THESIS

EVALUATING THE HOMOGENEITY OF PREFERENCES ACROSS RESIDENT AND NONRESIDENT ELK HUNTERS IN COLORADO

Submitted by

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In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Summer 2016

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ABSTRACT

EVALUATING THE HOMOGENEITY OF PREFERENCES ACROSS RESIDENT AND NONRESIDENT ELK HUNTERS IN COLORADO

Competition between resident and nonresident elk hunters in Colorado vying for hunting permits has led to much debate about the equitability of the current allocation of permits between the two parties. This study evaluates whether or not resident and nonresident hunters have the same preferences for elk permits, evidenced by application rates. While many studies have examined the reasons why hunters choose this form of recreation, this study goes a step further in examining how these reasons might differ between residents and nonresidents. Because nonresident hunters have greater expenditures per recreation day, analyzing whether or not residents and nonresidents prefer the same hunts will allow for a better understanding of how Colorado Parks and Wildlife could reallocate permits in order to ensure a greater economic impact throughout Colorado.

In order to allow for different levels of spatial correlation, two models are estimated with one model for resident applications and one with nonresident applications. Upon finding that there is spatial correlation of OLS residuals, spatial error models are fitted to the resident and nonresident models. With the coefficient estimates and standard errors from the spatial error models, Z-tests are calculated in order to determine if the independent variables have different effects on the respective dependent variables. While many of coefficient estimates calculated in this analysis are not significantly different for residents and nonresidents, illustrating that these two groups of hunters are alike in many ways, there are some differences present between

resident and nonresident propensities to apply for specific hunts. Although further analysis would be necessary in order to disentangle the welfare effects of a reallocation of permits, this study does demonstrate that resident and nonresident hunters do not have equal preferences for specific hunt codes.

ACKNOWLEDGEMENTS

I would like to begin by thanking my advisor, Dr. Jordan Suter, who has been an incredibly patient, helpful, and understanding advisor, without whom I would likely still be working to finish this project. I would also like to thank the members of my committee, Dr. John Loomis and Dr. Mike Manfredo, both of whom have provided invaluable advice and assistance. Assistance from a great team of committee members has made this research a truly rewarding endeavor.

I would like to thank all of my professors and fellow classmates who have made this experience at Colorado State so much fun over the last two years. The environment of learning, collaboration, and friendship within the Department of Agricultural and Resource Economics has been amazing.

I would also like to thank my family, and especially my brothers, to whom I owe a debt of gratitude for continued support and encouragement throughout college and beyond. The value of all your great support cannot be measured.

Finally, I would especially like to thank Brittany for her continued support. Words cannot describe how thankful I am to have you with me for every adventure, every day.

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CHAPTER 1: INTRODUCTION

Elk hunting in Colorado attracts hunters from across the country, all of whom must compete for permits in order to hunt. While there is a great body of literature studying the preferences of hunters, little attention has been paid to the differences between the preferences of resident and nonresident hunters. A better understanding of the differences between the preferences of resident hunters and those traveling from outside the state to take part in this outdoor recreation will allow the Colorado Department of Parks and Wildlife (CPW) to better tailor permit allocation regulations to reflect the preferences of the two parties, potentially allowing for a greater economic impact to local economies across the state because nonresident hunters exert a greater economic impact per recreation day in the areas where they hunt (BBC Research & Consulting, 2008).

BBC Research & Consulting (2008) noted that resident big game hunters spent about $106 per day while non-resident big game hunters spent an estimated $216 per day, bringing money into the Colorado economy that would have likely gone to another state if not for Colorado's variety of hunting opportunities. However, CPW currently uses nonresident quotas and additional regulations to restrict nonresident access to the permit market so that a greater share of permits can be allocated to resident hunters; resident hunters have generally felt that allocating more permits to nonresidents is dismissive of the intrinsic value of resident sportsmen and their attendant contributions to wildlife management and conservation statewide (Willoughby, 2014). Furthermore, resident hunters have voiced a concern that reducing opportunities for high-quality hunts among residents could have a negative effect on hunter recruitment and retention objectives, potentially undermining the tradition of Colorado sportsmen and jeopardizing future generations critical to the success of state wildlife programs.

In order to allow for a seemingly equitable allocation of permits, CPW has applied quotas and regulations to every permit as if residents and nonresidents were equally likely to choose a particular hunt code, or specific hunting permit, among many. However, it may not be the case that residents and nonresidents prefer the same types of elk hunts. With a better understanding of whether or not residents and nonresidents have homogenous preferences regarding the array of elk hunting opportunities across heterogeneous seasons and plots, policymakers will be poised to enact permit allocation policies that can reflect these differences between resident and nonresident preferences, thus resulting in a movement towards optimal economic activity generation across local economies throughout Colorado.

1.1 Goals and Scope of the Study

The intention of this study is to assess the degree to which resident and nonresident hunters exhibit dissimilar preferences with regard to limited[1] elk hunting permits available from CPW through the limited lottery system. This study will use the formulation and application of spatial models with secondary data regarding the application rates of residents and nonresidents to estimate resident and nonresident application rates for a sample of hunt codes, with the application rates being a function of hunt code characteristics, land characteristics, and spatial characteristics.

The scope of this study includes limited hunt codes offered by CPW in the 2013 elk hunting season excluding Ranching for Wildlife permits, as these are only available to residents, "youth only" hunts for which data does not differentiate between residents and nonresidents, and

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(1) Limited licenses describe hunting permits that are fixed in number, and rationed through a ranked lottery system.

over-the-counter permits[2] for which data is also limited. This study will use only the applicant's first choice hunt code,[3] as I have assumed this hunt code to most accurately represent the applicant's preferences.

1.2 Importance of the Project

Loomis (1982) demonstrated that using a non-price allocation mechanism in order to allot goods would result in a reduction of total benefits within a market. Because Colorado's market for elk permits uses a limited lottery system to allocate permits, there must exist a more efficient manner of allocation between resident and nonresident hunters. This study will demonstrate that addressing the differences between resident and nonresident preferences for hunt codes could be one method for increasing the efficiency of the permit market.

While many studies have focused on studying factors contributing to the participation or non-participation of consumers in lotteries for recreational opportunities (Yoder et al., 2014), estimated the demand for hunting permits (Little et al., 2006; Manfredo et al., 2004; Scrogin and Berrens, 2003), or studied the spatial characteristics of elk (Rost, 1979; Sawyer et al., 2007), few studies have addressed the spatial preferences of hunters or noted the differences between resident and nonresident preferences for recreational opportunities. Because there are only a select number of states in the US that offer elk hunting as a recreational opportunity, there is considerable competition for the fixed number of permits. Therefore, if there exist permits for which nonresidents exhibit a greater preference than residents, there would be an opportunity for

(2) Over-the-counter licenses are available on a first-come, first-served basis for both resident and nonresident hunters through an online portal, by phone, or Colorado Parks and Wildlife license agents across the state. These permits are identical to limited licenses with the exception that over-the-counter permits do not require an applicant to enter the lottery system.

(3) Applicants can submit up to four choices for hunt codes. The second, third, and fourth choice hunt codes will be evaluated in the event of the applicant not securing their first choice.

CPW to generate a greater economic impact to the local economies reliant on hunter expenditures by allocating more permits to nonresidents who have greater expenditures per day.

Colorado has one of the largest permit fee differentials with respect to resident and non-resident elk hunting permits, even though most of the hunting has historically taken place on federal lands that are essentially owned by the collective population of the United States. In the 1970 elk hunting season, 85% of the elk harvest in Colorado occurred on federal lands (Thomas and Toweill, 1982). In addition to economic activity generated in the areas where hunting takes place, the relative magnitude of the nonresident contribution to CPW revenues generated from license sales suggest that nonresidents have a greater impact on the overall revenues generated from license sales, and serves to further motivate the case that if differences in preferences for hunt codes are present, they should be exploited.

CHAPTER 2: BACKGROUND

The focus of this section will be to provide background information regarding elk hunting in Colorado, as well as review CPW procedures related to the elk permit allocation mechanism and the nature of the explicit decisions regarding hunt codes that applicants must make in order to apply for a permit. The following sections will provide background information and insight into the spectrum of hunt characteristics available to applicants in order to provide further context regarding applicant behavior.

2.1 A Brief History of Elk Hunting and Game Management in Colorado

Elk hunting in Colorado has long been a highlight of big game hunting in America. The hunting culture in America has roots in the 17th century European hunting culture, with recreational hunting stemming from the sport hunting traditions of the European aristocracy. As recreational and subsistence hunting took root in America, a uniquely American concept soon established that hunting was the right of not only the wealthy, as was the case in Europe, but additionally the common man had an equal right to hunting opportunities (McCorquodale, 1997). With this notion that the region's game animals were a common pool resource, the overexploitation of the elk population was sure to strike in the absence of proper game management.

Before the arrival of European settlers, elk *(Cervus elaphus)* stretched nearly throughout the United States and Canada, with habitat ranging from the Adirondacks in New York State to eastern Oregon (Warren, 1910). As settlers moved west across America, Colorado's early years saw the influx of thousands of settlers rushing to join the mining expansion in new towns along the Rocky Mountains, followed closely by big game hunters who found hunting opportunities unrestricted by governance. Because of this, elk in America were nearly driven to extinction in the 1910s (Swift, 1945). The US Forest Service estimated that only 500 to 1,000 elk remained in Colorado in 1910 as a result of the unregulated hunting access.

In order to address the critical needs of the dwindling elk population, wildlife management was brought about. Modern wildlife management had its origins in citizen movements of the late 1800s and early 1900s, with Colorado beginning to issue elk hunting permits in 1891. However, the development of wildlife management as a scientific discipline did not emerge until the 1930s. Since the time when elk hunting licenses were first introduced by Colorado regulatory agencies in order to limit elk harvesting, elk populations have seen incredible revitalization, allowing the number of permits issued as well as the number of elk successfully harvested by permit holders to increase dramatically, attesting to the success of modern elk management strategies. In 1976, Colorado was home to one of the largest populations of Rocky Mountain elk in North America (Thomas and Toweill, 1982).

Today, CPW regulates hunting season dates and lengths, hunting permit allocations, bag limits, and further restrictions in order to maintain the health of the state's elk population. Colorado's elk hunting draws hunters from both within the state and from afar, who enter the market for elk permits specific to seasons, locations, and more. It is now estimated that Colorado is home to 280,000 elk, the most of any state in the United States, with the extent of elk territory concentrated mainly within the Rocky Mountain region (Colorado Parks and Wildlife, 2015). In the 2013 elk hunting season, there were 197,371 applications for elk hunting permits, with 103,482 applicants successfully obtaining permits, (Colorado Parks and Wildlife, 2013).

