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Determinates of Georgia White-Tailed Deer Harvests

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By

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Abstract

This manuscript provides recent evidence regarding the determinates of white-tailed deer harvest densities in the state of Georgia. The data from the 2016/17-2020/21 deer hunting seasons indicates total deer harvest density is positively influenced by the prior year's mature buck harvest density, the turkey harvest density, higher unemployment rates, higher median incomes, and a higher level of education. Deer harvest density was found to be negatively impacted by larger public land harvests the year before and greater human population densities.

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Introduction

The white-tailed deer (*Odocoileus virginianus*) is one of the most popular big game species in North America and has been for centuries. Native Americans hunted white-tailed deer for food, clothing, shelter, and tools (from bones and antlers). Today, these animals are hunted primarily for recreation, although there are still groups of hunters that depend on white-tailed deer for food. The late 1800s to the mid-1900s saw a rise in habitat loss and over-hunting that pushed this once abundant animal to the threshold of extinction. Thankfully, due to hunting regulations and proper game management, populations of deer were able to rebound and their numbers have remained healthy in recent years.

The past five deer hunting seasons in Georgia have resulted in relatively stable harvests with the average number of deer taken in a season being around 18,300. The 2020/21 season peaked at 19,400, being 6% higher than the average and the 2018/19 season being the lowest at 17,500 deer, 4% lower than average. The variation between seasons' harvests is said to be caused by a variety of factors, notably harvests from previous years (Pang 2017), hunting land available (Cho, et al. 2012), and amount of recreation available (Sukhomirov 2016). The aim of this paper is to determine to what degree, if any, these and other variables affect the harvests of white-tailed deer in Georgia.

Literature Review

In the field of environmental economics, it is important to examine both the effects of humans and the natural environment. White-tailed deer, for example, are a popular game animal for humans and they are often considered an indicator species for the overall wellbeing of their ecosystems, meaning the health of an ecosystem can be implied based on the health of the deer population in that area. The existing literature shows that human and natural factors are very closely related, likely due to the expansion of human society/cities and the subsequent increase in human/animal interactions. There has been little work in the field of natural resource economics that addresses white-tailed deer, but there is ample work on habitats and harvests of other wildlife to lay the foundation for white-tailed deer research. Basic information on deer biology and behavior as well as hunter behavior are considered by Clancy and Nelson (1991). Having a comprehensive understanding of the factors that influence harvest rates helps to provide insight into the overall health deer populations as well as the health of the ecosystem in which they live. Given the literature, socioeconomic and wildlife factors are expected to be important factors in this model. The initial hypothesis for this project is that unemployment rate during the hunting season, past seasons' deer harvest, county population density, and median income of the county all affect the magnitude of deer harvests for a given hunting season.

Kahui, Moyle, and Brunell (2018) examine various factors that influence alligator hunting in the state of Florida. Alligator hunting is typically for the purpose of selling the alligator hide, meat, and other parts of the alligator, and because of this, alligator hunting is heavily affected by the market for alligator parts and products. This differs from deer hunting because it is illegal to sell any part of a harvested game animal in the state of Georgia; therefore, deer harvesting is conducted for recreation and personal consumption only. Kahui et al. (2018) find that variables such as hide price, meat price, permit cost, number of permits issued, revenue, and size of the alligators harvested explained much of the demand for alligator hunting. An important insight from Kahui et al. (2018) was that alligator hunters tend to optimize their hunts, meaning they would rather use their few tags to harvest large alligators rather than fill the tags quickly with small alligators. Due to the fact the deer hunters also have limited tags, it can be expected that their hunting behavior will be similar. For example, in a county that has large amounts of hunting land and a healthy deer population, a hunter may prefer to wait on a large buck rather than taking a smaller one (or even a doe). However, in a county with less opportunity, the hunter may harvest whatever is available, regardless of size or sex. This notion is likely important in understanding the prosperity of long-term populations and short run harvesting decisions.

Milon and Clemmons (1991) provided a manuscript that connected the demand for species variety in a hunting area with the expenditures spent by hunters to go hunting there. This approach allowed the researchers to evaluate the contributions of individual land characteristics to recreational quality (as measured by demand). The variables in question for this research were hunting harvests, urban/rural areas, number of species hunted, and variety in the number of individual species (or rather the "demographics" of the hunted species). The most notable outcome was the hunters' demand for species variety was positively related to hunting expenditures (travel, gear, opportunity costs, etc.). As research in this field continues, more complex choice models, more detailed data on hunting expenditures, and further understanding of wildlife availability will be needed.

