noncomparative diversity measures is present alongside the Hachman index, both indices become significant. As the Hachman index can be thought of as measuring industry employment diversity with respect to the state, the Herfindahl index and Shannon's index only measure industry employment diversity with respect to the reservation itself. The difference between the comparative Hachman and the non-comparative Shannon or Herfindahl is evident in their VIF scores for models in which they are both present. For the models listed in appendix D that only include the Herfindahl index or Shannon index and resulted in insignificant coefficients, this may suggest that the spatial effects of the states were impacting the estimates. Inclusion of the Hachman Index separates the effect of state-driven differences in observed diversity. Furthermore, as seen in table 6.4, when state fixed effects are excluded in the model specifications, all 3 diversity index coefficients are significant. Therefore, industry employment diversity does likely have a spatial component dependent upon the state in which the reservation falls, a phenomenon that can be observed only with the inclusion of both a comparative and non-comparative diversity index.

Beyond the significance of both diversity measures, the reported coefficient of WTRRGHT is of interest. As discussed in chapter 2's literature review, Young (2019) estimated models where they found a negative relationship between counties that had quantified tribal water rights and county income. This relationship was found to be significant at the 10% level at the county spatial scale. Those results were not reflected in the models estimated in this study, as WTRRGHT remained negative and insignificant across all specifications.

The effect of the year being 2012 is insignificant across all specifications and is negative in sign. The insignificance of this variable may indicate that the data may not be capturing post-shock (2012) and recovery (2018) periods as had been hypothesized. Given the limited data (no 1-year ACS estimates available for this time period) and the fact that it averages over 5 years, the exact temporal weight within the period is difficult to determine. 2012, the last year of the first time period of observations, was already 5 years past the start of the Great Recession in 2007. The suspected recovery seen in per capita income from this time period may have occurred primarily within that initial year from 2007-2008, instead of within the 5-year estimate timeframe. When the data is divided between the two time periods and the models are run on the 74 observations from each time period, it is clear the 2008 data drives the significance for the diversity indices in the two time-period model. It could be argued that because the 2012 data is inclusive of a shock period and an immediate recovery period, the diversity indices hold a greater impact on income because they factored into the economy's resistance and recovery capacity within the shock period. Further research is warranted into the typical length of post-shock impacts and recovery periods in order to validate this claim and posit the 2012 data as containing the observable shock recovery data. Again, this study is limited as it does not include data prior to the 2007-2008 recession with which to establish an equilibrium or observable growth path to compare the during or post shock variables against. Additionally, as the two data time periods are 5-year summaries, granularity between years is difficult to observe and comment on. While the limited data the ACS provides on reservations may prevent these changes from taking place, future studies would benefit from being able to establish a pre-shock time period with which to compare post-shock values to, enabling a stronger data narrative to be established.

Chapter 7*: Conclusion*

The models estimated in this thesis add to the literature by quantifying employment diversity and measuring its impact on income at the reservation spatial scale. Particularly, the inclusion of the Hachman index alongside the Herfindahl or Shannon index is novel. Whereas previous econometric studies of reservation income have focused on the historic variables reflecting reservation formation, this effort draws from emerging literature on regional economic resilience that focuses on economic growth paths and adaptive capacity. This study finds evidence that the diversity of employment on reservations contributes positively toward income, particularly when the spread of employment is different from that of the state the reservation falls within. While the explanatory power of the models discussed here is limited by a small number of observations over only two time periods, these findings may spur further exploration of employment diversity impacts as more data becomes available.

As indigenous homelands are further threatened by the shocks such as the COVID-19 pandemic and the effects of climate change, the need for tribal nation building is increasingly imperative. Consequently, exploratory definitions and measurements of economic resilience are important for envisioning the future of reservation livelihoods and economies. While employment diversity represents only one of many potential factors of resilience, it is of interest due to its reoccurrence within the literature as well as data availability that enables its measurement within limited data sources at the reservation spatial scale. The significance and magnitude of both diversity measures across most model specifications is encouraging for further research using these measures. Both the Shannon and Herfindahl indices displayed a greater relative impact on income (in terms of magnitude) than employment or education. Future studies may do well to include the employment diversity measures alongside other hypothesized measures of resilience in order to build a more comprehensive resilience index, as seen in Dinh et al. (2017). Additionally, literature examining reservation economies through a more historical lens could begin to introduce employment diversity as an additional control or area of focus.