2.2 Overview of CPW Permit Allocation Mechanism

Hunters must have a license to hunt, and they may only hunt the animal, season, and Game Management Unit (location) explicitly stated on the license. Potential hunters, both residents and nonresidents, apply for a permit specific to the date, location, sex, and method of take[4] of the hunter's choosing; all of these specific attributes of the permit are referred to as the *hunt code*[5] (Colorado Parks and Wildlife, 2013). If the potential hunter is not successful in securing the permit for their first-choice application, they will receive a *preference point* that they will accrue in order to designate preference to their future applications in the limited lottery.[6] These preference points remain linked to the hunter, and will serve to rank the hunter's next application; as a hunter fails to secure their first-choice hunt code, thus accumulating preference points, they are then more likely to receive that hunt code in the next year. Applicants who possess more than the minimum preference points needed for the hunt code will secure a permit, while the remaining applicants who possess only the exact number of preference points required to secure the hunt code will all have an equal probability of drawing a permit.[7]

According to CPW, the following rules apply to nonresident permit allocations: the minimum number of preference points needed for a nonresident hunter to acquire a permit for a specific hunt code is determined by the average number of preference points needed by a Colorado resident during a 3-year period that ended with the 2009 draw; for hunt codes that require six or more preference points for a Colorado resident, no more than 20% of the total

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(4) The "method of take" refers to the weapon used to harvest the animal.
(5) Hunt codes each represent a unique hunting opportunity, and thus some are more sought after than others, creating a unique value for each.
(6) These preference points are specific to only the species, but are not specific to the other specifications of the individual's failed permit application; if a hunter fails to secure a permit for a Northern Colorado property in any given year, they are free to use their preference point to apply for a permit in any area of Colorado, so long as they are applying for an elk permit.
(7) For instance, if eight preference points are required to secure a hunt code but the quota is less than the total number of applicants with eight or more preference points, then all applicants who possess nine or more points will secure the permit, and those with eight preference points will all have an equal probability of securing that permit.

number of permits to be allocated could be distributed to nonresident hunters; for hunt codes that require fewer than six preference points for a Colorado resident, no more than 35% of the total number of permits to be allocated could be distributed to nonresident hunters; the percent of nonresident permits to be allocated is only able to increase if a surplus of licenses remains after all of the Colorado resident first choices have been drawn for the hunt code.

There are also optional second, third, and fourth choice hunt codes that applicants can apply for. The total number of hunt code choices that an applicant can choose is four. If an applicant receives a license that they have listed as their second, third, or fourth choice, they will also receive a preference point because they did not receive their first choice hunt code (Colorado Parks and Wildlife, 2013). However, it is possible that an applicant will not receive any of their choices. As noted earlier, this study will focus on only an applicant's first choice hunt code, as this study has made the assumption that the applicant's first choice hunt code is most representative of their preferences.

Permits available in the draw include limited licenses, private-land-only licenses,[8] and leftover-draw-option licenses.[9] This study will focus on limited licenses and private-land-only licenses allocated to applicants through the limited lottery system.

2.3 Elk Characteristics

Many studies have calculated elk movements, habits, and behaviors, and in response to the progression of hunting seasons (Proffitt et al., 2013), ranging topography (Sappington et al., 2007; Lyon, 1979), and varying quality of habitat across the landscape (Montgomery et al., 2013;

(8) These licenses are for specific units on private land and other state owned lands not leased by CPW.
(9) If an applicant is unsuccessful in the draw, they can receive a refund for the amount of the permit, at which point they will receive a preference point, or they can be sent a list of licenses that are still available for purchase after the limited lottery drawing. Elk applicants will be given the first choice of limited licenses that are leftover after the drawing of the limited lottery if they check the "leftover draw" box on the application. These permits are the same permits offered through the limited lottery, but CPW did not meet the quota through the applications.

Sawyer et al., 2007). Although this study will be concerned with elk hunting, elk behavior will only be discussed in Chapter 4 with regard to possible influences on the preferences of applicants for elk permits.

2.4 An Overview of Hunting Areas

Colorado Parks and Wildlife has divided the state into Data Analysis Units (DAUs) in order to manage big game populations, and then further divided DAUs into Game Management Units (GMUs) in order to distribute hunters within the DAU managed herd. GMU boundaries start with and are confined by the herd population boundaries or DAU boundaries.[10] Statewide there are 185 GMUs, with 108 allowing elk hunting. These GMUs are of varying sizes, with the average GMU measuring approximately 360,112 acres, shown below in Figure 1. Many GMUs contain State Wildlife Areas (SWAs), to which residents and nonresidents have free access. These SWAs are state-owned lands that offer hunting and fishing opportunities to the public, among other recreational activities depending on the site's location and available resources.

(10) In order to mitigate areas where hunters tend to concentrate, like public land, or to ensure big game harvest in other parts of a DAU, like remote areas that hunters typically do not go, CPW will end up creating GMUs to distribute those hunters. GMU's are formed on boundaries that can be recognized in the field by hunters.

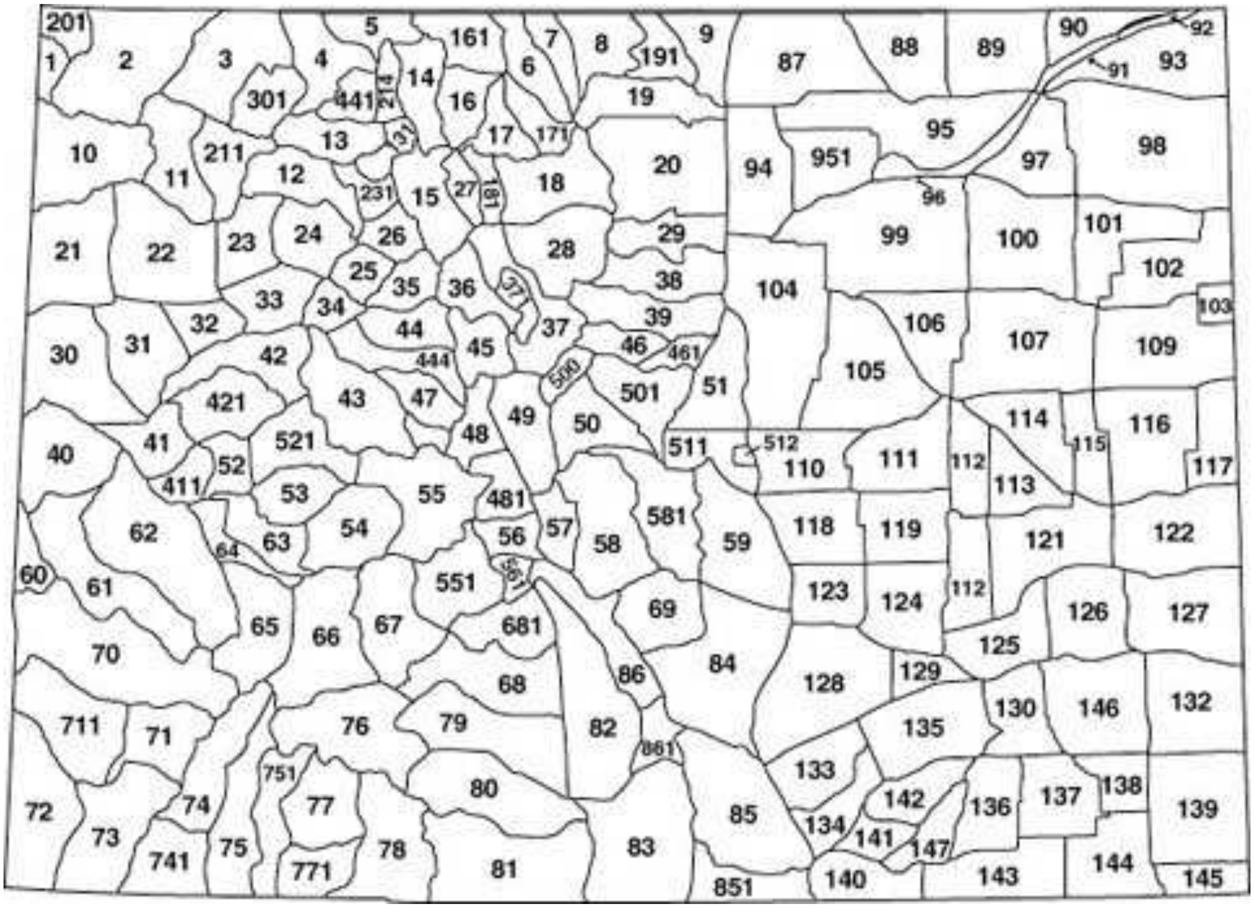

Figure 1: Colorado Game Management Unit Boundaries
retrieved from http://www.coloradowilderness.com/gameunit.html

2.5 An Overview of Hunting Seasons and the Allowable Methods of Take

The series of Colorado's elk hunting seasons begins with archery hunting, offered in August. Following the start of the archery season is the muzzleloader season, with four rifle seasons following, in addition to late rifle seasons. The 2013 Archery Season began on August 31st and ended in late September, only allowing hunters to use hand-held bows.[11] The Muzzeloader Season starts in the middle of archery season, with the 2013 Muzzleloader Season beginning in mid-September and running until the late September. This season only allows the use of muzzleloaders of at least forty (0.40) caliber. There is one "Early" rifle season, four

(11) Some hunt codes abide by slightly different season dates. Every hunt code's dates can be located on pages 33 – 44 in the following link: (https://www.schoolforguides.com/PDF/DOW%202013%20Hunting%20Brochure.pdf).

“Regular” rifle seasons, and two “Late” rifle seasons. All rifle seasons allow the use of centerfire rifle, in addition to shotguns, handguns, muzzleloaders, hand-held bows, and crossbows. The First Rifle Season is limited to elk hunting only, while the Second, Third and Fourth Rifle Seasons overlap with deer hunting dates, allowing both deer and elk hunters in the field at the same time. Each rifle season was about one week, beginning one after another from early October until mid-November. Following the fourth rifle season are “late” seasons, ranging from late November until the end of December.

2.6 CPW Hunting Statistics

Every year, CPW publishes several reports recapping the previous year’s license quotas, application statistics and post-draw statistics that detail the hunt codes for which hunters have applied, the number of preference points used to draw each license, harvest estimates, and the overall average number of reported recreation days for every hunt code. Potential applicants for elk permits are encouraged by CPW to study the statistics of the hunt codes that they are interested in hunting prior to applying in order to best align hunter preferences with the hunt code that contains these traits. Because this information is made available to applicants, this study assumes that applicants employ the information when making decisions regarding which hunt code they will apply for by choosing the permit that most accurately represents their bundle of preferences. These publications are made available online through the CPW website in order to facilitate resident and nonresident access to information.

CHAPTER 3: LITERATURE REVIEW

This work adds to a body of literature combining economic analysis and wildlife management practices. In the past, many economists have studied recreation site choices within many frameworks, noting that site choice is a function of travel time and travel cost, among other factors. However, because nonresident hunters traveling to Colorado have expressed a much greater willingness-to-pay in terms of permit fees and travel costs, there is reason to believe that nonresident preferences may be different from residents, whose hunting activities do not require the same level of travel cost and time. Manfredo et al., (2004) demonstrated that hunters do not all seek the same experience when elk hunting, but are instead driven by an array of motivations to seek satisfaction from different elements of a hunt. While this analysis did study the preferences of resident and nonresident hunters separately as they related to big-game management practices, assessing a hunter's willingness to wait for a permit in order for a bull elk to grow larger, many other factors of the hunt were not evaluated.

Loomis (1982) concluded that non-price rationing mechanisms result in diminished total benefits within a market. Inherent in the CPW limited lottery permit allocation mechanism is a tradeoff between equity and efficiency; in order to allow for a seemingly equitable allocation of elk hunting permits, CPW has forgone the efficiency that would arise from another mechanism that allocates permits based strictly on willingness to pay. Loomis (1982) went on to suggest that the inefficient allocation of hunting permits will ultimately result in the suboptimal allocation of wildlife management funds and the misrepresentation of the benefits associated with a species. Although this study does not suggest a divergence from the current limited lottery mechanism, I do suggest the potential of using the relative preferences of resident and nonresident hunters to direct the regulations governing the allocation mechanism in order to approach a more efficient outcome.