To properly understand and model wildlife harvests, it is important to understand as much about the species in question as possible. Jensen, et al. (2014) addresses the topic of “smart wildlife” and the movement of game animals from protected areas (sanctuaries, state parks, or any natural habitat where hunting is not allowed) into non- protected/ huntable areas and vice versa. The basis for this argument is that when protected from hunting, wild game populations will grow and in turn the growing populations will start to move into huntable areas, resulting in more game harvested around the protected areas. Given this theory, to properly model deer harvests in Georgia counties, it is necessary to account for cross-county migration and movement from protected areas to huntable areas. Deer do not migrate, and typically stay in their “home ranges” (which are areas that seldom extend larger than one square mile), unless prompted by human encroachment, scarce resources, or the mating season. While not likely a major factor, deer movement was enough of a concern to include in the model. Consideration was given to state park acreage per county, county size, and Wildlife Management Area (WMA) acreage per county given Jensen et al. (2014) with respect to white-tailed deer, but these variables were dropped because there were no significant changes in these land areas for the time frame 2016-2020. The percentage of total deer killed on public land was used as an alternative to measure the productivity of public lands (areas where anyone with a Georgia hunting license may hunt).

Similar to Jensen, et al. (2014), Balkan and Khan (1988) approach deer hunting from the understanding that deer do not remain stationary and hunting on public lands is often plagued with open access resource problems. To address these issues, the researchers created a travel cost model that included number of hunting trips, socioeconomic factors, and hunting quality factors. Several of these variables were introduced in other papers, but Balkan and Kahn's inclusion of an education variable was different than previous literature and was a significant factor in their analysis. Balkan and Kahn (1988) provide evidence that the demand for deer hunting is closely related to the quality of hunting for a given area and that socioeconomic factors of the hunters (such as income, family size and education) should be included in an economic model for hunting.

Anderson & Hill (1995) investigated the relationship between the market forces of supply and demand and the incentives they offer hunters and game managers alike. While not very useful in understanding Georgia deer harvests, this manuscript provided a discussion of the challenges of preserving endangered predators in a healthy ecosystem. When discussing the demands of both wildlife and hunting, it is important to understand that hunting must be a sustainable practice all around. It cannot cost hunters more than it is worth to hunt, and more importantly, the overall health of the ecosystem cannot be compromised by human hunting activity. The conclusion that Anderson & Hill (1995) reached is that hunting, and wildlife demands are positively correlated.

Similar to Kahui et al. (2018), it is assumed hunters not only optimize their harvests, but their hunting locations as well. Pang (2017) observed the likelihood of harvesting a game animal would increase the demand for recreational hunting in that area. Determining the probability of harvesting game in each location depends on a number of factors, including travel costs and land available, but the most interesting is the number of historical harvests in the area. It can be assumed that counties with large historical harvests will continue to experience large harvests in the future due to the increased interest in hunting in these counties, assuming the hunting practices are sustainable. It is possible that historically successful hunting areas will be depleted of game over time due to over-harvesting. When this occurs, hunters will simply move to the next optimal location until either another area becomes more optimal or the original area's populations recover. If the population is so depleted that it cannot replenish, the hunters will not choose to hunt there and will hunt in the new area until displaced. To account for the issue of historical harvests affecting present and future harvests in terms of animal reproduction, two lag variables were included in the model for Georgia white-tailed deer. The first is the number of doe harvested in the previous year and second is the number of mature bucks harvested in the previous year (a mature buck is defined herein as having four or more tines on one antler). To properly model the theory in Pang (2017), the human hunting element must be addressed as well. Hunters who have been successful may tell their hunting partners where they have had successful harvests in the past, which may prompt other hunters to expend more hunting time and effort in these locations. Following Jensen, et al. (2014), the percentage of deer killed on public land, may be utilized to capture this phenomenon in this model.

