The Amenity Value of Climate Change Across Different Regions in the United States

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ABSTRACT

This article estimates the amenity value from climate change by analyzing the effect of climatic variables on house prices near ski resorts in different regions in the United States using a hedonic model. We find that higher average winter temperatures tend to increase house price near ski resorts at a decreasing rate. Using the implicit value of average winter temperature, we estimate its demand and find that the crossing point temperature, where the homeowner's consumer surplus from average winter temperature moves from positive to negative, varies in each region. The highest crossing point temperature is in the Western region at 46°F and lowest is in the Midwest at 8°F. Based on projections in the next 30 years, we find that the consumer surplus from average winter temperature for the median home owner is negative in the Midwest and Northeastern regions where the crossing point temperatures are lowest and it is positive for the West and Mountain regions where the crossing point temperatures are highest. The long run effect of climate change on homeowner's consumer surplus is negative for all regions.

1. Introduction

Amenity value is an important determinant of housing prices. Houses located near open spaces, parks and other recreation amenities tend to have higher property prices (Cho et al., 2008; Geoghegan et al., 1997; Geoghegan, 2002; Irwin, 2002; Acharya and Bennett, 2001; and Nelson, 2010). Changes in the environment can significantly affect amenity value. For example, incidences of wildfire decrease property value (Stetler et al., 2010). Furthermore, climate change directly affects the environmental amenities which, in turn, affect property value. Given this link, we can estimate the value of climate change through changes in the amenity value as reflected by housing price fluctuations.

The impact of climate change is not limited to amenity value. Since climate variables such as temperature and precipitation directly affect agricultural production, there is a significant literature that studied the effect of changes in climatic variables on farmland value and agricultural profits. There has been disagreement on the magnitude and sign of climate variables and the measures of welfare from the agricultural sector. For instance, there seems to be a robust negative effect of climate change on farmland value (Schlenker et al., 2005) but the same climate variables have no significant effect on agricultural profit (Deschenes and Greenstone, 2007) in some specifications.

Ambiguous effects of climate change are also found when considering the amenity value of climate change. High latitude countries benefit from limited climate change in the form of milder temperature and less extreme cold but low latitude countries (Maddison, 2003) and coastal areas (Hamilton, 2007) are negatively affected by rising sea levels, changes in coastal landscape and more extreme heat. The ski resort industry is directly affected by climate changes because it is not only affected by changes in average winter temperature but also change in the amount of snowfall and length of the ski season each year (Burakowski and Magnusson, 2012). Several papers found a robust negative effect of climate change on the ski industry. For instance, Butsic et al. (2011) find that most housing prices near ski resorts in the Rocky Mountain region will decline by single digit percentage values when greenhouse gas emission levels are low and may reach up to a 50% decline at high greenhouse gas emission levels.

The studies we reviewed that linked climate change and the ski resort industry do not account for three important aspects in estimation: (1) the spatial dependence between house prices; (2) non-linear effect of temperature; and (3) a comprehensive set of climate variables. Several studies indicated that spatial autocorrelation occurs through geographic location dependence (Dubin, 1988; Se Can and Megbolugbe, 1997). Estimating the determinants of house prices using ordinary least squares (OLS) without accounting for the spatial dependence of the variables in the data leads to biased estimates (Pace and Gilley, 1997). Moreover, previous studies linking climate change and house value near ski resorts do not account for the nonlinear effects of temperature. Temperature has a non-linear effect on crops yield (Schlenker et al., 2009) where increasing temperature to some point can increase crops yield, but increasing beyond a threshold can be harmful to crops. A similar non-linear relationship may exist between temperature and house prices near ski resorts where a slightly warmer temperature with more snow can make it more conducive for outdoor recreation during winter. However, temperature above a certain threshold can lead to less snow for outdoor recreation and an unambiguous decline in utility. Finally, focusing only on one particular type of climate variable without accounting for the effect of other variables may lead to omitted variable bias which skews the estimated effect of climate change on welfare.