Reservation economies are shaped by historic and current day circumstances in a way that is not fully explored within this thesis. The history of oppression and injustice these nations have faced and continue to face deserves acknowledgement through nuanced economic assessments of the industries and opportunities present on these lands. It is important to acknowledge that employment diversity may systematically differ for a reservation community compared with a nearby non-tribal community. Some reservation communities prefer to engage with traditional livelihoods that do not lend themselves to conventional econometric analyses. Further modeling of economic resilience for reservations will benefit from better quality data that is inclusive of a distinguishable shock that can be substantiated by those who lived through it.

Better data will lead to finer measures of empirical resilience and clearer and more actionable narratives with which to frame results, in this way future studies of economic resilience on reservations may better connect with tribal nations themselves, aiding ongoing nation building efforts.

Appendices

Appendix A: History of Federally Reserved Water Rights or Winter's Rights

The current structure of the settlement process for Winters rights, is predicated on three primary pieces of legislation: the *Winters v. United States* decision, the McCarren Agreement, and the 1963 *Arizona v. California* decision. The formalization of a priority date was the most transformative outcome from the *Winters* case, as it allowed federally reserved rights to be acknowledged in state courts as senior rights effective from the date that the reservation was created, essentially superseding all non-tribal users in Western states.

While *Winters* rights initially held sovereign immunity from state courts through the federal government's trustee relationship, the 1952 McCarran Agreement waived sovereign immunity in the case of water rights adjudications. The agreement enabled both the federal government and Tribes themselves to be brought into state adjudications. The third piece of legislation was the establishment of the Practically Irrigable Acreage (PIA) standard for quantifying water rights via the 1963 Arizona v. California supreme court case. Prior to the 1963 decision, quantification of water rights had no metric, leading to further complications in the settlement process. The PIA standard quantifies *Winters* rights by measuring how many acres of land on a reservation can be feasibly irrigated for agricultural cultivation. This myopic reliance on agricultural livelihood metrics, which may not be consistent with the goals of the tribal nation pursuing quantification. However, PIA maintains popularity in low elevation areas with long growing seasons for its more generous quantification amounts compared with other accepted standards. Mountainous tribal reservations with higher elevation experience smaller water right quantified by the PIA system, as agriculture is less viable.

The United States system of established senior tribal water rights may seem impressive in comparison with nations that lack any consideration for indigenous rights (such as Australia), but a policy level analysis of *Winters* rights is incomplete without an understanding of the evolution of the reservation system itself. The Winters decision, the McCarran Agreement, and the Arizona v. California decision all explicitly dictate how tribal water rights function, but any legislation affecting the reservation system has informed the nature of water rights as well as the reasons for pursuing quantification. Upon the creation of the reservation system in the 1850s, considerably large amounts of land were reserved for tribes. The treaties establishing the reservations were essentially property rights that came with the promise of sovereignty. The strength of these property rights was then gradually reneged on by the federal government moving into the 20th century. After a congressional halt was put on new peace treaties between the federal government and tribes in 1871, the U.S. gained complete authority over the creation of additional reservations (Burton 1991).