Cho, et al. (2012) investigated the demand for recreational hunting with respect to the woodlands available for hunting and county characteristics in nine southeastern states. Increasing levels of urbanization and population growth has resulted in decreased hunting lands which has caused the demand for hunting to, in effect, become crowded out. Income level, employment level, and whether the county was primarily metropolitan were important variables of question in Cho, et al. (2012). The analysis by Cho, et al. (2012) prompted the consideration of wildlife management area acreage (WMA), amount of urbanized land, county population, and median income as variable in a county based analysis of white-tailed deer harvests, but given the nature of the analysis (panel data analysis), WMA acreage and urbanized land were not included because they did not offer enough variation in the time period in question to have a notable effect. County population and median household income were adopted as variables. To capture the hunting demand per county, another lag variable was created: the number of turkeys harvested the year before. It is assumed deer hunters also hunt turkeys (given Milon and Clemons's research on species variety affecting hunting demand), so by including data from turkey season (which occurs at a different time than deer season), more robust empirical results can be obtained. Cho, et al. (2012) also used the number of hunting licenses sold per year as a direct measure of hunting demand, but serval attempts have been made to gather this data at the county level from the Georgia DNR with no success.

Sukhomirov (2016) poses the problem of food scarcity and offers recreational berry picking to help those in need add to their food supply. The research is from Russia and does not have any direct connections to deer hunting in Georgia, but it shows that natural resources can, to a degree, satisfy human demand for food. When applied to deer hunting in Georgia, demand for dietary protein can be met through hunting. It is expected that in areas with ample wealth and food, people will not need to engage in hunting for food. However, poor areas with fewer alternatives may need to rely on nature to fully satisfy demand. Following Cho, et al. (2012) and Sukhomirov (2016) median household income is included in the model. Additionally, the local unemployment rate during the hunting season may also characterize the need to utilize nature to supplement people's food supplies. Several other variables were considered, including cost of living per county and average length of work week, but they did not offer enough variability between the observed years to be included in the data analysis. An alternative interpretation of this theory would be that individuals engage in recreational hunting and other outdoor activities (i.e. berry picking) in poorer areas because of the lack of substitutable recreation/entertainment. The effects of this may be captured by the median income level of the counties due to the high correlation between wealth and amenities.

Whitehead and Aiken (2007) used data from the U.S. Fish and Wildlife Service to determine the willingness to pay for wildlife recreation activities, such as hunting and fishing. The data was survey data, but the structure of their model was consistent with other research. Whitehead and Aiken (2007) used socioeconomic variables very similar to those used by Balkan and Kahn (1988) and harvest variables such as total fish caught and whether a buck has been harvested. Whitehead and Aiken (2007) concluded that hunters' income and other big game opportunities in the hunting area are significant factors for hunter's willingness to pay for deer hunting (the latter of which provides justification for keeping the turkey harvest variable derived from Cho et al. (2012)).

Theory and Model

Given the literature and data availability, a panel data analysis may be optimal to capture the effects of the variables across the four years of available data. Due to the nature of the panel data, serval variables introduced in the literature review were revised or removed because they did not change during the 2016/17-2020/21 hunting seasons, and would have effectively been folded into the constant term of the model. The unit of observation is a county in Georgia during each of the four years of available data. There are 159 counties in Georgia, allowing for robust estimation with numerous variations in county-level data.

The dependent variable is total deer harvest density rather than total deer harvest because the counties in Georgia vary considerably in size, meaning more deer could be killed in county X simply because it has more land area than county Y. Other variables such as doe harvest the year before, mature buck harvest the year before, turkey harvest, and county population are also expressed as densities to control for the land acreage for the counties. These densities were calculated by dividing the raw variable (such as the number of doe killed last year) by the square mileage of the counties.

The hypothesis is that the deer harvest density of the current year is influenced by the doe and mature buck harvest densities of the prior year, the current year's turkey harvest density, the percentage of total deer killed on public land the previous year, the unemployment rate throughout the hunting season, county population density, median income, and the education level of county residents (defined as the percentage of the county aged 18-24 with a bachelor's degree or higher). Additionally, five binary variables were created to address forest coverage of the counties (a concern raised by Cho, et al (2012)) that group counties based on the percentage of land that is covered with forests. The group of counties with the lowest percentages of forest land were the omitted group. The hypothesized equation of the model is given as: $THARDEN_{t,j} = B0 + B1(DOEDEN_{t-1,j}) + B2(MBDEN_{t-1,j}) + B3(TURDEN\ t, j) + B4(PUBHAR_{t-1,j}) + B5(UNEM_{t,j}) + B6(POPDEN_{t,j}) + B7(INCOME_{t,j}) + B8(EDU_{t,j-1}) + B9(36\text{-}50\%) + B10(51\text{-}60\%) + B11(61\text{-}70\%) + B12(71\text{-}85\%) + B13(86\text{-}97\%) + U_{t,j}$, where the null hypothesis is B1, B2, ... B13 =0 and the alternative hypothesis is B1, B2, … B13 $\neq$ 0.