Our paper estimates the amenity value of climate change through housing markets by determining the effects of different climate variables on house prices near ski resorts. We use a hedonic model to find the implicit marginal value of the most robust and significant climate variable, in our case it is average winter temperature, and its corresponding demand curve. We account for the spatial dependence between housing prices, allow for non-linear impacts of temperature and include a set of climate variables. This paper adds to the literature by estimating the non-linear effect of temperature on amenity value and calculating the consumer surplus across different regions in the United States due to climate change variables that correctly adjusts for their projected annual variability over time. This paper has important policy implications because we illustrate the variable effects of climate change in different regions where the ski industry in the Midwest and Northeastern regions are most sensitive to changes in average winter temperature in the next 30 years. In the very long run, we show that all regions are adversely affected if the overall trend of climate change remains the same.

Only a few studies have used the hedonic framework in estimating recreational value from ski resorts (Nelson, 2010; Soguel et al. 2008). The impact of climate change on the ski industry has been studied in countries such as Switzerland (Konig and Abegg, 1997), Austria (Wolfsegger et al., 2007), Canada (Scott et al., 2007), Japan (Fukushima et al., 2003), and the United States (Lipski and McBoyle, 1991). These papers show a negative impact of climate change on the ski industry but they do not use a hedonic framework.

Our paper is most related to Butsic et al. (2011) where they used a hedonic pricing method to estimate the impact of climate change as proxied by snowfall percentage of precipitation on house prices in ski areas in the Rocky Mountains. Their estimates show a reduction in housing prices near ski resorts due to reduced snowfall. We extend their work by using a spatial model to capture the spatial dependence of prices in the housing market; increase the number of climate variables; allow nonlinear effects of temperature on house prices and expanding to more areas in the US by including the Western, Northeast and

Midwest regions. Moreover, our paper measures consumer surplus based on the implicit value of average winter temperature as a proxy for the amenity value from climate change.

We find that the most significant climate variable affecting housing prices near ski resorts is average winter temperature. A rise in average winter temperatures increases house prices at a decreasing rate so that the implicit value of average winter temperature eventually declines and becomes negative. Houses near ski resorts with summer recreation also tend to have higher prices.

We show that the calculation of consumer surplus of a climate variable such as average winter temperature needs to account for two important factors. First, the estimated implicit marginal value of average winter temperature in a hedonic model accounts for its contribution to housing price assuming there is no change in the variable over time. Since average winter temperature is projected to change over time, the present value of such a change needs to be adjusted in the calculation of consumer surplus of a representative owner. Second, climate variables are non-rival and non-excludable. This implies that aggregating consumer surplus entails a vertical summation and not a horizontal summation such as those done in other hedonic regressions.

Given the relationship between average winter temperature and housing prices, the long run effect of climate change on homeowner's consumer surplus is negative for all regions but there are variations across regions during the short and medium run. In the medium run, we find that the consumer surplus is positive for the Western and Mountain regions but it is negative for the Midwest and Northeastern regions after accounting for changes in average winter temperature over time and discounting. Without such an adjustment, the calculated consumer surplus can be overestimated by as low as 9% or as high as 238%. One important reason why some regions have negative consumer surplus while others have a positive surplus is because the crossing point temperature, where the implicit value of temperature changes from positive to negative, is lower in the Midwest and the Northeast than the Western and Mountain regions.

Section 2 describes the theoretical model, which explains the hedonic price method and our measure of welfare. Section 3 shows the empirical model based on our theory. Section 4 describes all variables related to our model and their sources. Section 5 summarizes the empirical results, which includes results from a spatial regression and an evaluation of consumer surplus. Section 6 concludes the paper.

2. Theoretical Model

We modify the hedonic pricing method introduced by Roback (1982) to estimate the impact of temperature changes on house prices. Let $\boldsymbol{Z}$ represent a vector of characteristics such that $\boldsymbol{Z} = [\boldsymbol{Z^H}, \boldsymbol{Z^N}, \boldsymbol{Z^S}, \boldsymbol{Z^W}]$, where $\boldsymbol{Z^H}$ is a vector of house characteristics, $\boldsymbol{Z^N}$ is a vector of neighborhood characteristics, $\boldsymbol{Z^S}$ is a vector of the ski resort, and $\boldsymbol{Z^W}$ is a vector of weather characteristics. Individuals buy a house depending on these characteristics. Individuals also consume other goods, x, where we normalize its price to 1. The individual's utility function, $U\ (x, \boldsymbol{Z})$, is increasing and concave in x, $\boldsymbol{Z^H}, \boldsymbol{Z^N}$ and $\boldsymbol{Z^S}$. We assume that an optimal weather characteristic exists that maximizes utility. For example, an optimal average winter temperature, Z_i^{W*}, exists where $\frac{\partial U}{\partial Z_i^w} > 0$ if $Z_i^{W*} > Z_i^W$ but $\frac{\partial U}{\partial Z_i^W} < 0$ if $Z_i^{W*} < Z_i^W$. For skiing, the optimal winter temperature is usually between 20°F to 32°F. A higher temperature melts snow and a lower temperature results in icy conditions.