Lancaster (1966) was the first to suggest that consumer demand was not simply driven by the consumption of goods, but by the attributes that comprised those goods. Within the CPW limited lottery structure, a hunter's preference for any given hunt code relative to another hunt code will depend on the full set of available hunt code attributes as well as the probability of being able to successfully procure the permit, (Yoder et al., 2014). In choosing a hunt code, applicants are faced with a discrete, finite set of mutually exclusive choices that serve to illustrate hunter preferences, as Lancaster suggested. With elk hunting, the many attributes of a hunt code will influence the perceived quality, thus necessitating the study and analysis of the many land and spatial characteristics of the available hunt codes.

The measure of the quality associated with a given hunt code is not as straightforward with elk hunting as it may be with other recreational activities since hunters do not all necessarily share the same objective. The notion of quality is intrinsically unique to the consumer, and in our case will defy the neoclassical notion of comparing homogenous goods. As illustrated in many other endeavors wherein consumers exhibit heterogeneous preferences, it is also true that not everyone seeks the same types of satisfaction from a hunting engagement (Manfredo et al., 2004). Hunters are driven by a variety of motives, including but not limited to the desire to harvest a trophy animal, harvest meat for sustenance, or by recreational motives, including solitude or simply an experience as an outdoorsman. Hunt codes that appeal to these unique motivations will often have ties to unique land characteristics. Similarly, the physical characteristics of an area that could potentially influence a recreational motivation are also tied to the landscape fixed in space. Hunts that emphasize obtaining meat and those that focus on the challenge of obtaining a trophy animal are different experiences, likely leading hunters to prefer different hunt codes. This study, however, will not focus solely on the various motivations of Colorado elk hunters or their varying willingness to pay for different types of hunt codes, but will assess the degree to which these motivations differ, leading residents and nonresidents to prefer different hunt codes, as evidenced by patterns in hunt code application rates.

Another measure of hunt quality, elk habitat can also influence hunter preferences for given hunt codes, as these conditions would influence the likelihood of successfully harvesting an elk. In Colorado, elk inhabit both a summer range and a winter range, moving between the summer range in the higher elevations and the winter range in lower elevations as the seasons change. Wennergreen et al. (1977) studied the effects of reported hunter success, range of habitat areas, and hunter density on the perceived quality of hunting sites, but treated the number of nonresident hunters per square mile as an independent variable in the estimation of site quality. This measure of nonresident hunter congestion, an independent variable different from their hunter congestion variable which only counted resident hunters, was hypothesized to be inversely related to the quality perceived by resident hunters; in doing so, this study suggests that resident and nonresident have inverse preferences, as a high concentration of nonresidents within a given site would translate into poor quality for residents. This notion was not further explored in the text.

Coyne and Adamowicz (1992) studied recreation site selection with the use of a discrete-choice model, positing that the scenic attributes, access, and distance to a hunting site, “i", would influence the probability of a hunter visiting the site. Furthermore, the attractiveness of site “i" would also depend on other sites, “j”. If the attributes of site “j” improve, then the relative preference of a hunter for site “i" will diminish. Because of this, the formulation of the applicant's hunt-code preference involves the relative attractiveness of all of the sites within that hunter's choice set, thus necessitating the incorporation of spatial components.

Scrogin and Berrens (2003) estimated changes in welfare resulting from policy changes in the hunting permit market, showing that individuals maximize expected utility, not necessarily just utility, when making decisions about which, if any, lottery permit to apply for. A random expected utility model was created for lotteries that are used to ration access to recreational opportunities. Scrogin and Berrens (2003) showed changes in the total number of applications submitted for a permit (or changes in the probability of an applicant successfully securing a permit), licenses, and harvest rates, but again treated all hunters as one party. Policies affecting the ability of hunters to secure permits would likely not affect resident and nonresident hunters equally; as the number of preference points required to secure a permit increases, CPW further restricts the nonresident permit quota so that a greater proportion of permits are allocated to residents. Because of this tendency for resident hunters to be favored in the case of further restrictions applied to the overall area, the effect of policies would likely not have identical effects on residents and nonresidents, an oversight that merits attention.

CHAPTER 4: DATA ANALYSIS AND MODELING

The research question implies two models: an estimation of resident applications and an estimation of nonresident applications. Within both unique regressions, the dependent variable will be the number of applications. Both estimations will include variables describing the discrete choices made by applicants when applying for a hunt code, variables describing the spatial and land characteristics associated with a hunt code, and variables describing the hunt code quality. By utilizing two models, resident and nonresident preferences are allowed to have different spatial dependencies, something that could not be achieved with the use of one model. Allowing both residents and nonresident preferences to exhibit unique spatial dependencies will allow for a better understanding of how the preferences differ between the groups.

First, a Moran's I test will be conducted on both of the dependent variables, the natural log of resident applications and natural log of nonresident applications. This will establish whether or not the dependent variables follow a spatial distribution across Colorado or are instead randomly distributed across the area. Following the results of the first Moran's I test, two OLS models will be estimated using a log-log form. Using the log-log form will demonstrate the percent changes in application rates for percent changes in variables, thus allowing for the regression results to illustrate the degree to which preferences are different between residents and nonresidents, as opposed to using absolute terms.

As a result of the OLS regressions, much of the variation present in the dependent variable will be explained by the independent variables, but it is likely that there will still be spatial correlation of error terms. In order to assess whether or not this is the case, a second Moran's I test will be conducted on the OLS residuals, testing the spatial correlation of the values of the error terms. If the second Moran's I test illustrates that spatial dependency is still present, two spatial error models (SEM) will be estimated in order to spatially lag the error terms, thus accounting for spatially dependent unobserved multiple-satisfaction factors.

4.1 Study Area

The relevant region for this study includes the 461 hunt codes offered for the 99 GMUs that allow elk hunting for both residents and nonresidents, pictured below in Figure 2. These GMUs range the full latitude of Colorado, and extend to the western border. The unit of analysis with regard to the spatial distribution of hunters is limited to Colorado GMUs that allow elk hunting.

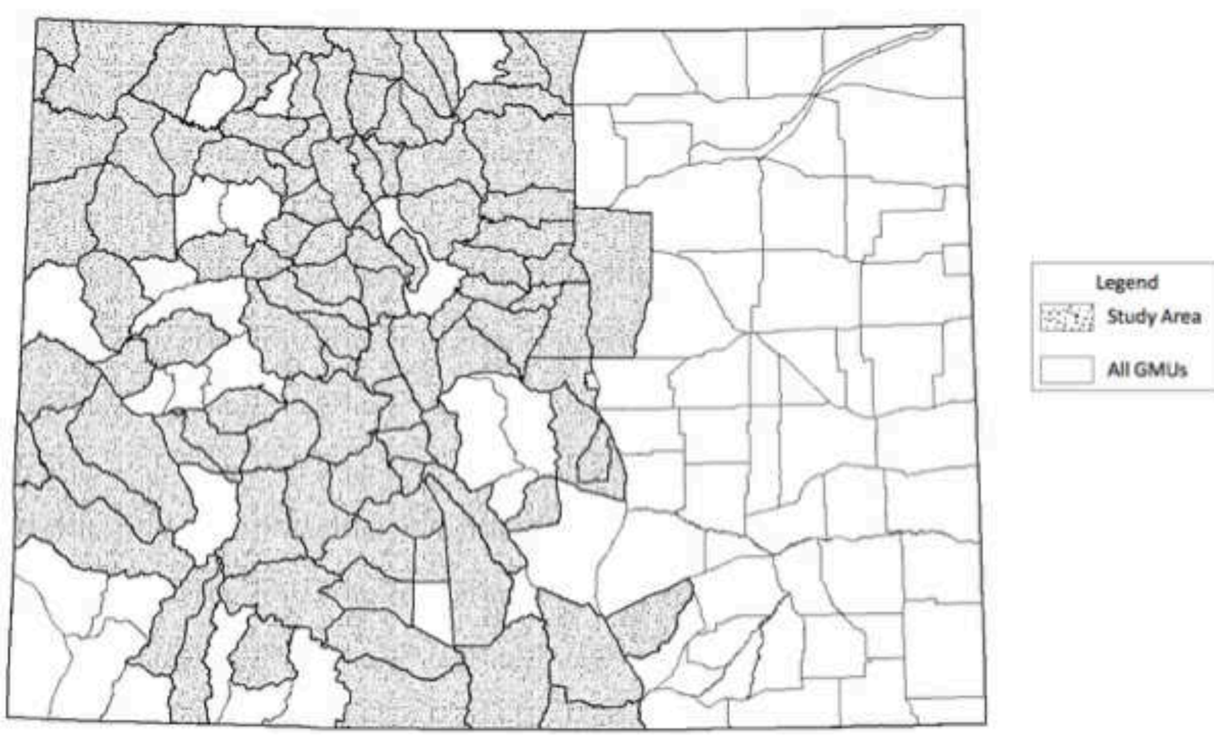

Figure 2: Relevant Game Management Units

4.2 Variables of Interest

Using ESRI ArcGIS software, map layers containing information relevant to spatial and land characteristics were integrated with CPW data regarding hunt code and hunt quality information. Shapefiles for roads, interstates, GMU boundaries, and elevation were sourced from ColoradoView,[12] part of the United States Geological Service nationwide program AmericaView.

Because this study is analyzing the preferences of hunters relative to the spatial characteristics inherent to hunt codes, not necessarily analyzing the preferences of elk relative to habitat preferences, the model will include variables describing the spatial characteristics of elk, but will be limited to include only the characteristics that would influence a hunter's decision to apply for a specific hunt code.

4.2.1 Hunt Code Choice Variables

In order to control for the explicit choices made by hunters at the time of their application, variables describing the applicant's choices related to the sex of the animal, method of take, season, and game management unit were generated from data collected by CPW.[13] One of the econometric challenges present in the data is the fact that muzzleloader and archery hunts are only offered during their own seasons before any rifle hunting takes place; in order to avoid the dummy variable trap, it is necessary to include only (k-1) dummy variables when there are k possible decisions. Because of the mutual exclusivity inherent in the method of take and season combination, the econometric models will include 8 dummy variables describing 9 possibilities for seasons and methods of take shown below in Figure 3.

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(12) These data are made available to the public via the following website:
http://coloradoview.org/cwis438/websites/ColoradoView/Home.php?WebSiteID=15
(13) These data are made available to the public via the following CPW website:
http://cpw.state.co.us/Documents/Hunting/BigGame/Statistics/Elk/2013ElkDrawSummary.pdf

Season	Dates
Archery	Aug. 31 - Sept. 29
Muzzleloader	Sept. 14 - Sept. 22
Early Rifle	Oct. 1 - Oct. 11
First Rifle	Oct. 12 - Oct. 16
Second Rifle	Oct. 19 - Oct. 27
Third Rifle	Nov. 2 - Nov. 10
Fourth Rifle	Nov. 13 - Nov. 17
First Late Rifle	Nov. 23 - Dec. 1
Second Late Rifle	Dec. 1 - Dec. 29

Figure 3: Seasons and Dates

The hunt code that a hunter selects will limit their ability to access elk in some cases. Beginning with the Archery Season and progressing through winter, elk are less likely to inhabit areas where the public has access to hunting (Proffit et al., 2013). During these hunting seasons, elk are observed moving across a landscape with a mix of public and private lands to relocate outside of areas with restricted hunting access, such as private lands with significantly less hunting pressure, as well as areas that do not allow hunting. These private lands offer elk habitat with less hunting pressure and less road density; as noted earlier, elk are averse to occupying areas with large road density, and this effect is amplified during the hunting seasons as elk become increasingly wary of human activity. In order to access these properties, hunters must either ascertain landowner permission or possess a Private Land Only permit. While hunters typically prefer to hunt relatively early in the fall because of a lack of hunting pressure, hunts on private land offer a type of substitute in consumption due to the reduced hunting pressure. This lack of hunting pressure can be likened to an improvement in hunt code quality for some hunters.