The descriptive statistics for the variables above (omit binary variables) are given in Table 1 and a correlation matrix of the variables is provided in Table 2.

Table 1: Descriptive Statistics

Variable	Mean	Standard Deviation	Maximum	Minimum
Deer Harvest Density $_{t, j}$	3.35	1.60	7.79	0.32
Doe Harvest Density $_{t-1, j}$	1.60	0.80	4.46	0.09
Mature Harvest Density $_{t-1, j}$	0.99	0.48	2.57	0.09
Turkey Harvest Density $_{t, j}$	0.21	0.13	1.19	0.00
Public Land Harvest % $_{t-1, j}$	0.04	0.07	0.62	0.00
Unemployment Rate $_{t, j}$	0.04	0.01	0.11	0.02
Population Density $_{t, j}$	211.27	425.08	2880.63	7.71
Median Income $_{t, j}$	54898.74	12587.70	82700	23900
Education $_{t-1, j}$	0.04	0.03	0.21	0.00

Every Georgia county (159) reported deer harvests and were included

Table 2: Correlation Matrix

	TDHD	DHD	MBHD	TDH	PubHar	Unemp	PopDen	MED	EDU
TDHD	1								
DHD	0.89	1							
MBHD	0.85	0.88	1						
THD	0.34	0.21	0.29	1					
PubHar	-0.29	-0.30	-0.32	0.07	1				
Unemp	0.03	0.15	0.02	-0.02	-0.03	1			
PopDen	-0.16	-0.19	-0.15	-0.28	-0.06	-0.08	1		
MED	0.06	-0.10	0.02	0.02	0.00	-0.35	0.52	1	
EDU	0.01	-0.03	-0.02	-0.11	0.09	-0.19	0.52	0.49	1

Note: TDHD= total deer harvest density $_{t, j}$, DHD=doe harvest density $_{t-1, j}$, MBHD=mature buck harvest density $_{t-1, j,}$ THD= turkey harvest density $_{t, j,}$ PubHar= Public land harvest % $_{t-1, j,}$ Unemp= unemployment rate $_{t, j}$, MED= median income $_{t, j}$, and EDU= education $_{t-1, j}$.

The correlation matrix revealed that doe harvest density (lagged) is highly correlated with total deer harvest density (0.89) and mature buck harvest density (lagged) (.88). Mature buck harvest density (lagged) is also highly correlated with total deer harvest density (the dependent variable), which suggests that this variable may be of significance in the model. The remaining variables do not exhibit high levels of correlation amongst themselves. If unaddressed, the highly correlated variables could result in multicollinearity problems in the regression analysis. To address this, doe harvest density will be removed from the analysis and the remaining correlation will most likely be unproblematic. Mature buck harvest density (lagged) and doe harvest density (lagged) were considered in this regression as a measure of the reproductive/replenishment capacity of deer populations consistent with Pang (2017). Doe harvest density is a straightforward measure of this because female deer birth more deer that replace the harvested deer in an area. Mature bucks were considered as a measure of reproductive capacity because they are the most sought-after deer by hunters, and they are the most likely out of the bucks to mate (Clancy and Nelson, 1991, pg. 28-33). Therefore, if more mature bucks are killed in an area, it is possible for less doe to become pregnant and replenish the killed deer. Doe harvest density was dropped from the model rather than mature buck harvest density because this is a hunting model and mature bucks are typically more sought after than doe. Because these variables were essentially measuring the same thing, the removal of the doe harvest variable to address correlation problems does not harm the structure of the model.

Based on the literature, it is expected that the mature buck variable (lagged) will have a positive effect on the total deer harvest density. Assuming that hunting regulations are appropriate and sustainable, a good county/area for mature buck harvests in year t-1 will likely yield a similar amount of harvests in year t. Due to the limited availability of deer season records (five years), this research is a short run analysis and, typically, deer populations do not get decimated in such a short time frame (with the proper hunting regulations).

The following variables are also expected to have a positive effect on deer harvest density: turkey harvest density, public land harvest as a percent of total harvest t-1, the unemployment rate, and education.