Individuals choose x and characteristics $\boldsymbol{Z}$ with an income constraint, y, to maximize her utility. Since each element of $\boldsymbol{Z}$ cannot be chosen separately, we can write the problem of the buyer as choosing a bid, θ, which describes the amount that an individual is willing to pay for a house with varying characteristics to achieve a particular level of utility. Determining the marginal bid function, tells us how much an individual is willing to pay for an extra unit of Z_i to keep their utility constant, $\hat{u}$. The optimal bid function is determined by solving the equation: $U(x,\ \boldsymbol{Z}) = \hat{u}$. Since total income is $y = x + \theta$, the problem becomes,

$$(1)\quad U(y-\theta, \boldsymbol{Z}) = \hat{u}$$

where the optimal bid is $\theta^* = \theta^*(y, \boldsymbol{Z}, \hat{u})$.

The impact of a climate change variable, such as average winter temperature, on the optimal bid price is derived by taking the differential of (1) and manipulating,

$$(2)\ \frac{\partial U}{\partial x}\left(\frac{dy}{dZ_i^w} - \frac{d\theta}{dZ_i^w}\right) + \frac{\partial U}{\partial Z_i^w}\frac{dZ_i^w}{dZ_i^w} = \frac{du^*}{dZ_i^w}\,.$$

For a given utility and income level, $\frac{du^*}{dZ_i^w} = 0$ and $\frac{dy}{dZ_i^w} = 0$; therefore,

$$(3)\ \ \frac{d\theta}{dZ_i^w} = \frac{\frac{\partial U}{\partial Z_i^W}}{\frac{\partial U}{\partial x}}.$$

Holding the effect of other variables constant, equation (3) shows that the marginal bid function for average winter temperature, which is the implicit price of average winter temperature, is equal to the negative of the Marginal Rate of Substitution between average winter temperature and *x*. Note that since $\frac{\partial U}{\partial Z_i^W}$ depends on the value of Z_i^W relative to Z_i^{W*}, its sign and the corresponding marginal bid $\frac{d\theta}{dZ_i^W}$ may be positive or negative.

The house owner decides on an offer price for the house, Φ, to achieve a target profit, $\hat{\pi}$. The target profit will be dependent on the cost of the house, which depends on characteristics $\boldsymbol{Z}$, where cost is increasing and convex in all elements of $\boldsymbol{Z}$ except the climate variables. The climate characteristics may have an adverse effect on cost depending on the type of climate variable. For example, lower average winter temperatures are likely to increase cost of constructions such that $\frac{dC(\boldsymbol{Z})}{dZ_i^W} < 0$. The target profit is defined as:

(4) $\hat{\pi} = \Phi - C(\boldsymbol{Z})$.

Solving for the optimal offer price, we obtain $\Phi^* = \Phi^*(\boldsymbol{Z}, \hat{\pi})$. The impact of average winter temperature change on the optimal offer function is,

(5) $\frac{\partial \Phi}{\partial Z_i^W} = \frac{\partial C}{\partial Z_i^W}$,

where the marginal offer price is equal to the marginal cost of average winter temperature and is decreasing in the variable.

The equilibrium house price, P*, is where the offer function and bid function are equal, $\Phi^*(\boldsymbol{Z}, \hat{\pi}) = \theta^*(y, \boldsymbol{Z}, \hat{u})$. Therefore, the equilibrium price depends on income, target utility, target profit, and characteristics $\boldsymbol{Z}$**,**

(6) $P^*(y, \hat{u}, \boldsymbol{Z}, \hat{\pi}) \equiv \theta^*(y, \boldsymbol{Z}, u^*) - \Phi^*(\boldsymbol{Z}, \hat{\pi}) = 0$.