The quota of permits associated with a hunt code is set by CPW and although the exact number is not published for the year of application, the previous years' hunt code quotas are available to all applicants. Including the total permit quota to be allocated amongst residents and nonresidents as an independent variable will serve to scale the possible number of applicants.

4.2.2 Hunt Quality Variables

Factors affecting the quality of a hunt will affect a hunter's preferences for a hunt code.[14] The average amount of time spent in the field by each hunter, measured here as the average recreation days per hunter (RECPH), will capture both the effort exerted by the average hunter, in addition to possible recreational benefits offered by a GMU; because this variable is capturing both the benefit of recreation and the added cost of effort, it will have an ambiguous effect on the application rates. The presence of other hunters, measured as hunter density (HDENS), will approximate the solitude of a hunt code, with a lower hunter-density representing a greater measure of solitude. The probability of a successful harvest, approximated by the hunt code's success rate from the previous year (SUCCESS), will also seek to capture the perceived quality of a hunt, with a higher success rate being preferred by those motivated by meat hunts. These hunt quality variables will all have an ambiguous effect on the dependent variable(s), as different hunters will be attracted to different hunts, perceiving different measures of different variables as representing high quality hunting experiences (Manfredo et al., 2004). Here, a success rate of 1 denotes every hunter reporting that they had successfully harvested an elk, while a success rate of 0 represents no hunters reporting a harvest.

As is the case with all recreational experiences, congestion will affect a hunter's preference for a particular hunt code as GMUs differ in size and the number of hunters on a plot during a given season (Coyne and Adamowicz, 1992). Because elk hunting can oftentimes range from a three to seven-day experience, solitude, or low levels of congestion, can also be a motivational characteristic to some hunters (Manfredo et al., 2004). Hunters motivated by an

(14) The data for the SUCCESS, RECPH, and HDENS variables are made available to the public via the following CPW website: http://cpw.state.co.us/Documents/Hunting/BigGame/Statistics/Elk/2013ElkHarvestSurvey.pdf

experience of solitude during an elk hunt would likely select a hunt code with low hunter density.

For the purpose of this study analyzing the 2013 application rates, the success of the 2012 season is relevant as reported by CPW in an annual ex-post analysis of the elk hunting season.[15] A shapefile of Colorado's GMUs[16] was used in addition to the CPW data regarding the number of hunters per hunt code in order to generate the hunter density (HDEN).

4.2.3 Spatial and Land Characteristic Variables

Inherent in the GMU are characteristics that influence desirability to hunters, including GMU size, accessibility, terrain characteristics, and ease of access. In order to extract information regarding hunter preferences for hunt codes based on spatial characteristics of the GMU, variables measuring the size and accessibility of the property, in addition to the land cover in the area.

The presence of a road network within a given GMU will influence the perceived quality of a hunt code, as the distance traveled by a hunter to a hunt site is often used as an approximation of the amount of effort that a hunter will exert in order to successfully harvest an animal (Read et al., 2010). Hunters may likely be less inclined to travel further into the mountainous regions inhabited by the elk, and may prefer accessibility linked to the proximity to the major interstates in Colorado, Interstate-25 and Interstate-70. Data collected by Colorado Division of Wildlife[17] were used to calculate the centroids of the GMU parcels, measured within ArcGIS, were then used to calculate the IDIST variable, measuring the distance from the centroid to the nearest interstate highway; these variables were generated via data collected by

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(15) http://cpw.state.co.us/Documents/Hunting/BigGame/Statistics/Elk/2013ElkHarvestSurvey.pdf
(16) http://ibis-live.nrel.colostate.edu/WebContentData/WS/ColoradoView/Metadata%20downloads/BigGameGMUBoundaries.shp.xml
(17) http://coloradoview.org/cwis438/websites/ColoradoView/Data.php?WebSiteID=15

Colorado Department of Transportation.[18] In addition to interstates serving as a measure of accessibility, public road networks within GMUs will affect accessibility. Stedman et al. (2004) found that hunters carrying GPS units overestimated their reported maximum distances traveled from the nearest public road by an average of 265.47%; hunters estimated their maximum distance to be an average of 2.23 kilometers, while GPS monitors calculated their actual distance as 0.84 kilometers from the nearest road at maximum.

Many studies estimating the movement of elk and the preferences of hunters have utilized measures of habitat as an independent variable, such as Haener et al. (2004) which used measures of elk habitat in order to model recreation site choice for hunters. However, because this study is focused on the preferences of hunters whose preferences could potentially be influenced by the components of elk habitat, habitat will be measured as bundled attributes. As Pendleton and Shonkwiler (2001) noted, studying the bundled characteristics of the good results in a more accurate estimation of preferences. In order to estimate elk habitat, the elevation and ruggedness of a GMU's terrain will be evaluated.

With Colorado's elevation fluctuating from approximately 1,010 meters above sea level to a maximum of 4,400 meters above sea level, the variable topographic conditions in Colorado, including slope, elevation, and ruggedness, are known to influence the habitat selection patterns of elk (Sawyer et al., 2007; Rost, 1979). During colder fall and winter months, elk generally prefer areas with lower elevation and more moderate slopes, appealing to their need for greater foraging ability. Furthermore, elk are prone to predatory attacks when they inhabit valleys or ravines, as these areas make evading predators difficult; these areas of more rugged slope offer less attractive habitat to elk. Additionally, hunters exert greater effort while hunting in these

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(18) http://ibis-live.nrel.colostate.edu/WebContentData/WS/ColoradoView/Metadata%20 downloads/STATE_META _HIGHWAYS.HTML

areas of increasingly rugged terrain. Similar to a hunting area that requires relatively more travel to reach, a relatively more rugged GMU will present a hunter with greater costs, in terms of effort, that are required to successfully harvest an elk. Ruggedness and elevation will also have an affect the scenic and recreational qualities inherent to a landscape, affecting hunter preferences.

The ruggedness of the GMUs was estimated using elevation raster datasets from the United States Department of Agriculture's National Cartography & Geospatial Center. Using script made available by Mark Sappington,[19] the ruggedness of the terrain was calculated with the Vector Ruggedness Measure (Sappington et al., 2007), with the ruggedness of a point dependent on the elevation of 3 adjacent grids within the raster dataset.

4.2.4 Summary Statistics

The following table describes the summary statistics of the variables included in the analysis.

Table 1: Summary Statistics by Hunt Code

Variable	Description	Mean	Min	Max	Standard Deviation
RES_APPS	The number of resident applications for a hunt code.	102.9306	0	1409	161.1817
NR_APPS	The number of nonresident applications for a hunt code.	56.5640	0	1813	127.6841
QUOTA	The maximum number of permits sold in the previous year for a specific hunt code, specified by CPW.	134.4620	2	5000	287.5155
BULL	(Dummy) License to hunt only bull elk.	0.3145	0	1	0.4648
EITH	(Dummy) License to hunt either bull or cow elk.	0.3579	0	1	0.4799

(19) http://www.arcgis.com/home/item.html?id=9e4210b3ee7b413bbb1f98fb9c5b22d4

COW	(Dummy) License to hunt only cow elk.	0.3275	0	1	0.4698
ARCH	(Dummy) License to hunt using archery equipment during archery season.	0.0803	0	1	0.2720
MUZZ	(Dummy) License to hunt using a muzzleloader during the muzzleloader season.	0.3015	0	1	0.4594
EARLY	(Dummy) License to hunt during the earliest rifle season.	0.0152	0	1	0.1224
FIRST	(Dummy) License to hunt during the first regular rifle season.	0.2082	0	1	0.4065
SECOND	(Dummy) License to hunt during the second regular rifle season.	0.0325	0	1	0.1776
THIRD	(Dummy) License to hunt during the third regular rifle season.	0.0456	0	1	0.2087
FOURTH	(Dummy) License to hunt during the fourth regular rifle season.	0.1996	0	1	0.4001
LATE1	(Dummy) License to hunt during the first late rifle season.	0.1020	0	1	0.3029
LATE2	(Dummy) License to hunt during the second late rifle season.	0.0152	0	1	0.1224
PRIV	(Dummy) Illustrates whether the permit is restricted to only hunting on private land parcels.	0.1649	0	1	0.3715
SUCCESS	The reported success rate of the hunters from the previous year for a given hunt code.	0.2540	0	1	0.1572
RECPH	The average recreation days per hunter for each hunt code in terms of the previous year's reported recreation days.	4.6856	1.3333	16.5000	1.8373
HDENS	Hunter density, shown as the average number of acres per hunter.	8113.653	328.8270	258935.4761	22641.8021

RUGGED	The measure of average ruggedness within a GMU. A ruggedness value of 0 denotes a flat plane, while a measure of 1 denotes complete terrain variation.	0.0063	0.0000	0.0138	0.0032
ELEVATION	The measure of average elevation within a GMU measured in meters above sea level, normalized to Colorado's minimum elevation.	202.1414	176.7335	226.0426	9.8065
ACRES	The size of the GMU, measured in acres.	3.5350E+5	5.2875E+04	9.6724E+05	2.1441E+05
IDIST	The distance from the GMU to the closest interstate, either Interstate-25 or Interstate-70, measured in kilometers.	51.7027	0.0000	187.2632	48.7849
ROADS	The kilometers of roads within a game management unit.	912.0186	0.1770	9030.8850	1099.1276
					Number of Observations: 461

Because the empirical analysis will make use of a log-log format, zero values for continuous variables will later be replaced with (0.0001) in order to allow for the natural-log to be taken.

4.3 Generating the Spatial Weights Matrix

In order to estimate the SEM regressions, a spatial weights matrix was created using queen adjacency, signifying that a hunt code is weighted by all of the hunt codes located on immediately adjacent GMUs. Typically, individual observations are located on unique parcels, meaning that preventing an observation "i" from being weighted by itself with weight "w" only requires that all of the diagonal entries in the matrix are zero: $w_{i,i} = 0$.

An example of the conventional spatial weights matrix is shown below with 10 hunt codes on 3 GMUs that neighbor each other. Typically, an observation of interest, an archery hunt on GMU-1 for our example, would be weighted by other hunt codes within GMU-1 in addition to the hunt codes on neighboring GMU-2 and GMU-3. This is shown below in Figure 4, with values of 1 denoting an observation weighting the observation of interest.