Turkey hunting is related to deer hunting in that they are typically conducted in the same habitat, but they differ in their legal seasons. Turkey hunting is allowed in the spring (March-May), whereas deer hunting is permitted in the fall into the beginning of winter (September-January). Because these two seasons do not overlap, deer hunters and turkey hunters will not be in the woods at the same time, therefore, it is expected (to some degree) that turkey hunters are also deer hunters and vice versa. When a hunter has a good turkey season in an area, he may return during deer season, because the forests proved to be fruitful. This is consistent with Pang (2017), Cho, et al. (2012), and Whitehead and Aiken (2007).

The lagged variable, public land harvests as a percent of total harvests, was based on the theory in Pang (2017) that addresses the word-of-mouth affect and from Balkan and Kahn’s (1988) discussion of open-access problems. The word-of-mouth affect occurs when a hunter is successful in an area and tells his friends/family and they, in turn, begin to hunt there as well. An alternative explanation is that hunters review harvest reports from past years (available from the Georgia Department of Natural Resources) and choose to hunt in the “optimal” counties or Wildlife Management Areas. As presented in Balkan and Kahn (1988), public land hunting is dramatically influenced by open access problems. Any person with a Georgia hunting license can hunt public land, therefore hunters have little incentive to preserve the wildlife for future use and therefore, prefer to harvest whatever legal deer is available. Combined, these two theories suggest this variable will be positively related to total deer harvest density in a short run analysis. In the long run, public hunting land may become so depleted of wild game that they yield little to no harvests, but this outside the scope of this research.

It is anticipated that unemployment rates will be positively related to deer harvest density, because as people lose their jobs, they have an incentive to turn to nature to feed themselves. This notion was derived from Sukhomirov (2016) and his discussion of poor Russian families resolving to pick wild berries as an effort to save on food costs. It is reasonable to expect this type of behavior from people in areas where there is ample hunting land and low travel costs to hunt. The unemployment rate variable is defined as the average unemployment rate per county during the deer hunting season (the average unemployment rate from September-January for the four hunting seasons in question). Use of the unemployment rate during the hunting season helps to determine if deer hunting is a direct response to job loss. Higher unemployment could result in larger deer harvests simply because of the availability of free time that comes with job loss. It is likely that this variable will capture the effects from both human responses to unemployment.

An education variable was included in Balkan and Kahn (1988), where it was found to be positively related to number of hunting trips made per season, and in Whitehead and Aiken (2007), where it had a positive relationship with hunter's willingness to pay for deer hunting. In Balkan and Kahn (1988), education was not clearly defined, however Whitehead and Aiken (2007) defined their education variable as years of education. For this analysis, education is defined as the percentage of the county population aged 18-24 with a bachelor's degree or higher (lagged one year). This was chosen to capture the effects of higher education on hunting demand and, in turn, hunting success. The one-year lag was included to have a complete data set for the education variable (the 2020 education statistics were not released at the time of this writing). Had the literature review not yielded positive relationships between education and hunting factors, the education variable would have been expected to yield a negative relationship. As people become better educated, they find better jobs, which could lead to less demand for outdoor recreational activity. People with higher levels of education may approach hunting differently than uneducated people, which may give them an advantage in hunting ability. Alternatively, because hunting demand increases with education, it can be assumed that hunting is a normal or possibility luxury good. As education increases, wages typically increase leading to more demand for recreation, including hunting. The literature did not offer a rationale for the positive coefficients and left it for interpretation.

The variables most expected to negatively impact total deer harvest density are population density and median income. These variables are measures of socioeconomic factors that were significant in several manuscripts from the literature review. Population density is a measure of the number of people per square mile of a county. Higher population densities imply that more resources (land) must be allocated to humans and their endeavors rather than wildlife. Less available forest land negatively impacts the demand for hunting in that area (Cho, et al. (2012)) and could negatively affect the species variety of an area (a factor deemed important by Milon and Clemmons (1991)). Based on these theories and the notion that more humans require more space and resources, higher population densities are anticipated to have negative coefficients. The median income variable came from the theory in Sukhomirov (2016), because in areas where people earn higher incomes, they have less of an incentive to supplement food supply with wildlife. Based on this theory, the relationship between income and deer harvests will be negative. On the other hand, higher income areas may have fewer reported game harvests because they have more recreational opportunities available that would draw demand away from hunting.

Table 3 below illustrates the distribution of the forestland dummy variables followed by a brief discussion of the dummies.