The marginal effect of average winter temperature affects the buyer's bid and supplier's offer such that,

(7) $P_i = \frac{d\theta^*}{dZ_i^W} - \frac{d\Phi^*}{dZ_i^W}$

where $P_i \equiv \frac{dP^*}{dZ_i^W}$ is the marginal housing price due to a change in average winter temperature which represents the implicit price of average winter temperature. Interestingly, P_i may be positive or negative because it depends on the position of Z_i^W relative to Z_i^{W*}. Therefore, an increase in average winter temperature may have a negative or positive impact on the optimal house price.

To derive consumer welfare, we estimate a demand curve for average winter temperature, Z_i^W, using the implicit price in (7). After obtaining the implicit price from every sample observation, we estimate its determinants as a function of the neighbor's implicit price of temperature, P_i^n, income, average winter temperature, and population density, *n*,

(8) $P_i = f(P_i^n, Z_i^W, y, n)$.

Given the non-rival and non-excludable nature of climate variables, the consumer surplus at a given year and average winter temperature level is equal to the implicit marginal price along the estimated demand curve.

There are two important notes regarding the calculation of consumer surplus from a climate variable such as average winter temperature. First, since climate variables are non-rival and non-excludable, aggregate consumer surplus over a population entails a vertical summation and not a horizontal summation across implicit marginal values. Second, the predicted implicit value derived from (8) measures the total consumer surplus attributed to Z_i^W for the entire purchase of the house during the duration of the homeowner's stay, holding Z_i^W constant. However, since Z_i^W changes over time, an adjustment needs to be made regarding the impact of Z_i^W on the annualized implicit marginal present value over time. The consumer surplus, CS, for staying in the house will depend on the length of stay and the effect of changes in average winter temperature on the implicit price over that length,

$$(9)\ CS = \frac{1}{T}\sum_{j=0}^{T} g\left(Z_{ij}^W, y, n\right) \delta^i,$$

where T is the total length of stay in the house, j is the time index and δ is a discount factor. Note that $g\left(Z_{ij}^W, y, n\right)$ is a function that already accounts for the neighbor effect in the implicit marginal value of average winter temperature.

3. Empirical Model

We estimate the effect of climate variables on house prices near ski resorts by specifying an empirical model based on equation (6). Given the composition of $\boldsymbol{Z}$, we find,

$$(10) \qquad P^* = f(\boldsymbol{Z^N}, \boldsymbol{Z^H}, \boldsymbol{Z^S}, \boldsymbol{Z^W}, y, \hat{u}, \hat{\pi}).$$

Following the literature on the determinants of housing prices, we proxy the neighborhood characteristic, $\boldsymbol{Z^N}$**,** by a measure of income in the area and neighborhood house prices. This allows us to specify a spatial autoregressive model, which captures the spatial dependence of housing prices between neighbors,

$$(11) \qquad \ln P_{cs} = \alpha_0 + \rho \sum_n \omega_{ns} \ln P_{ns} + \sum_w \alpha_w \ln Z_{wc}^W + \sum_t \alpha_{1t} \ln Z_{tc}^W + \sum_t \alpha_{2t} \ln Z_{tc}^{W^2} +$$

$$h\alpha h \ln ZhcH + s\alpha s \ln ZscS + \alpha y \ln y + \epsilon s + \varepsilon cs$$

where P_{cs} is the house price of the median home buyer in the c^th^ city in state s, ω_{ns} is the weight assigned to the n^th^ city neighbor in state s, P_{ns} is the house price of the neighbor's median home buyer in state s, Z_{wc}^W is the w^th^ measure of climate variable in a season in the c^th^ city, Z_{tc}^W is the average temperature level in the c^th^ city in season *t* where *t=i,u* for summer and winter seasons, respectively, Z_{hc}^H is the h^th^ house characteristic in the c^th^ city, Z_{sc}^S is the s^th^ ski resort characteristic in the c^th^ city, ϵ_s is a state fixed effect that proxies for $\hat{u}$ and $\hat{\pi}$ along with other time invariant state characteristics and ε_{cs} is a random disturbance with the usual desirable properties. The dependent variable and independent variables are measured in log form.[1] Also note that we allow for a non-linear effect of average temperature by introducing the square of the average temperature in the season.