GMU		GMU 1				GMU 2		GMU 3			
	Hunt Code	Arc.	Muzz.	Early Rifle	Late Rifle	Muzz.	Early Rifle	Arc.	Muzz.	First Rifle	Second Rifle
GMU 1	Arc.	**0**	1	1	1	1	1	1	1	1	1
	Muzz.	1	**0**	1	1	1	1	1	1	1	1
	Early Rifle	1	1	**0**	1	1	1	1	1	1	1
	Late Rifle	1	1	1	**0**	1	1	1	1	1	1
GMU 2	Muzz.	1	1	1	1	**0**	1	1	1	1	1
	Early Rifle	1	1	1	1	1	**0**	1	1	1	1
GMU 3	Arc.	1	1	1	1	1	1	**0**	1	1	1
	Muzz.	1	1	1	1	1	1	1	**0**	1	1
	First Rifle	1	1	1	1	1	1	1	1	**0**	1
	Second Rifle	1	1	1	1	1	1	1	1	1	**0**

Figure 4 Conventional Spatial Weights Matrix Example

Because there are many permits offered on identical parcels across seasons, the spatial dependency within this analysis is specified such that a hunt code is spatially dependent on every hunt code on immediately adjacent GMUs, and not by hunt codes on the same GMU parcel. In order to prevent hunt code observations from being weighted by other hunt codes on the same GMU parcel, it is necessary for not only the diagonal values to be zero, but for all weights from the identical GMU parcel to be zero. For the purposes of this study, hunt code observation "i" on GMU parcel "g" is weighted by all of the hunt codes "j" on neighboring GMU parcels "p"; “i” will not be weighted by hunt codes “j” on the same GMU parcel "g". This is expressed in the following expression, $w_{i_g,j_g} = 0$.

Following the example from above, an archery hunt code on GMU-1 will not be weighted by other hunt codes on GMU-1, but will instead only be weighted by all hunt codes on neighboring parcels GMU-2 and GMU-3. This is example is shown in Figure 5.

GMU		GMU 1				GMU 2		GMU 3			
	Hunt Code	Arc.	Muzz.	Early Rifle	Late Rifle	Muzz.	Early Rifle	Arc.	Muzz.	First Rifle	Second Rifle
GMU 1	Arc.	**0**	**0**	**0**	**0**	1	1	1	1	1	1
	Muzz.	**0**	**0**	**0**	**0**	1	1	1	1	1	1
	Early Rifle	**0**	**0**	**0**	**0**	1	1	1	1	1	1
	Late Rifle	**0**	**0**	**0**	**0**	1	1	1	1	1	1
GMU 2	Muzz.	1	1	1	1	**0**	**0**	1	1	1	1
	Early Rifle	1	1	1	1	**0**	**0**	1	1	1	1
GMU 3	Arc.	1	1	1	1	1	1	**0**	**0**	**0**	**0**
	Muzz.	1	1	1	1	1	1	**0**	**0**	**0**	**0**
	First Rifle	1	1	1	1	1	1	**0**	**0**	**0**	**0**
	Second Rifle	1	1	1	1	1	1	**0**	**0**	**0**	**0**

Figure 5: Adjusted Spatial Weights Matrix Example

For the purposes of this study, the spatial weights matrix is specified with queen adjacency and has been row standardized in order to normalize weights by the number of neighbors that a GMU is adjacent to.

4.4 Description of Moran's I Testing

The standard Moran's I test will estimate the degree to which the variable of interest, the dependent variable in the first estimation and then the OLS residuals once the OLS regressions have been estimated, are spatially dependent. A positive value for the calculated statistic denotes observations that are clustered together in spatial patterns, while a negative value means that observations are evenly spaced from one another across a given space.[20]

(20) The classic example of negative spatial correlation would be a checkerboard pattern.

Following a normal distribution, the null hypothesis states that the calculated "I" is not significantly different from the expected value, denoting a random spatial pattern, while the alternative hypothesis states that the null is not true, and the observations of X are distributed spatially with meaning.

4.5 Baseline Econometric Framework

The following equations will be used for all regression analyses, with "R" denoting the resident model and "N" the nonresident model:

$$\begin{aligned} \ln(RES\_APPS) = {} & \alpha_R l + \beta_{R1}\ln(QUOTA) + \beta_{R2}\ln(BULL) + \beta_{R3}\ln(EITH) + \beta_{R4}\ln(ARCH) + \\ & \beta_{R5}\ln(MUZZ) + \beta_{R6}\ln(FIRST) + \beta_{R7}\ln(SECOND) + \beta_{R8}\ln(THIRD) + \beta_{R9}\ln(FOURTH) + \\ & \beta_{R10}\ln(LATE1) + \beta_{R11}\ln(LATE2) + \beta_{R12}\ln(PRIVATE) + \beta_{R13}\ln(SUCCESS) + \\ & \beta_{R14}\ln(RECPH) + \beta_{R15}\ln(HDENS) + \beta_{R16}\ln(ELEVATION) + \beta_{R17}\ln(RUGGED) + \\ & \beta_{R18}\ln(ACRES) + \beta_{R19}\ln(IDIST) + \beta_{R20}\ln(ROADS) + P_R W\varepsilon + u_R \end{aligned} \tag{1}$$

$$\begin{aligned} \ln(NR\_APPS) = {} & \alpha_N l + \beta_{N1}\ln(QUOTA) + \beta_{N2}\ln(BULL) + \beta_{N3}\ln(EITH) + \beta_{N4}\ln(ARCH) + \\ & \beta_{N5}\ln(MUZZ) + \beta_{N6}\ln(FIRST) + \beta_{N7}\ln(SECOND) + \beta_{N8}\ln(THIRD) + \beta_{N9}\ln(FOURTH) + \\ & \beta_{N10}\ln(LATE1) + \beta_{N11}\ln(LATE2) + \beta_{N12}\ln(PRIVATE) + \beta_{N13}\ln(SUCCESS) + \\ & \beta_{N14}\ln(RECPH) + \beta_{N15}(HDENS) + \beta_{N16}\ln(ELEVATION) + \beta_{N17}\ln(RUGGED) + \\ & \beta_{N18}\ln(ACRES) + \beta_{N19}\ln(IDIST) + \beta_{N20}\ln(ROADS) + P_N W\varepsilon + u_N \end{aligned} \tag{2}$$

4.6 Description of the Spatial Error Model

Utilizing a Spatial Error Model (SEM), the spatial dependency of estimated error term can be observed and estimated. Additionally, unobserved motivations that would drive hunter preferences towards a specific permit would be able to be measured and controlled for in order to differentiate the differences in preferences between residents and nonresidents. As discussed in Manfredo et al. (2004), there are many motivations that drive individuals' desires to hunt; using the SEM framework I will be able to account for motivations not reflected in the independent variables that are tied to spatial components. Factors driving the spatial patterns could be linked to the scenic qualities of an area's landscape, additional recreational or solitude characteristics associated with a GMU's landscape, or other measures of perceived quality associated with spatial characteristics.

This framework makes use of the following Maximum Likelihood (ML) estimation:

$$(\text{Applications})_i = \alpha_i l + \mathbf{X}\boldsymbol{\beta}_i + \varepsilon_i$$

$$\text{where } \varepsilon_i = P_i W \varepsilon_i + u_i$$

$$u_i \sim N(0, \sigma^2 I) \qquad (3)$$

$$i = \{\text{Resident, Nonresident}\}$$

Where:

$(\text{Applications})_i$ = quantity of first choice applications from resident or nonresident applicants;

$X_{[h, c]}$ = an 'h' by 'c' matrix of observations of independent variables, with 'h' hunt codes and 'c' independent variables;

β_i = a 'c' by 1 vector of estimated coefficients;

ε_i = the spatially correlated error term;

ρ_i = coefficient parameter estimating the spatial dependence of the spatially correlated error term;

W = spatial weights matrix;[21]

u_i = random error term.

4.7 Testing for Similarity of Preferences

In order to assess the degree to which resident and nonresident preferences are dissimilar, the each respective coefficient estimate will need to be compared across regressions. This will be

(21) Again, this spatial weights matrix is specified according to the discussion in Section 4.3 regarding hunt codes not being weighted by other hunt codes on the same parcel.

done by calculating Z-Statistics for each coefficient from the Resident and Nonresident models according to the following formula:

$$Z = \frac{\widehat{\beta}_{Ri} - \widehat{\beta}_{Ni}}{\sqrt{SE(\widehat{\beta}_{Ri})^2 + SE(\widehat{\beta}_{Ni})^2}} \ , \qquad (4)$$

which follows the normal distribution, with a null hypothesis of the two estimated coefficients equaling each other. Given a confidence interval to be specified in the following sections, rejecting the null hypothesis states that the two estimated coefficients have a significantly different affect on their respective dependent variables:

$$H_0: |Z_{Calculated}| \leq Z_{Critical}$$

$$H_A: |Z_{Calculated}| > Z_{Critical}$$

$$n_R = n_{NR} = 461$$

The results of these Z-tests will detail whether or not the land, spatial, and hunt characteristics have dissimilar influences on resident and nonresident application rates.

4.7.1 Hypotheses

Many coefficients are likely similar for residents and nonresidents, as the majority of hunters tend to prefer hunting earlier in the season, hunt areas with less congestion, or hunt trophy bull elk. However, recalling the permit price differential for residents and nonresidents it is likely the case that residents prefer hunts that emphasize harvesting meat while nonresidents prefer trophy hunts. Variables that would reflect this difference in preferences would include: EITHER, because this permit allows the hunter to harvest the animal of their choosing and would likely reflect the choice of a "meat hunter"; FIRST, as hunting earlier in the season is typically conducive to trophy hunting; in contrast to FIRST, the later seasons FOURTH, LATE1, and LATE2, are typically conducive to harvesting meat instead of harvesting a trophy; because a

Private-Land Only hunt requires the hunter to ascertain a landowner's permission before hunting on their land, it is reasonable to hypothesize that residents would prefer PRIVATE hunts more so than nonresidents; with nonresidents incurring greater costs associated with the hunting permit as well as traveling to Colorado, it is likely the case that nonresidents would tend to prefer hunt codes with a greater average measure of recreation days per hunter; lastly, the variables associated with GMU accessibility are likely more favored by nonresidents who would be less familiar with the area or traveling into the state via an interstate, therefore preferring a road network more conducive to newcomers.

CHAPTER 5: RESULTS

5.1 Analysis of Dependent Variable Spatial Correlation

In order to first determine the degree to which the dependent variables are spatially dependent, a Moran's I test was calculated for both the resident and nonresident models using the spatial weights matrix specified in Section 4.3. The results are shown below:

Table 3: Moran's I Test on Dependent Variables

	Calculated Moran's I Statistic	Expectation	Variance	Calculated Moran's I Standard Deviate	P-value
Resident	0.07020	-0.002174	0.0002632	4.4158	5.301×10^{-6}
Nonresident	0.1534	-0.002174	0.0002253	9.4167	$<2.2 \times 10^{-16}$

The null hypothesis states that the dependent variables are randomly distributed across space, experiencing no spatial correlation, while the alternative hypothesis states that there is a non-random distribution of values. Many of the independent variables within the econometric analysis will account for the spatial dependency illustrated above, but there may still be spatial autocorrelation of OLS error terms that would require spatial error modeling. The calculated value of the spatial dependency within the nonresident model has a greater magnitude than that of the resident model, illustrating that the elk permits that nonresidents apply for are less randomly distributed across Colorado than the permits for which resident hunters apply. This outcome would be expected because residents have already located their households across the state of Colorado, and may have a greater preference for permits across the space. Nonresident hunters, unlike resident hunters, may be more willing to travel to centralized locations, such as outfitters and guides, in order to hunt because their decision to travel to Colorado for a hunting opportunity has already driven them a great distance from their household location. Here, we start to see that resident and nonresident hunters do not have identical preferences, but are instead influenced by location at differing rates.