Table 3: Dummy Variables

Groups/Variables	**Count**	**Counties Included**
11-35% Forest Coverage	11	Chatham, Clarke, Clayton, Cobb, DeKalb, Fayette, Fulton, Gwinnett, Hart, Rockdale, Seminole
36-50% Forest Coverage	23	Barrow, Bibb, Catoosa, Colquitt, Cook, Crisp, Dooly, Forsyth, Franklin, Glynn, Hall, Henry, Irwin, Jackson, McIntosh, Miller, Mitchell, Newton, Peach, Tift, Turner, Whitfield, Worth
51-60% Forest Coverage	28	Banks, Bartow, Berrien, Brooks, Calhoun, Camden, Carroll, Cherokee, Clay, Coffee, Columbia, Decatur, Early, Floyd, Gordon, Grady, Houston, Liberty, Madison, Muscogee, Paulding, Pierce, Pulaski, Richmond, Thomas, Walker, Walton, Webster
61-70% Forest Coverage	34	Appling, Atkinson, Bacon, Baker, Ben Hill, Bleckley, Bulloch, Burke, Butts, Candler, Coweta, Dougherty, Douglas, Elbert, Evans, Habersham, Haralson, Heard, Jefferson, Jenkins, Lee, Lowndes, Macon, Murray, Oconee, Pike, Randolph, Spalding, Sumter, Tattnall, Terrell, Toombs, Troup, Wilcox
71-85% Forest Coverage	44	Baldwin, Bryan, Dade, Dawson, Dodge, Effingham, Emanuel, Fannin, Glascock, Greene, Harris, Jasper, Jeff Davis, Johnson, Jones, Lamar, Lanier, Laurens, Lincoln, Lumpkin, Marion, McDuffie, Meriwether, Monroe, Montgomery, Morgan, Oglethorpe, Pickens, Polk, Putnam, Quitman, Screven, Stephens, Stewart, Talbot, Telfair, Towns, Union, Upson, Washington, Wayne, Wheeler, White, Wilkes

86-97% Forest Coverage	19	Brantley, Charlton, Chattahoochee, Chattooga, Clinch, Crawford, Echols, Gilmer, Hancock, Long, Rabun, Schley, Taliaferro, Taylor, Treutlen, Twiggs, Ware, Warren, Wilkinson

The dummy variables were added to the analysis after the review of Cho, et al. (2012), which deduced that the demand for recreational hunting was tied to the amount of forestland in a geographic area. The Georgia Forests Report has six categories of forest coverage (listed above) in which all 159 Georgia counties were categorized. These groupings served as the basis of the dummy variables to capture the effects of having certain percentages of forest coverage on deer harvest density. It is expected that the counties with more forest coverage will have better deer harvests because of the ample habitat and resources available. It should be noted that the 11-35% forest coverage variable was excluded from the analysis to avoid singular matrix problems.

The likelihood that endogeneity is a problem in this model is low. Bidirectional causality from the dependent to independent variables is not a concern because the variables that could have caused this effect (mature buck harvest density and percent of harvest on public land) have been lagged one year, making it impossible for this year's deer harvest to influence the number of bucks killed last year. Turkey hunting takes place during a different time of the year, thus reducing the endogeneity between turkey harvest density and the dependent variable. It is fair to assume that the dependent variable does not exhibit much bidirectional causality between the remaining independent variables (unemployment, median income, population density, and education). Endogeneity caused by omitted variables has not been entirely ruled out, but the inclusion of fixed effect for time and the nature of a panel data analysis have reduced the possibility of this form of endogeneity. Further testing may be appropriate to account for remaining endogeneity.

Results

The model was estimated using the ordinary least squares (OLS) method of regression with period fixed affects to control for changes related to the progression of time. The results reported in Table 4 below are per 1,000 square miles (the original regression results were multiplied by 1,000). The R-Square, Adjusted R-Square, and F-Statistic were not altered from the regression results. * indicates statistical significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Table 4: Regression Results

Variable	**Coefficient**	**T-Statistic**
Constant	-549.07	-2.40
Mature Buck Harvest Density t-1	2976.12***	56.33
Turkey Harvest Density	629.12***	3.22
Public Land Harvest % t-1	-420.14	-1.22
Unemployment Rate	2446.38	1.04
Population Density	-0.11	-1.26
Median Income	0.007***	2.96
Education	2084.27***	2.69
36-50% Forest	145.81	1.09
51-60% Forest	273.60**	2.02
61-70% Forest	275.59**	2.00