There are two issues that need to be addressed in estimating (11). First, since we analyze the effect of climate change across different regions in the US, we use median house prices in a city instead of individual house prices. Other papers have also used median house prices to estimate the value in a hedonic approach.[2] O'Byrne et al. (1985) found that using actual property prices of individual housing units achieves similar results as when using the median property prices.

The second issue is the introduction of a spatial weight, which informs us whether observations are considered neighbors and how they are related to each other. Following the

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[1] The Box-Cox test favors the double log specification over the linear and semi-log specifications.

[2] See for example Cho et. al., 2009; Loomis, 2004; Gatzlaff and Ling, 1994; Kockelman, 1997; Greenstone and Gallagher, 2008; Kim and Goldsmith, 2009; Williams, 2001; and Ketkar, 1992.

literature, the spatial weight matrix we use is based on distance where we use the coordinates for each city and find the distance between the center points of the cities. Two cities are considered neighbors if the distance between them is less than 100 miles. The spatial weight between cities is equal to 1 if the distance between the city and its neighbor is less than 100 miles and 0 otherwise. The coefficient ρ captures the effect of neighborhood characteristics, through neighbor's house price, on own house price.

Our main parameters of interest are the coefficients related to the climate variable to determine their effects on house prices near ski resorts. In particular, we focus on the effect of average winter temperatures. Based on the assumptions in our model, if an optimal average winter temperature exists, we might expect that average winter temperature increases housing prices at a decreasing rate such that $\alpha_{1i} > 0$ and $\alpha_{2i} < 0$ when $Z_{ic}^{W} < Z_{ic}^{W*}$. However, average winter temperature could decrease housing prices at an increasing rate when $Z_{ic}^{W} > Z_{ic}^{W*}$.

To calculate consumer surplus during the individual's stay in the house as specified in equation (9), we first estimate the marginal effect of average winter temperature on housing price. This allows us to derive observations for each city to use as data points in estimating the inverse demand of average winter temperature. Using equation (11), the marginal effect of average winter temperature, Z_{ic}^{W}, on the average house price in the c$^{\text{th}}$ city is,

$$(12)\ P_{ci} = \frac{P_{cs}}{Z_{ic}^{W}}\left(\frac{\alpha_{1i}}{1-\rho\sum_{n}\omega_{ns}} + 2\frac{\alpha_{2i}}{1-\rho\sum_{n}\omega_{ns}}\ln Z_{ic}^{W}\right),$$

where $P_{ci} \equiv \frac{\partial P_{cs}}{\partial Z_{ic}^{W}}$ is the implicit marginal value for average winter temperature. Here an increase in average winter temperature will decrease the marginal value of average winter temperature as long as $\alpha_{2i} < 0$ and $1 - \rho\sum_{n}\omega_{ns} > 0$.

To derive the inverse demand curve for average winter temperature, we estimate the following spatial autoregressive model,

(13) $P_{ci} = \beta_0 + \gamma \sum_n \omega_{ns} P_{ni} + \beta_i Z_{ic}^W + \beta_y y + \beta_n n + \mu_s + \mu_{cs}$,

where γ is the spatial coefficient, P_{ni} is the implicit marginal value for average winter temperature of neighbor, n is population density, μ_s is a state fixed effect and μ_{cs} is a random disturbance with the usual desirable properties. Finally, we obtain the annualized predicted implicit marginal value of average winter temperature in each time period during the home owners stay in the house. The discounted sum of the values is equal to the consumer surplus of the median homeowner as shown below,

(14) $CS = \frac{1}{T}\sum_{j=1}^{T}\left(\frac{\beta_0}{1-\gamma\sum_n \omega_{ns}} + \frac{\beta_i}{1-\gamma\sum_n \omega_{ns}} Z_{icj}^W + \frac{\beta_y}{1-\gamma\sum_n \omega_{ns}} y + \frac{\beta_n}{1-\gamma\sum_n \omega_{ns}} n\right)\delta^j$.

Aggregate consumer surplus is the total homeowner population multiplied by this value.