Following the 1871 decision, the federal government took aim at existing reservations by passing the General Allotment Act of 1887, also known as the Dawes' Act. This was an aggressive piece of legislation meant to assimilate tribes into communities of single-family homesteads. The Dawes' Act sought to partition tribal communities by allotting Reservation land to individual Tribal members for agricultural cultivation, though with the title still held by the federal government. After 25 years of maturation the title could be severed, with the land being converted to fee simple and then sold to non-tribal settlers expanding West. The land that was seized from Indian allottees was usually on more productive and fertile soil. The results of the seizure and sale led to patchwork reservations, with fractionation contributing to a vast diminishment in reservation acreage, as well as a decline in the overall quality of reservation land (Burton 1991). While the transfer of lands through the Dawes' Act was finally put to end through the Indian Reorganization Act (IRA) of 1934, it left many reservations with a haphazard mix of tribal lands, allotments, and fee simple tenures (Leonard, Parker & Anderson 2018).

The Dawes' Act was a result of not only the federal government's desire to assimilate indigenous communities, but was also heavily informed by their goal of promoting westward expansion. The desire to populate the western U.S. shaped the property and water rights systems developed there, inadvertently expanding the breadth of the influences on *Winters* rights even further. The initial system of water rights in the Western U.S. followed from the English Common Law riparian doctrine incumbent in the Eastern U.S., wherein water rights were apportioned accordant with the land abutting streams and rivers (Burton 1991). The riparian system quickly proved problematic in the more arid west where streams and rivers were far less abundant and where livelihoods relied on the consumptive uses of water. The growing presence of miners and irrigating farmers led to the gradual adoption of prior appropriation. Prior appropriation operates on a seniority basis with occupancy preceding ownership and nonuse of a water right leading to forfeiture. Despite the establishment and defense of *Winters* rights in federal court, state law and the Bureau of Reclamation both accelerated the pace with which non-tribal users claimed water. As conflict grew between tribal users and non-tribal claimants, the settlement of *Winters* rights became increasingly necessary, leading to the protracted settlement processes seen in the 20th and now 21st centuries (Thorson et al. 2006).

Due to *Winters* rights being informed by so many historic pieces of legislation and federal government actions, they represent the history of oppression as well as a series of attempted reparations by the federal government. *Winters* rights are a piece of policy that could be posited as a vicarious actor, a set of rules informed by previous rules that were iterated on by the governing bodies in a recursive approximation of the four level approach detailed in Bromley (1985). In the case of economic development, Bromley (1985) expands upon the institutional approach by detailing four levels with which to analyze a system: the policy level, the organizational level, the operating level, and the evaluative level. The process works in a top-down fashion from rules, to governing bodies, to individuals, and finally to reactions to the actions of individuals, creating an iterative cycle. Social-ecological economics builds upon the foundation of institutional economics through explicit focus on issues of the environment and natural resources, particularly highlighting the power relations present in natural resource conflict and how institutions are formed by that dynamic. The rules of *Winters* rights say that reservations are entitled to a set amount of water quantifiable by PIA, given that an agreement can be reached between states and non-tribal users. The settlement process itself, taking shape through litigation and negotiation, acts as the governing body. Once quantified, the tribal government's internal policies then take over at the governance level. With quantified *Winters* rights, actors at the individual level within the tribal community decide how to use the rights apportioned for livelihood activities.

Economic analysis of *Winters* rights using traditional methodology is difficult due to its defiance to neo-classical assumptions. The of institutional economics, which concerns itself with law, governance, and the mutual interactions between economic actors and the rules and doctrines of their behavior, is more apt for analysis of natural resource issues such as water right quantification. Bromley (1982) enumerates four primary problems of the efficiency-minded approach: Pareto efficiency's disregard for distributional justice, externalities that do not adhere to the Pareto criteria, the belief that well-defined property rights can lead to proper management (referred to as the "property rights school"), and finally the evaluation of institutional effectiveness based only on the value of the goods and services the institution provides. Institutional economic thought believes that law is "fundamentally a matter of rights creation and re-creation," that rules are evolutionary and mutable, and that economic actors work and change based on the systems they are forced to operate in (Mercuro & Medema 1997). In a crucial difference from the dominant neo-classical economic approach, institutionalist interpretations of efficiency reject the Pareto notion and instead weigh initial distribution heavily into considerations of efficiency.