71-85% Forest	257.37*	1.82
86-97% Forest	241.73	1.63
R-Square	0.880	
Adjusted R-Square	0.877	
F-Statistic	305.38	

The OLS regression yielded results that were mostly consistent with the existing literature with four independent variables and three of the dummy variables being statistically significant over the 90% confidence level. The adjusted R-Square from the regression of 0.877 indicates that approximately 88.7% of the variation in total deer harvest density is explained by the independent variables used in this analysis. The F-statistic of 305.38 and its accompanying probability of 0% provides evidence that the model is statistically significant. Residual tests were conducted and provided assurance that the residuals were evenly distributed around zero and there is a low probability for heteroskedasticity in this model.

The coefficient for the mature buck harvest density (lagged) of 2976.12 provides evidence that past year's harvest influence current year's harvest. This coefficient indicates that as the mature buck harvests per square mile increase by one, the total deer harvested per square mile during the following season is expected to increase by 2.9 (the coeffects in the table are given per 1,000 square miles. This result supports Pang (2017) and provides evidence that deer populations are not being over-hunted in Georgia (this would have been reflected by a negative coefficient of this variable). The very large t-stat of 56.33 assures that this is a statistically significant variable at the 99% confidence level.

Turkey harvest density resulted in a positive coefficient as well, providing evidence that successful turkey hunting areas are also good deer hunting locations. This variable was statistically significant at the 99% confidence level (indicated by the t-stat of 3.22) and the coefficient of 629.12 suggests as the turkey harvest increase by one per square mile, the deer harvest density will increase by 0.629. This result could offer some indication that turkey hunters also hunt deer, because counties and seasons with better turkey harvests also have better deer harvests. An alternative explanation to the positive correlation could be that the forestlands most productive for turkeys are also most productive for deer and that seasonal harvests are directly tied to the health and productivity of the ecosystem.

The percent of total harvests taken on public land was expected to have a positive coefficient based on the word-of-mouth phenomena that was deduced from Pang (2017), but the results showed that this variable was negatively related to total deer harvest density. The t-stat of -1.22 is too low to consider this variable statistically significant at the traditional levels of confidence, therefore no sound conclusions can be drawn from this variable because there is not ample evidence to reject the null hypothesis.

Unemployment during the hunting season and population density both failed to be statistically significant (t-stats of 1.04 and -1.26, respectively), however, their coefficients were consistent with the literature (positive for unemployment and negative for population density). The lack of statical significance mean that no solid conclusions can be made from these variables in this analysis.

The median income variable was expected to have a negative relationship with the dependent variable, but the regression resulted in a positive coefficient for this variable.

The t-stat of 2.96 implies statistical significance at the 99% confidence level and the coefficient of 0.007 implies that a $1 increase in income causes the deer harvest to increase by 0.007 per square mile of county. This effect seems quite small, but a $10,000 increase in median income would result in an increase of deer harvests per square mile to increase by 7. This was unexpected; however, it offers some evidence that as income rises, hunting demand increases as for a normal good. In particular wealthier people can pay hunting club fees and buy better hunting gear which could give them hunting advantages.

Education was shown to be positively related to deer harvest density, which is consistent to the research of Balkan and Kahn (1988) and Whitehead and Aiken (2007). The t-stat of 2.69 grants statistical significance at the 99% confidence level. The resulting coefficient of 2084.27, means that as the segment of the county population aged 18-24 with a bachelor's degree or higher increases by 1%, the deer harvest is expected to increase by 2.08 per square mile. This effect is not easily explained; however, a cause could be higher-educated people place greater value on nature and are more likely to engage in outdoor recreation such as hunting. An alternative explanation is that educated people are better wildlife stewards, resulting in healthier forests which produce more wildlife, and hunters free-ride on this benefit.

Two out of the five dummy variables achieved statistical significance at the 95% confidence level (the 51-60% and 61-70% groups) and one was significant at the 90% level (71-85%). Because two of the groups were not statistically significant, no definitive statements can be made about their affects within this model. The three significant dummies fall in the middle range of forest coverage, which was unexpected but explainable. Previously, it was thought that more forestland in a county would drive a higher demand for hunting (Cho, et al. (2012)), but the problem with these areas is they have very small populations. The areas that fall in the 51-85% groupings have a better balance of forestland to human population, which probably explains the higher coefficients for these variables and the achievement of statistical significance.