4. Data

To estimate equation (11), we compile a unique dataset that includes, median house prices, income, house characteristics, ski resort characteristics, and weather characteristics for different states in the United States. Our data contains 216 observations of cities near ski resort for the year 2010, which are divided into 4 regions: West, Midwest, Northeast, and Mountain region.[3] We do not include the Southern region because there are not many ski resorts in that location. Table 1 provides the summary statistics of variables used in the estimation and Appendix 1 describes variables that are used in our estimation.

4.1 House Characteristics (Z^H) and Neighborhood Characteristics (Z^N)

Our median house prices in a city are obtained from the 2010 Zillow Real Estate Market Report. Median house prices are obtained from the city or nearest city that the ski resort is located. Since individuals may purchase houses in the nearest city to access ski resorts, the marginal value individuals place on this accessibility could significantly affect individual and median housing prices. We also compile other house characteristics that are

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[3] See Appendix 2 for a list of states in each region.

commonly used in hedonic house price estimates from the 2010 U.S. Census tract such as area, number of rooms, number of bedrooms, and age of the house.

We use neighborhood house prices as a proxy of neighborhood characteristics. In addition, we include per capita income for homeowners and population density from the same source. The median house price is highest in the Mountain region at \$486,000 and lowest in the Midwest region at \$163,000. This coincides with income and house size since the Mountain region has the highest homeowner income and largest houses among our regions.

4.2 Ski Resort Characteristics (Z^S)

Ski resort characteristics are obtained from White Book of Ski Resorts. It provides information such as elevation base, vertical drop, ski area, and the number of months open for operation. Vertical drop is the vertical distance between the top and base elevation of the ski resort. Higher vertical drops increase the quality of the ski resort because skiers and snowboarders enjoy longer runs. The Mountain region has the longest vertical drop and also the highest elevation base while the Midwest region has the shortest vertical drop and the lowest elevation base.

Summer recreation areas are also important because people engage in summer activities when the weather gets warmer. Therefore, ski resorts that have summer activities on site will have an advantage when temperature increases. These ski resorts can offer both winter and summer recreations, which attract more people to visit the area all year round. Thus, they may be less affected by shortened ski seasons. We created a dummy for summer recreation sites by going through individual ski resort websites. If they advertised summer recreation activities, they are given a 1 and 0 otherwise. We find that 59% of ski resorts offer summer recreation activities where the highest percentage of ski resorts that also offer summer activities are concentrated in the Mountain region at 67%.

4.3 Weather Characteristics (Z^W)

We collect a set of weather characteristics from the Weather Channel website pertaining to climate variables in the winter and summer seasons. This includes average temperature, average precipitation, variance of temperature and variance of precipitation. Average winter temperatures are calculated for the months of December, January, and February while average summer temperatures are calculated for the months of June, July, and August. Weather Channel provided average temperature and precipitation for each month, and then we calculated their corresponding variance. The data on average precipitation is our proxy for the average snowfall.

There is a large degree of climate variability across the regions. The region that has the lowest average winter temperature is the Midwest at 21°F, while the highest is the West region at 31°F. Note that the range of average winter temperature in all regions still fall within the ideal range to conduct winter activities, i.e. 20°F to 32°F. The variance of the estimates varies widely across regions as well. The average winter precipitation is highest in the West and Northeast which implies the most snowfall. In contrast, the average summer temperatures across the regions are less variable since they fall between 64°F to 68°F but summer precipitation also varies from a low of 1 inch in the West to a high of 4 inches in the Northeast.

5. Empirical Results

We present spatial autoregressive estimates linking the effect of climate variables on house prices near ski resorts. Using the results from the estimation, we derive the implicit marginal value of average winter temperature and its corresponding inverse demand to obtain a measure of consumer surplus.

5.1 The determinants of housing price

Table 2 presents the coefficient estimates of the determinants of house price using a spatial autoregressive model for the entire sample compared with the results separated in each region. We use the Huber-White robust estimator of variance to calculate the standard errors of the coefficients to account for heteroskedasticity. All models have satisfactory goodness-of-fit. Also, we control for any unobserved state factor by including state dummies.