5.1 Empirical Results: OLS Models

Recalling the specification detailed in Section 4.5, the following OLS regressions were estimated with no spatial weighting, causing the $P_iW\varepsilon$ term to become zero, and the error term "u_i" to be treated as truly random.

Table 4: OLS Regression Results

Equation	(1) Resident	(2) Nonresident
Dependent Variable	RES_APPS	NR_APPS
(Intercept)	-49.040***	-18.778
	(15.944)	(23.874)
QUOTA	0.56914****	1.19033****
	(0.1383)	(0.2071)
BULL	2.44229****	3.58713****
	(0.3078)	(0.4609)
EITH	2.89608	3.4502****
	(0.3277)	(0.4907)
ARCH	-1.5955*	-2.7444*
	(0.9611)	(1.4392)
MUZZ	-1.6003*	-0.8561
	(0.8382)	(1.2551)
FIRST	-1.9828**	-2.0697
	(0.8653)	(1.2957)
SECOND	-2.1205**	-1.7588
	(0.997)	(1.4929)
THIRD	-1.4232	-2.4606*
	(0.9611)	(1.4391)
FOURTH	-3.6868****	-4.2410***
	(0.8676)	(1.2992)
LATE1	0.11822	-1.5814
	(0.8902)	(1.3331)
LATE2	-0.0552	-2.7555
	(1.1702)	(1.7523)
PRIV	-3.5954	-2.4941****
	(0.3781)	(0.5661)
SUCCESS	0.2312***	0.42183****

	(0.0745)	(0.1115)
RECPH	-0.4994	0.98321
	(0.5497)	(0.8231)
HDENS	0.03855	0.31672
	(0.1680)	(0.2516)
ELEVATION	8.50137***	-1.0974
	(3.1386)	(4.6998)
RUGGED	0.84978****	0.80677***
	(0.2018)	(0.3022)
ACRES	0.96864****	2.00218****
	(0.2535)	(0.3797)
IDIST	0.01967	0.10159****
	(0.0180)	(0.0270)
ROADS	-0.2408*	-0.4869**
	(0.1318)	(0.1974)
Adjusted R Squared	0.5391	0.5202
F-Statistic [21, 450]	24.45	25.94
p-value	2.2 e-16	2.2 e-16
Number of observations	461	461

Standard errors in parentheses
Significance: **** p<0.001, *** p<0.01, ** p<0.05, * p<0.1

Results from the OLS regressions and Moran's I calculations begin to illustrate the existing differences between factors leading to resident and nonresident application rates with respect to not only the location of the hunts, but other hunt characteristics. Due to the nature of the log-log model, the coefficient estimates on the continuous variables describe the percent change in applications for a one percent change in the independent variable. Because the COW variable was omitted, the positive coefficient estimates on BULL and EITHER signify that these two types of hunts are preferred to hunts for smaller cows. Similarly, with the EARLY variable omitted from the series of seasons, it can be inferred that hunters tend to prefer the early rifle hunt, as the remaining eight coefficients are negative.

With the exception of the RECPH and ELEVATION coefficients, which are not significantly different from zero for both residents and non-residents, all of the coefficients have the same sign in both models, demonstrating that residents and nonresidents have similar preferences for hunt codes, although further examination is required to determine whether or not the two parties have identical preferences to the same degree. However, while the independent variables in the OLS models are able to explain about 53% of the variation in each of the dependent variables, further analysis of the residuals will determine if there is still spatial dependency that has gone unaccounted for.

5.1.1 Spatial Dependency of OLS Residuals

Using the residuals from the estimated OLS models, the following Moran's I test was calculated. Here, the null hypothesis states that the OLS residuals are randomly distributed across space, not spatially correlated, while the alternative hypothesis states that there is a non-random distribution of residuals abiding by some spatial pattern.

Table 5: Moran's I Test on OLS Residuals

	Calculated Moran's I Statistic	Expectation	Variance	Standard Deviate	P-value
Resident	-0.01892	-0.006464	0.0002236	-0.82932	0.7930
Nonresident	0.0 4044	-0.006464	0.0002235	3.0785	0.00104

While both dependent variables were spatially dependent, the OLS residuals from the resident model are spatially random, unlike the OLS residuals from the nonresident model that exhibit considerable spatially dependency. Possible reasons that the nonresident residuals are spatially correlated could be because nonresidents may be attracted to the landscapes, proximity to other activities, or outfitter and guide services located in certain GMUs that would require them to apply for specific hunt codes. These spatial dependencies will be accounted for in the following SEM estimations.

5.2 Empirical Results: Spatial Error Models

Again recalling the basic econometric formulation described in Section 4.5, the following spatial error models were estimated in order to account for the spatial dependency of the OLS error terms:

Table 6: Spatial Error Model Results

Equation	(1) Resident	(2) Nonresident
Dependent Variable	RES_APPS	NR_APPS
(Intercept)	-51.006****	-28.925
	(15.326)	(23.341)
QUOTA	0.57007****	1.12472****
	(0.1352)	(0.1972)
BULL	2.47742****	3.41672****
	(0.2988)	(0.4478)
EITH	2.89454****	3.36237****
	(0.3198)	(0.4703)
ARCH	-1.5893*	-2.4148*
	(0.9369)	(1.3830)
MUZZ	-1.6171**	-0.3940
	(0.8154)	(1.2104)
FIRST	-2.0180**	-1.3572
	(0.8418)	(1.2490)
SECOND	-2.1697**	-1.0511
	(0.9718)	(1.4351)
THIRD	-1.4951	-1.8739
	(0.9361)	(1.3856)
FOURTH	-3.7427****	-3.6170***
	(0.8442)	(1.2510)
LATE1	0.05705	-1.1584
	(0.8648)	(1.2915)
LATE2	-0.0015	-2.2932
	(1.1370)	(1.6975)
PRIV	-3.6164****	-2.4035****
	(0.3714)	(0.5330)
SUCCESS	0.23455***	0.35914****

	(0.0727)	(0.1067)
RECPH	-0.5134	1.30609*
	(0.5375)	(0.7782)
HDENS	0.04728	0.25552
	(0.1619)	(0.2507)
ELEVATION	8.86169***	1.67028
	(3.0265)	(4.5621)
RUGGED	0.85853****	0.95763***
	(0.1932)	(0.3009)
ACRES	0.99998****	1.49206****
	(0.2425)	(0.3802)
IDIST	0.01658	0.07121**
	(0.0162)	(0.0344)
ROADS	-0.2892**	-0.0913
	(0.1241)	(0.2083)
λ	-0.1557	0.41975
λ p-value	0.24513	0.004290
Log-Likelihood	-979.7097	-1162.426
Number of Observations	461	461

Standard errors in parentheses
Significance: **** p<0.001, *** p<0.01, ** p<0.05, * p<0.1

The estimation results indicate that the coefficients for the permit quota, bull, either, archery, and fourth rifle season hunts, hunts that had greater success rates in the previous year, take place in a more rugged terrain, and take place on larger GMUs are significant and have the same sign in both resident and nonresident models. However, both the LATE1 and RECPH coefficients have opposite signs across the two models, signifying that residents and nonresidents have opposite preferences for these two characteristics of a hunt code, although these coefficient estimates are not all significantly different from zero at a 90% confidence level.

Because the OLS residuals from the Resident model are not as spatially dependent as the residuals from the Nonresident model, λ_R is not as significant as λ_N, which would be expected.

Again, the results demonstrate that the hunt codes preferred by resident hunters are more spatially random than those hunt codes preferred by nonresident hunters.

5.3 Empirical Results: Z-Testing for the Homogeneity of Preferences

Using the formula described earlier in Section 4.6, the following Z-Tests were conducted with coefficient estimates and standard errors from the SEM regression framework:[22]

Table 7: Z-Score Results from Spatial Error Models

Coefficient	Resident Coefficient	Nonresident Coefficient	Z-Score
(Intercept)	-51.006****	-28.925	-0.7907
QUOTA	0.57007****	1.12472****	-2.3193**
BULL	2.47742****	3.41672****	-1.7445*
EITH	2.89454****	3.36237****	-0.8224
ARCH	-1.5893*	-2.4148*	0.49413
MUZZ	-1.6171**	-0.3940	-0.8380
FIRST	-2.0180**	-1.3572	-0.4386
SECOND	-2.1697**	-1.0511	-0.6453
THIRD	-1.4951	-1.8739	0.22653
FOURTH	-3.7427****	-3.6170***	-0.0832
LATE1	0.05705	-1.1584	0.78202
LATE2	-0.0015	-2.2932	1.12163
PRIV	-3.6164****	-2.4035****	-1.8668*
SUCCESS	0.23455***	0.35914****	-0.9645
RECPH	-0.5134	1.30609*	-1.9236*
HDENS	0.04728	0.25552	-0.6976
ELEVATION	8.86169***	1.67028	1.31355
RUGGED	0.85853****	0.95763***	-0.2770
ACRES	0.99998****	1.49206****	-1.0911
IDIST	0.01658	0.07121**	-1.4349
ROADS	-0.2892**	-0.0913	-0.8161

Standard errors in parentheses
Significance: **** $p<0.001$, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

(22) In addition to the above table, the Z-Scores were calculated for the OLS regression framework in order to ensure robustness. These results are located in Appendix 2.

The results detailed in Table 7 work to further illustrate that residents and nonresidents have similar preferences in some respects, but have markedly different preferences for hunt codes with respect to certain aspects of the hunt. For instance, both residents and nonresidents prefer hunt codes with greater success rates, and they prefer this characteristic at the same rate. Both groups also prefer the chance to hunt a bull, either by applying for a BULL or an EITHER permit, although nonresident hunters demonstrate a greater preference for bull hunts. Residents and nonresidents both prefer to apply for a hunt code on a larger GMU, but there is also a greater preference by nonresidents than residents for this GMU characteristic.

While many of the estimated coefficients from the resident and nonresident models are not different from one another, there are a few variables that do show distinctly different preferences. According to the models, nonresidents tend to prefer hunt codes with a greater average measure of recreation days per permit while residents prefer fewer recreation days. Although the RECPH estimate is not statistically significant in the resident model, the estimate is significant in the nonresident model with sign that is opposite of the coefficient estimate in the resident model. The fact that nonresidents prefer hunt codes that require more recreation days while residents prefer fewer recreation days will have great implications on the possible economic impact of altering the permit allocation mechanism.

CHAPTER 6: CONCLUSION

In the market for elk hunting permits there is considerable competition and excess demand for permits. The empirical models in this study illustrated that Colorado's market for elk hunting permits includes two consumer groups with dissimilar preferences. Allowing CPW to make use of information regarding the unique preferences of hunters in order to create an allocation mechanism that better reflects hunter preferences would allow for both residents and nonresidents to acquire hunt codes that they prefer, thus increasing the overall efficiency within the market. While it is the case that resident and nonresident hunters have very similar preferences for most hunt code attributes, there are differences between some of the independent variables included in the analyses that serve to illustrate the fact that the two groups do differ in a meaningful way.