Discussion and Conclusion

This paper provides some recent evidence concerning the determinates of white-tailed deer harvest densities in Georgia counties. The regression model provided statistical evidence that was mostly consistent with the theories presented and derived from the literature review. Socioeconomic factors and wildlife factors were found to be important in determining the quantity of deer harvests.

The socioeconomic factors included in the analysis (unemployment, population density, median income, and education) focused on human activity outside of hunting and offered interesting findings concerning the willingness to hunt and the quality of the land. Unemployment rates during the hunting season and population density were found to not be significant factors in this analysis; however, income and education were significant and higher levels of income and education led to more deer harvests per square mile. As people become wealthier, they have more disposable income to spend on recreation, therefore they are more likely to adopt hunting practices when income becomes higher. Due to this positive relationship between income and deer hunting, hunting can be considered a normal good/activity. The alternative outcome that wealthier areas have a smaller incentive to use nature to supplement their food supply, and therefore are less likely to hunt, was not supported by the model. Education exhibited a positive effect on deer harvest density as well. This implies that as people become more educated, they are more likely to hunt or be more successful than before. However, it is more likely that higher education is a signal to the county's willingness/awareness to preserve natural habitat, and the hunters reap some of this benefit.

Wildlife factors used in this model include hunting factors and a deer reproductive factor. The hunting variables included the percent of the deer harvest taken on public land (lagged one year) and the turkey harvest density. The lagged variable resulted in the negative coefficient which may imply that Georgia's public lands are being overhunted, but this variable was found to lack significance in the model and this claim cannot be substantiated. Turkey hunting density shares a positive relationship with deer hunting density which offers evidence that either optimal turkey hunting areas are also optimal deer hunting areas or that turkey hunters also hunt deer. Either way, this variable supports the theory that species variety increases hunting demand and success in an area. The ability for deer populations to reproduce after a hunting season was measured by the mature buck harvest density (lagged one year). The model revealed that this variable was important and that it has a positive relationship with total deer harvest density for the current hunting season. The positive relationship implies that greater harvests last year lead to greater harvests in the present year, which provides evidence for the word-of-mouth phenomenon and the theory that past harvests effect present harvests (both theories from Pang (2017)). It also implies that deer can reproduce well enough to replace the killed deer from last season and, therefore, are not being over-hunted. Further data on the number of hunters per year would be able to clarify this point further, because the additional harvests each year could result from more hunters and more effort being expended in the woods. If the number of hunters stayed approximately the same, there is a better argument for the deer's reproductive ability. Numerous attempts were made to gather this data, but none were successful.

The dummy variables were built into the analysis to determine if the amount of forest coverage per county was a significant factor in determining deer harvests. It was found that three of the five dummies were statistically significant and that forest coverage of a county between 51% and 85% was an important factor for deer harvest per square mile. It was expected after the literature review that the counties with the most forest coverage would have the most deer harvest due to the availability of quality hunting land, but this was not the case. Counties with very low forest coverage and very high forest coverage were not significant factors and had smaller coefficients that counties in the mid-range of coverage. This is likely to the imbalance of people-to-wildlife in the low and high coverage areas. Low forest coverage implies more humans and human actives because it is assumed that, typically, there is a trade-off between developments and nature. These counties do not have enough wildlife to support the people resulting in low harvests in these areas. Counties with high forest coverage typically have small, sparse populations and an ample supply of wildlife. This imbalance results in lower harvest densities as well because there are not many hunters in these areas. The coverages that were most significant fall in the middle and these counties typically have a population density that is towards the middle. These conditions result in larger harvest densities because there is a balance of hunters to wildlife available. Further literature review and more years of harvest data will be needed moving forward with research into determinates of Georgia white-tailed deer harvests.

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Data Appendix

Wildlife harvest data: https://gamecheckresults.gooutdoorsgeorgia.com/

Forest coverage data: https://gatrees.org/wp-content/uploads/2020/01/Georgias-Forests-5-Year-Report-2014.pdf

County square milage: http://www.usa.com/rank/georgia-state--land-area--county-rank.htm

WMA and State park acreage: https://georgiawildlife.com/allwmas

Monthly unemployment data: https://explorer.gdol.ga.gov/

Yearly income and population data: https://www.census.gov/

Educational data: https://data.census.gov/