Institutionalists commonly adopt a comparative approach to analysis by examining the (usually governmental and legal) systems dictating rules, the incentives and disincentives within that rule set, and finally the economic outcomes that result from the governing systems (Mercuro & Medema 1997). Issues of natural resources, mainly land and water, lend themselves to the institutionalist approach due to their defiance of the neo-classical assumptions specified above. Bromley's (1982) analysis is aimed mostly at natural resource issues concerning public lands, and thus it provides an alternative approach with three framing questions – "who is in control of the management rules that determine the time-rate of use of natural resources? Who is in a position to receive the benefits arising from any particular use pattern? Who is exposed to the costs arising from the use of natural resources?" These questions, echoed within social ecological economics, are pertinent within Winters rights settlements.

As the settlement process initially governs the outcomes of *Winters* rights quantification, its own rules also should be itemized. Settlements are broken up into nine key stages, detailed in Thorson et al. (2006) as "preparation for negotiation, coordination of litigation with negotiation, development of information and positions, federal review and approval, funding of settlements, authorization by states and tribes, court approval, and implementation." Each of the stages involves the three primary actors in the settlement: tribes, non-tribal appropriative water rights holders (usually represented by the state government), and the federal government. The actual negotiating process is usually the lengthiest of the stages, as it requires agreement on settlement components and can constantly teeter at the brink of litigation. Litigation is viewed by most as undesirable for several reasons. The most prominent reason to avoid litigation is cost, both in time and money, fir all involved parties. While tribal governments have benefited from the legal principles established through litigation efforts, the massive monetary costs hinder the ability of the tribal nations to use their entitlement for their desired economic development purposes (Thorson et al. 2006). Due to the risks and costs of litigation, most modern settlements avoid it unless the negotiation process breaks down completely.

Appendix B: List of Acronyms Used

Acronym	**Meaning**
ACS	American Community Survey
IGRA	Indian Gaming Regulatory Act
NAICS	North American Industry Classification System
PIA	Practicably Irrigable Acreage

Appendix C: First Difference Models

VARIABLES	(1) Hachman Index	(2) Hach Shan	(3) Hach Herf
EMPLYPERC = D,	0.00650**	0.00674**	0.00657**
	(0.00261)	(0.00263)	(0.00265)
BOHIGH = D,	0.00842	0.00894	0.00868
	(0.00551)	(0.00554)	(0.00565)
WTRRGHT = D,	-0.0935	-0.104	-0.0972
	(0.195)	(0.196)	(0.197)
HACH = D,	-0.0909	-0.257	-0.129
	(0.194)	(0.258)	(0.249)
SHAN = D,		0.118	
		(0.121)	
HERF = D,			-0.0815
			(0.330)
Constant	-0.0282	-0.0279	-0.0283
	(0.0231)	(0.0231)	(0.0232)
Observations	74	74	74
R-squared	0.106	0.118	0.106

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix D: Alternative OLS Model Specification

D.1: No State Fixed Effects

VARIABLES	(1) Hachman Index	(2) Hach Shan	(3) Hach Herf
YR2012	-0.0317	-0.0259	-0.0269
	(0.0388)	(0.0369)	(0.0370)
EMPLYPERC	0.0122***	0.0118***	0.0121***
	(0.00217)	(0.00206)	(0.00207)
BOHIGH	0.0285***	0.0283***	0.0297***
	(0.00366)	(0.00346)	(0.00349)
WTRRGHT	-0.0911**	-0.0923**	-0.0854**
	(0.0405)	(0.0384)	(0.0386)
POPPACRE	-0.00863	-0.0141	-0.0134
	(0.0130)	(0.0124)	(0.0125)
HACH	-0.308***	-0.622***	-0.572***
	(0.109)	(0.128)	(0.123)
SHAN		0.362***	
		(0.0880)	
HERF			-1.151***
			(0.294)
Constant	9.105***	8.579***	9.451***
	(0.115)	(0.168)	(0.141)
Observations	148	148	148
R-squared	0.488	0.543	0.539