Based on the results of the Z-tests, residents have a greater propensity to apply for hunt codes that are more randomly distributed across Colorado that require fewer recreation days, in addition to areas with less road density located at a higher elevation where there is likely a greater density of elk. Because of this, and the fact that nonresident hunters have a greater propensity to apply for hunt codes that require a greater average number of recreation days, it can be inferred that resident hunters could be categorized as 'meat hunters', hunting in order to harvest food, while nonresident hunters tend to prefer 'trophy hunts' that are more recreational in nature.

The key result from this analysis is that nonresident hunters have a greater propensity to apply for hunt codes that require a greater average number of recreation days. Assuming that the average number of recreation days spent on an elk hunt is endogenous to the hunt code and not the hunter, allocating permits associated with longer hunts would be instrumental in generating a greater economic impact throughout Colorado. Because nonresident hunters have greater expenditures per recreation day, if CPW were able to allocate longer hunts, in terms of the average recreation days, to nonresident hunters the resulting economic impact would increase dramatically. These hunts, favored by nonresidents and disliked by residents, evidenced by the negative coefficient in the resident model and the positive coefficient in the nonresident model, would be less contested if a reallocation in favor of nonresidents were to occur, as opposed to reallocating bull hunts which are preferred by both parties, even though nonresidents have a greater preference. Many of the hunts that have a greater average number of recreation days tend to be archery hunts or hunts that take place during the first late season, which nonresidents have a greater propensity to apply for. Other hunts that have a greater number of average recreation days include muzzleloader hunts, which residents have a greater propensity to apply for.

6.1 Limitations of the Study and Areas for Further Research

Due to computing challenges, only queen adjacency was able to be used in the spatial weighting scheme; while this relationship may accurately reflect spatial distribution of OLS residuals, robustness checks using different weighting schemes would need to be calculated in order to confirm this. Further analysis in this arena should make use of these robustness checks in order to ensure that the spatial dependency is most accurately accounted for. In addition, because two dummy variables were omitted from the regression framework in order to avoid the dummy-variable trap, it was not possible to assess the differences in the preferences of residents and nonresidents with regard to hunts for cows or early rifle hunts. Further analysis of these characteristics would allow for a better understanding how residents and nonresidents differ in their preferences for early rifle hunts and cow hunts thus furthering the illustration of differences between the two groups.

Limitations in the data included the fact that applications for youth hunts did not specify whether the applicant was a resident or nonresident. The data also included some observations that were lumped, showing some hunt codes that allowed for hunting during multiple seasons or for a group of GMUs as opposed to a single GMU. More detailed data would allow for a more complete empirical analysis, and would likely increase the robustness of the results. This would also allow for an understanding of how youth hunts may differ from the hunt codes analyzed in this study, as youth hunters may have dissimilar preferences compared to non-youth hunters.

There are many alternative forms that the empirical analysis could have taken. Another regression framework could make use of the number of applications normalized by a hunt code's quota as the dependent variable. This would allow for the calculation of a proxy for the probability of a hunter's success in acquiring a hunt code, but this would not account for the fact that hunters do not have an equal chance of acquiring a permit due to the nature of the preference point acquisition. Alternatively, using the minimum number of preference points required to successfully acquire a permit for a given hunt code could also be used as the dependent variable, although this measure is itself a function of the number of applications submitted for a hunt code. These measures could be used in future analysis as a robustness check for the analyses detailed in this study.

Binding constraints on the total number of permits allocated within a hunting season means that CPW would likely make one group worse-off by reallocating permits, with residents feeling as if they are being dismissed by their state of residence. As was the case with muzzleloader hunts that require more recreation days, it is difficult to parse out every component of a hunt in order to allocate to residents and nonresidents only the characteristics that they most prefer. Because of this, future research studying the welfare effects of reallocating permits to reflect the preferences outlined in this study would allow for a better understanding of the true welfare implications resulting from a reallocation of permits. With an understanding of the welfare implications of possible reallocation schemes, it would then be possible to conduct further analysis aimed at increasing welfare using the relative preferences detailed in this study while holding hunt code quotas constant. However, this optimization could not be conducted without first defining a method for quantifying the welfare effects associated with reallocating portions of certain hunt codes.

A hunter's recreation site choice will be influenced by the price required to reach that site. Future analysis making use of observations of individual hunters' state of residence could illustrate how nonresident preferences may be dependent on the distance traveled by a hunter to reach Colorado. A better understanding of how a hunter's preferences may vary with increased travel time and travel costs would likely agree with the conclusions drawn in this study that suggest that residents tend to prefer "meat hunts" which emphasize a successful harvest, while nonresidents, traveling a greater distance and incurring greater costs, tend to prefer "trophy hunts" which are more recreational in nature.

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APPENDIX 1: Summary Statistics by GMU

GMU	Bull	Either	Cow	Archery	Muzzle-loader	Early Rifle	First Rifle	Second Rifle	Third Rifle	Fourth Rifle	Late1 Rifle	Late2 Rifle	Private	Total Hunt Codes
001	1	2	6	1	2	1	1	1	1	1	1	0	0	9
002	1	2	3	1	2	1	1	0	0	0	1	0	0	6
003	2	2	3	0	2	1	2	0	0	1	1	0	1	7
004	1	3	2	1	4	0	0	0	0	1	0	0	2	6
005	1	0	0	0	0	0	0	0	0	1	0	0	0	1
006	0	4	3	0	2	0	2	0	1	2	0	0	3	7
007	2	1	2	1	2	0	1	0	0	0	1	0	0	5
009	1	0	1	0	0	0	1	0	0	0	1	0	0	2
010	1	2	2	1	2	1	0	0	0	0	1	0	0	5
011	2	2	2	0	2	0	2	0	0	1	1	0	1	6
012	1	3	2	1	4	0	0	0	0	1	0	0	2	6
013	0	0	1	0	0	0	0	0	0	0	1	0	0	1
014	2	1	1	0	2	0	1	0	0	1	0	0	0	4
015	0	7	1	0	2	0	2	1	1	2	0	0	4	8
016	0	1	3	0	0	0	0	0	1	3	0	0	2	4
017	0	1	3	0	0	0	0	0	1	3	0	0	2	4
018	0	5	2	0	2	0	2	0	0	2	1	0	2	7
019	1	0	1	0	0	0	1	0	0	0	1	0	0	2
020	8	1	4	3	2	0	1	1	1	1	2	2	0	13
021	2	2	1	0	2	0	2	0	0	1	0	0	1	5
022	0	0	1	0	0	0	0	0	0	0	1	0	0	1
025	1	1	1	0	2	0	0	0	0	1	0	0	0	3
026	1	0	1	0	0	0	0	0	0	1	1	0	0	2
027	0	4	3	0	0	0	3	0	0	3	1	0	3	7
028	0	5	2	0	2	0	2	0	0	2	1	0	2	7
029	2	1	1	1	2	0	1	0	0	0	0	0	0	4
031	0	0	1	0	0	0	0	0	0	0	1	0	0	1
033	1	3	1	1	2	0	0	0	0	2	0	0	1	5
034	1	0	0	0	0	0	0	0	0	1	0	0	0	1
035	1	3	2	0	2	0	2	0	0	1	1	0	1	6
036	0	1	1	0	0	0	0	0	0	1	1	0	1	2
038	3	1	2	0	2	0	2	0	0	1	1	0	1	6
039	5	1	1	1	2	0	1	1	1	1	0	0	0	7
040	0	6	1	1	2	0	1	1	1	1	0	0	0	7
041	3	2	1	0	2	0	2	0	0	2	0	0	2	6
043	1	3	1	0	2	0	2	0	0	1	0	0	1	5
044	1	3	1	0	2	0	2	0	0	1	0	0	1	5

045	0	1	2	0	0	1	0	0	0	1	1	0	1	3
046	2	1	2	1	2	0	2	0	0	0	0	0	0	5
047	0	1	1	0	0	0	0	0	0	1	1	0	1	2
048	2	1	1	1	2	0	1	0	0	0	0	0	0	4
049	2	1	1	1	2	0	1	0	0	0	0	0	0	4
050	2	1	3	1	2	0	1	0	0	0	1	1	0	6
051	2	1	1	1	2	0	1	0	0	0	0	0	0	4
053	3	2	1	0	2	0	2	0	0	2	0	0	2	6
054	0	7	4	1	2	0	2	0	1	2	2	1	3	11
055	1	5	1	1	2	0	2	0	0	2	0	0	2	7
056	5	1	1	1	2	0	1	1	1	1	0	0	0	7
057	5	1	1	1	2	0	1	1	1	1	0	0	0	7
059	2	2	1	0	2	0	2	0	0	1	0	0	1	5
060	2	3	2	0	2	0	3	0	0	2	0	0	2	7
061	2	1	1	1	2	0	1	0	0	0	0	0	0	4
062	2	3	1	0	2	0	2	0	0	2	0	0	2	6
063	2	0	1	0	2	0	0	0	0	1	0	0	0	3
064	1	4	2	0	2	0	2	0	0	2	1	0	2	7
066	5	1	1	1	2	0	1	1	1	1	0	0	0	7
067	5	1	1	1	2	0	1	1	1	1	0	0	0	7
068	3	0	3	0	2	0	1	0	0	1	2	0	1	6
069	5	1	1	1	2	0	1	1	1	1	0	0	0	7
070	0	5	1	0	2	0	2	0	0	2	0	0	2	6
074	1	4	1	0	2	0	2	0	0	2	0	0	2	6
075	1	4	1	0	2	0	2	0	0	2	0	0	2	6
076	5	1	1	1	2	1	1	1	1	0	0	0	0	7
077	1	4	1	0	2	0	2	0	0	2	0	0	2	6
079	4	0	2	0	2	0	1	1	1	0	1	0	0	6
080	3	0	3	0	2	0	1	0	0	1	2	0	1	6
081	0	0	1	0	0	0	0	0	0	0	1	0	0	1
082	0	4	2	0	2	0	3	0	0	1	0	0	1	6
083	0	3	1	0	2	0	1	0	0	1	0	0	4	4
085	0	4	2	0	2	0	2	0	0	1	1	0	1	6
086	3	1	1	0	2	0	2	0	0	1	0	0	1	5
104	2	1	1	1	2	0	1	0	0	0	0	0	0	4
131	1	0	1	0	0	0	0	0	0	1	1	0	1	2
133	1	1	2	0	2	0	0	0	0	1	1	0	0	4
161	0	1	2	0	0	0	0	0	1	2	0	0	2	3
171	0	1	2	0	0	0	0	0	1	2	0	0	2	3
181	0	0	3	0	0	0	0	1	0	1	1	0	1	3
191	1	0	1	0	0	0	1	0	0	0	1	0	0	2

201	1	2	1	1	2	1	0	0	0	0	0	0	0	4
211	0	0	1	0	0	0	0	0	0	0	1	0	0	1
214	1	0	0	0	0	0	0	0	0	1	0	0	0	1
231	1	0	0	0	0	0	0	0	0	1	0	0	0	1
361	0	0	1	0	0	0	0	0	0	0	1	0	0	1
371	0	4	2	0	0	0	2	0	0	3	1	0	2	6
391	1	1	1	1	2	0	0	0	0	0	0	0	0	3
421	0	0	1	0	0	0	0	0	0	0	1	0	0	1
444	0	1	0	0	0	0	0	0	0	1	0	0	0	1
461	1	1	1	1	2	0	0	0	0	0	0	0	0	3
471	0	1	1	0	0	0	0	0	0	1	1	0	1	2
481	2	1	1	1	2	0	1	0	0	0	0	0	0	4
500	2	1	3	1	2	0	1	0	0	0	1	1	0	6
501	2	1	3	1	2	0	1	0	0	0	1	1	0	6
511	2	1	0	0	0	0	2	0	0	1	0	0	1	3
551	1	3	1	1	2	0	1	0	0	1	0	0	0	5
561	5	1	1	1	2	0	1	1	1	1	0	0	0	7
591	0	0	1	0	0	0	0	0	0	0	1	0	0	1
681	0	0	1	0	0	0	0	0	0	0	1	0	0	1
682	0	0	1	0	1	0	0	0	0	0	0	0	0	1
851	4	1	4	1	2	0	1	1	2	0	1	1	0	9
Grand Total	145	165	151	37	139	7	96	15	21	92	47	7	76	461

APPENDIX 2: Z-Testing Using OLS Estimates

Table 8: Z-Score Results from OLS Regressions

Coefficient	Resident Coefficient	Nonresident Coefficient	Z-Score
(Intercept)	-49.040***	-18.778	-1.0540
QUOTA	0.56914****	1.19033****	-2.4936**
BULL	2.44229****	3.58713****	-2.0656**
EITH	2.89608	3.4502****	-0.9389
ARCH	-1.5955*	-2.7444*	0.66384
MUZZ	-1.6003*	-0.8561	-0.4930
FIRST	-1.9828**	-2.0697	0.05581
SECOND	-2.1205**	-1.7588	-0.2014
THIRD	-1.4232	-2.4606*	0.59947
FOURTH	-3.6868****	-4.2410***	0.35475
LATE1	0.11822	-1.5814	1.06026
LATE2	-0.0552	-2.7555	1.28146
PRIV	-3.5954	-2.4941****	-1.6175
SUCCESS	0.2312***	0.42183****	-1.4207
RECPH	-0.4994	0.98321	-1.4979
HDENS	0.03855	0.31672	-0.9194
ELEVATION	8.50137***	-1.0974	1.69845*
RUGGED	0.84978****	0.80677***	0.11834
ACRES	0.96864****	2.00218****	-2.2636**
IDIST	0.01967	0.10159****	-2.5148**
ROADS	-0.2408*	-0.4869**	1.03633

Critical Z-Scores
(*) $\alpha = 0.1$; $Z = 1.645$
(**) $\alpha = 0.05$; $Z = 1.960$
(***) $\alpha = 0.01$; $Z = 2.576$

APPENDIX 3: Moran's I Output Tables

Table 10: Detailed Moran's I Calculation for Resident Applications

Moran I test under randomization		
weights: mat2listw(SpatWM)		
Moran I statistic standard deviate = 4.4158, p-value = 5.031e-06		
sample estimates:		
Moran I statistic	Expectation	Variance
0.070197286	-0.002173913	0.0002686

Table 11: Detailed Moran's I Calculation for Nonresident Applications

Moran I test under randomization		
weights: mat2listw(SpatWM)		
Moran I statistic standard deviate = 9.4167, p-value < 2.2e-16		
sample estimates:		
Moran I statistic	Expectation	Variance
0.1534117125	-0.002173913	0.0002729866

Table 12: Detailed Moran's I Calculation for Resident OLS Residuals

Moran I test under randomization		
weights: mat2listw(SpatWM)		
Moran I statistic standard deviate = -0.81694, p-value = 0.793		
sample estimates:		
Moran I statistic	Expectation	Variance
-0.0189122073	-0.0064644921	0.0002321637

Table 13: Detailed Moran's I Calculation for Nonresident OLS Residuals

Moran I test under randomization		
weights: mat2listw(SpatWM)		
Moran I statistic standard deviate = 3.0785, p-value = 0.00104		
sample estimates:		
Moran I statistic	Expectation	Variance
0.0404416593	-0.0064644921	0.0002321637

APPENDIX 4: Regression Output Tables

Table 14: Detailed Resident OLS Regression

Coefficient	Estimate	Std. Error	t-score	p-value
(Intercept)	-49.0403	15.9441	-3.076	0.002231
QUOTA	0.5691	0.1384	4.11E+00	4.65E-05
BULL	2.4423	0.3078	7.94E+00	1.77E-14
EITH	2.8961	0.3277	8.837	< 2e-16
ARCH	-1.5956	0.9612	-1.66	0.097617
MUZZ	-1.6003	0.8382	-1.909	0.056889
FIRST	-1.9828	0.8654	-2.291	0.022415
SECOND	-2.1206	0.9970	-2.127	0.03398
THIRD	-1.4232	0.9611	-1.481	0.139374
FOURTH	-3.6868	0.8677	-4.25E+00	2.62E-05
LATE1	0.1182	0.8903	0.133	0.894423
LATE2	-0.0552	1.1703	-0.047	0.962391
PRIV	-3.5955	0.3781	-9.509	< 2e-16
SUCCESS	0.2312	0.0745	3.103	0.002042
RECPH	-0.4995	0.5497	-0.909	0.364054
HDENS	0.0386	0.1680	0.229	0.818629
ELEVATION	8.5014	3.1387	2.709	0.00702
RUGGED	0.8498	0.2018	4.21E+00	3.10E-05
ACRES	0.9686	0.2536	3.82	0.000153
IDIST	0.0197	0.0181	1.087	0.277562
ROADS	-0.2409	0.1319	-1.827	0.068425

Residual standard error: 2.077 on 440 degrees of freedom
Multiple R-squared: 0.5591, Adjusted R-squared: 0.5391
F-statistic: 27.9 on 20 and 440 DF, p-value: < 2.2e-16

Table 15: Detailed Nonresident OLS Regression Results

Coefficient	Estimate	Std. Error	t-score	P-Value
(Intercept)	-18.7782	23.8747	-0.787	0.431979
QUOTA	1.1903	0.2072	5.75E+00	1.71E-08
BULL	3.5871	0.4609	7.78E+00	5.11E-14
EITH	3.4502	0.4908	7.03E+00	7.90E-12
ARCH	-2.7444	1.4392	-1.907	0.057187
MUZZ	-0.8562	1.2552	-0.682	0.495528
FIRST	-2.0698	1.2958	-1.597	0.11091
SECOND	-1.7588	1.4929	-1.178	0.239382
THIRD	-2.4607	1.4392	-1.71	0.088012
FOURTH	-4.2411	1.2992	-3.264	0.001183
LATE1	-1.5814	1.3331	-1.186	0.236153
LATE2	-2.7555	1.7524	-1.572	0.116562
PRIV	-2.4942	0.5662	-4.41E+00	1.33E-05
SUCCESS	0.4218	0.1116	3.78	0.000178
RECPH	0.9832	0.8231	1.194	0.23293
HDENS	0.3167	0.2516	1.259	0.208762
ELEVATION	-1.0975	4.6998	-0.234	0.815472
RUGGED	0.8068	0.3022	2.669	0.007882
ACRES	2.0022	0.3797	5.27E+00	2.11E-07
IDIST	0.1016	0.0271	3.75	0.000201
ROADS	-0.4869	0.1974	-2.466	0.014041

Residual standard error: 3.11 on 440 degrees of freedom
Multiple R-squared: 0.5411, Adjusted R-squared: 0.5202
F-statistic: 25.94 on 20 and 440 DF, p-value: < 2.2e-16

Table 16: Detailed Resident SEM Regression Results

Coefficient	Estimate	Std. Error	z-value	p-value
(Intercept)	-51.0065	15.3260	-3.3281	0.0008744
QUOTA	0.5701	0.1353	4.21E+00	2.50E-05
BULL	2.4774	0.2989	8.29E+00	2.22E-16
EITH	2.8945	0.3199	9.0485	2.20E-16
ARCH	-1.5893	0.9369	-1.6963	0.0898285
MUZZ	-1.6172	0.8155	-1.9831	0.0473574
FIRST	-2.0180	0.8419	-2.397	0.016531
SECOND	-2.1697	0.9718	-2.2327	0.0255694
THIRD	-1.4951	0.9362	-1.597	0.1102554
FOURTH	-3.7427	0.8442	-4.43E+00	9.28E-06
LATE1	0.0571	0.8648	0.066	0.9473982
LATE2	-0.0016	1.1370	-0.0014	0.9989098
PRIV	-3.6164	0.3714	-9.7362	2.20E-16
SUCCESS	0.2346	0.0727	3.2252	0.0012587
RECPH	-0.5134	0.5376	-0.9551	0.3395294
HDENS	0.0473	0.1619	0.292	0.7702598
ELEVATION	8.8617	3.0266	2.928	0.003412
RUGGED	0.8585	0.1933	4.44E+00	8.92E-06
ACRES	1.0000	0.2425	4.1233	3.73E-05
IDIST	0.0166	0.0162	1.0231	0.3062828
ROADS	-0.2892	0.1241	-2.3302	0.0197936

Lambda: -0.1557, LR test value: 1.3509, p-value: 0.24513
Asymptotic standard error: 0.13008
z-value: -1.197, p-value: 0.23132
Wald statistic: 1.4327, p-value: 0.23132

Log likelihood: -979.7097 for error model
ML residual variance (sigma squared): 4.1013, (sigma: 2.0252)
Number of observations: 461
Number of parameters estimated: 23
AIC: 2005.4, (AIC for lm: 2004.8)

Table 17: Detailed Nonresident SEM Regression Results

Coefficient	Estimate	Std. Error	z-value	P-value
(Intercept)	-28.9256	23.3411	-1.2393	0.2152502
QUOTA	1.1247	0.1972	5.70E+00	1.18E-08
BULL	3.4167	0.4479	7.63E+00	2.35E-14
EITH	3.3624	0.4704	7.15E+00	8.79E-13
ARCH	-2.4148	1.3831	-1.746	0.0808149
MUZZ	-0.3940	1.2105	-0.3255	0.7447779
FIRST	-1.3572	1.2491	-1.0866	0.2772244
SECOND	-1.0512	1.4352	-0.7324	0.4638967
THIRD	-1.8740	1.3856	-1.3524	0.1762318
FOURTH	-3.6170	1.2511	-2.8911	0.0038388
LATE1	-1.1585	1.2915	-0.897	0.3697295
LATE2	-2.2932	1.6975	-1.3509	0.1767215
PRIV	-2.4036	0.5330	-4.51E+00	6.50E-06
SUCCESS	0.3591	0.1068	3.3643	0.0007674
RECPH	1.3061	0.7783	1.6782	0.0933151
HDENS	0.2555	0.2507	1.0192	0.3081034
ELEVATION	1.6703	4.5621	0.3661	0.7142737
RUGGED	0.9576	0.3010	3.1819	0.0014629
ACRES	1.4921	0.3802	3.92E+00	8.70E-05
IDIST	0.0712	0.0344	2.0675	0.0386834
ROADS	-0.0913	0.2083	-0.4382	0.6612219

Lambda: 0.41975, LR test value: 8.157, p-value: 0.0042896
Asymptotic standard error: 0.10407
z-value: 4.0333, p-value: 5.499e-05
Wald statistic: 16.268, p-value: 5.499e-05

Log likelihood: -1162.426 for error model
ML residual variance (sigma squared): 8.9827, (sigma: 2.9971)
Number of observations: 461
Number of parameters estimated: 23
AIC: 2370.9, (AIC for lm: 2377)