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

D.2 2018 and 2012 Years Separate

D.2A 2012

VARIABLES	(1) Hachman Index	(2) Hach Shan	(3) Hach Herf
EMPLYPERC	0.0125***	0.0110***	0.0113***
	(0.00260)	(0.00251)	(0.00251)
BOHIGH	0.0292***	0.0299***	0.0321***
	(0.00441)	(0.00417)	(0.00432)
WTRRGHT	-0.0295	-0.0470	-0.0459
	(0.0555)	(0.0527)	(0.0531)
POPPACRE	-0.00656	-0.00823	-0.00748

	(0.0157)	(0.0148)	(0.0149)
HACH	0.0758	-0.387*	-0.315
	(0.166)	(0.223)	(0.213)
SHAN		0.344***	
		(0.118)	
HERF			-1.011***
			(0.370)
AZ	0.00877	-0.0968	-0.0774
	(0.233)	(0.223)	(0.224)
COL	-0.0188	-0.128	-0.130
	(0.259)	(0.247)	(0.249)
IDA	0.137	0.0328	0.0548
	(0.243)	(0.232)	(0.233)
MON	-0.225	-0.270	-0.278
	(0.227)	(0.215)	(0.217)
NEV	0.205	0.0511	0.0573
	(0.240)	(0.232)	(0.234)
NM	-0.0793	-0.146	-0.153
	(0.221)	(0.210)	(0.212)
UT	0.100	-0.134	-0.0999
	(0.275)	(0.272)	(0.272)
Constant	8.778***	8.534***	9.318***
	(0.314)	(0.308)	(0.358)
Observations	74	74	74
R-squared	0.656	0.698	0.694

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

D.2B 2018

VARIABLES	(1) Hachman Index	(2) Hach Shan	(3) Hach Herf
EMPLYPERC	0.0155***	0.0156***	0.0155***
	(0.00356)	(0.00360)	(0.00363)
BOHIGH	0.0378***	0.0375***	0.0378***
	(0.00568)	(0.00583)	(0.00587)
WTRRGHT	-0.0934	-0.0927	-0.0938
	(0.0589)	(0.0595)	(0.0599)
POPPACRE	-0.0385**	-0.0388**	-0.0385**
	(0.0181)	(0.0184)	(0.0183)
HACH	-0.219	-0.241	-0.214
	(0.183)	(0.220)	(0.208)
SHAN		0.0254	
		(0.141)	

HERF			0.0270
			(0.525)
AZ	-0.0411	-0.0449	-0.0403
	(0.243)	(0.246)	(0.245)
COL	-0.237	-0.242	-0.236
	(0.276)	(0.280)	(0.279)
IDA	0.0276	0.0226	0.0286
	(0.254)	(0.258)	(0.257)
MON	-0.365	-0.365	-0.366
	(0.238)	(0.240)	(0.241)
NEV	0.111	0.106	0.112
	(0.248)	(0.251)	(0.251)
NM	-0.203	-0.204	-0.203
	(0.230)	(0.232)	(0.232)
UT	-0.00767	-0.0161	-0.00566
	(0.281)	(0.287)	(0.286)
Constant	8.889***	8.854***	8.881***
	(0.360)	(0.411)	(0.392)
Observations	74	74	74
R-squared	0.636	0.636	0.636

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

D.3 No Hachman

VARIABLES	(1) Shan	(2) Herf
2012	-0.0187	-0.0189
	(0.0336)	(0.0336)
EMPLYPERC	0.0141***	0.0143***
	(0.00196)	(0.00197)
25BOHIGH	0.0299***	0.0305***
	(0.00323)	(0.00314)
WTRRGHT	-0.0536	-0.0532
	(0.0389)	(0.0389)
POPPACRE	-0.0219*	-0.0217*
	(0.0115)	(0.0115)
SHAN	0.107	
	(0.0671)	
HERF		-0.390*
		(0.230)
AZ	0.0179	0.0187
	(0.155)	(0.155)

COL	-0.0818	-0.0859
	(0.177)	(0.177)
IDA	0.0857	0.0888
	(0.169)	(0.168)
MON	-0.250	-0.253
	(0.156)	(0.155)
NEV	0.209	0.204
	(0.156)	(0.155)
NM	-0.114	-0.118
	(0.152)	(0.151)
UT	0.0781	0.0769
	(0.180)	(0.180)
Constant	8.579***	8.856***
	(0.241)	(0.194)
Observations	148	148
R-squared	0.636	0.637

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

D.4 No Water Rights Variable

VARIABLES	(1) Hachman Index	(2) Hach Shan	(3) Hach Herf
YR2012	-0.0227	-0.0208	-0.0212
	(0.0341)	(0.0336)	(0.0336)
EMPLYPERC	0.0139***	0.0134***	0.0137***
	(0.00204)	(0.00202)	(0.00201)
BOHIGH	0.0306***	0.0302***	0.0312***
	(0.00328)	(0.00324)	(0.00324)
POPPACRE	-0.0192	-0.0210*	-0.0206*
	(0.0116)	(0.0115)	(0.0115)
HACH	-0.0231	-0.249	-0.223
	(0.117)	(0.152)	(0.145)
SHAN		0.202**	
		(0.0878)	
HERF			-0.660**
			(0.287)
AZ	-0.0161	-0.0619	-0.0543
	(0.164)	(0.163)	(0.163)
COL	-0.107	-0.163	-0.163
	(0.184)	(0.183)	(0.183)
IDA	0.102	0.0512	0.0620
	(0.172)	(0.170)	(0.170)
MON	-0.277*	-0.290*	-0.293*

	(0.161)	(0.158)	(0.158)
NEV	0.195	0.131	0.130
	(0.167)	(0.167)	(0.167)
NM	-0.109	-0.130	-0.135
	(0.154)	(0.152)	(0.152)
UT	0.0792	-0.0217	-0.0121
	(0.191)	(0.193)	(0.192)
Constant	8.795***	8.590***	9.075***
	(0.227)	(0.241)	(0.255)
Observations	148	148	148
R-squared	0.624	0.638	0.638

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

D.5 Casino Variable Included

VARIABLES	(1) Hachman Index	(2) Hach Shan	(3) Hach Herf
2012	-0.0226	-0.0206	-0.0213
	(0.0341)	(0.0336)	(0.0336)
EMPLYPERC	0.0138***	0.0133***	0.0136***
	(0.00204)	(0.00202)	(0.00201)
25BOHIGH	0.0316***	0.0313***	0.0323***
	(0.00337)	(0.00332)	(0.00333)
WTRRGHT	-0.0595	-0.0633	-0.0611
	(0.0406)	(0.0399)	(0.0399)
CASINO	0.0260	0.0285	0.0226
	(0.0529)	(0.0520)	(0.0521)
POPPACRE	-0.0202*	-0.0221*	-0.0216*
	(0.0116)	(0.0115)	(0.0115)
HACH	-0.0407	-0.274*	-0.242*
	(0.119)	(0.153)	(0.145)
SHAN		0.207**	
		(0.0877)	
HERF			-0.667**
			(0.287)
AZ	-0.0260	-0.0738	-0.0646
	(0.164)	(0.163)	(0.163)
COL	-0.112	-0.171	-0.169
	(0.184)	(0.183)	(0.183)
IDA	0.0816	0.0276	0.0404
	(0.172)	(0.171)	(0.170)
MON	-0.292*	-0.306*	-0.308*

	(0.161)	(0.158)	(0.158)
NEV	0.162	0.0947	0.0956
	(0.168)	(0.168)	(0.168)
NM	-0.140	-0.164	-0.168
	(0.156)	(0.154)	(0.154)
UT	0.0728	-0.0307	-0.0231
	(0.196)	(0.198)	(0.197)
Constant	8.831***	8.622***	9.119***
	(0.233)	(0.245)	(0.260)
Observations	148	148	148
R-squared	0.630	0.645	0.644

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

D.6 Diversity Indices Interacted with Employment

VARIABLES	(1) Shan	(2) Herf
YR2012	-0.0148	-0.0137
	(0.0333)	(0.0332)
EMPLYPERC	0.0352***	0.00326
	(0.0115)	(0.00514)
25BOHIGH	0.0323***	0.0328***
	(0.00331)	(0.00328)
WTRRGHT	-0.0587	-0.0572
	(0.0383)	(0.0382)
POPPACRE	-0.0205*	-0.0206*
	(0.0113)	(0.0113)
HACH	-0.252*	-0.241*
	(0.150)	(0.142)
SHAN	0.749**	
	(0.293)	
emplyshan	-0.0117*	
	(0.00604)	
HERF		-3.128***
		(1.170)
emplyherf		0.0500**
		(0.0231)
AZ	-0.128	-0.108
	(0.163)	(0.161)
COL	-0.177	-0.173
	(0.181)	(0.180)
IDA	-0.0214	-0.00428

	(0.171)	(0.169)
MON	-0.354**	-0.344**
	(0.158)	(0.157)
NEV	0.0502	0.0540
	(0.168)	(0.167)
NM	-0.209	-0.204
	(0.153)	(0.152)
UT	-0.0804	-0.0735
	(0.192)	(0.191)
Constant	7.655***	9.668***
	(0.562)	(0.354)
Observations	148	148
R-squared	0.654	0.656

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix E: Previous OLS Model Specifications from Earlier Draft of Thesis (2017 data)

	(1) log_percap	(2) log_percap	(3) log_meaninc	(4) log_meaninc
BCHDGR	0.0131***	0.0137***	0.00834***	0.00869***
	(3.61)	(3.78)	(3.42)	(3.56)
COMTM	0.00526	0.00449	0.00448	0.00379
	(1.19)	(0.99)	(1.41)	(1.14)
CASINO	0.0426	0.0512	0.00871	0.0125
	(0.58)	(0.69)	(0.17)	(0.24)
WTRRGHT	0.0148	0.0179	0.0339	0.0351
	(0.29)	(0.35)	(0.84)	(0.88)
EMPLY	0.00640*	0.00575*	0.00443*	0.00395+
	(2.30)	(2.07)	(2.06)	(1.84)
YEAR2017	0.0532	0.0482	0.0416	0.0370
	(1.19)	(1.07)	(1.29)	(1.15)
POPPACRE	-0.000677*	-0.000666*	-0.000732***	-0.000737***
	(-2.19)	(-2.19)	(-3.47)	(-3.59)
SHAN	0.161		0.101+	
	(1.62)		(1.69)	
HERF		-0.570		-0.425+
		(-1.30)		(-1.83)
AZ	-0.0207	-0.0220	-0.0778	-0.0765
	(-0.27)	(-0.28)	(-1.69)	(-1.63)
CO	-0.00500	-0.0140	-0.267*	-0.273*
	(-0.07)	(-0.18)	(-2.51)	(-2.63)
NM	0.0691	0.0807	0.0294	0.0370
	(0.85)	(0.99)	(0.57)	(0.73)
UT	0.0848	0.0874	0.00975	0.00850
	(0.45)	(0.45)	(0.05)	(0.05)
NV	0.0964	0.0866	-0.0701	-0.0764
	(1.14)	(0.99)	(-1.11)	(-1.18)

ID	0.279**	0.278**	0.0779	0.0744
	(2.87)	(3.03)	(1.59)	(1.57)
WY	0.346**	0.357**	0.208+	0.213+
	(2.76)	(2.85)	(1.89)	(1.92)
Constant	8.598***	9.055***	10.08***	10.39***
	(30.66)	(33.47)	(52.66)	(51.42)
Observations	156	156	156	156
R-Squared	0.3027	0.3004	0.3394	0.3417

t statistics in parentheses
$^{+}p < 0.1$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

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