We find a positive spatial coefficient from our overall model indicating that the house price in a neighboring area has a positive influence on own house price. Thus, utilizing a spatial autoregressive model is preferred over OLS. Among the different regions, West and Mountain regions have house prices that are most spatially related. Houses with more bedrooms and larger areas are associated with a higher price. However, as the house gets older, the price decreases. Owner income is positively related with house price indicating that houses are normal goods.

There are two ski resort characteristics that significantly affect house price. First, vertical drop has a positive impact on house prices with high statistically significant coefficients for almost all regions. This shows that skiers value long ski runs and are willing to pay more for better experiences. Second, the summer recreation variable has a significant positive effect on housing prices overall but the results vary by region. Homeowners value summer recreation sites in ski resorts, especially those located in the West and Midwest. However, the result is not significant for the Rocky Mountains and is negative for the Northeast. This may be due to the presence of other recreational sites nearby that specialize on summer activities.

We find several climate variables that affect house prices. First, precipitation significantly affects house prices; however, the impact differs by season. More average winter precipitation positively significantly affects housing price near ski resorts for some regions since this correlates to more snow for use in winter related activities. However, there is a more robust negative impact of summer precipitation on house price with magnitudes that are slightly higher than the average winter precipitation effect. Since summer rain reduces most summer activities, such a result is not unexpected.

Temperature has a nonlinear effect on house price in both seasons. Average summer temperature increases house price at a decreasing rate but the effect is not consistent across regions. This only holds for the Midwest and Mountain regions. However, there is a consistent and significant nonlinear effect during the winter season. The results show that the house price increases at a decreasing rate as average winter temperature rises in each region.

Table 3 summarizes the elasticity of house price given a change in average winter temperature along with the corresponding implicit value of average winter temperature. Based on the average winter temperature across all regions, the point elasticity of house price evaluated at mean values given a change in average winter temperature is inelastic at -0.46. However, the effect of average winter temperature on house price varies across regions. The Midwest and Mountain regions have negative elasticities at -2.33 and -0.31, respectively, indicating that house prices in the Midwest are about seven times more responsive than the house prices in the Mountain regions at current average winter temperatures. In contrast, the West and Northeast regions have positive and inelastic values at 0.13 and 0.37, respectively.

The average winter temperature is expected to rise at a rate of 0.078°F annually in the next 30 years (USGCRP, 2009). Given the elasticities we calculated, this implies a decrease in house price in the Midwest and Mountain regions of about 0.9% and 0.1%, respectively. In contrast, the same change in temperature would lead to a 0.03% increase in house price in the Western region and 0.1% increase in the Northeast region. Our results show significant variability of climate change across different regions in the United States where some regions experience positive gains while other regions experience relatively larger losses. The average house price in the Midwest is the most sensitive since the effect of current average winter temperatures leads to an approximate $15,600 reduction in the average house price.

Unlike Butsic et al. (2011) where they find a consistent negative effect of climate change in the Mountain regions that can range from a mild single digit reduction in house price to almost a 50% reduction in house price depending on greenhouse gas emission levels, we find the effect of climate change differs depending on the type of climate variable. Average winter temperature has a mild positive effect while average winter precipitation has some positive effect but it is not significant in the Northeast and Mountain regions. The datasets between the two studies are different since Butsic et al. have individual house data over time but focused only in the Rocky Mountain region. In contrast, we have a cross section of median house prices across cities covering more regions in the United States.

We point to two potential reasons aside from data characteristics why we obtain different results. First, Butsic et al. (2011) rely on the snowfall percentage of precipitation as a measure for climate change and do not include other measures of climate. Second, we allow for potential nonlinearity of temperature effects. Omitting other climate variables and not testing for potential nonlinearity could lead to omitted variable bias. Table 4 mimics the two main specifications used by Butsic et al. (2011) as close as possible given our variables by omitting elevation base, number of months the ski resort is open, the summer recreation indicator, ski resort area and other climate variables. We find that, unlike our results, the effect of average winter precipitation is now positive and significant in the Mountain region. This is similar to Butsic et al. (2011), which focuses on only the Rocky Mountains region. Therefore, disregarding other climate variables and not accounting for nonlinear effects of some of the climate variables may lead to inaccurate and biased results.

There are two potential reasons why a slightly higher average winter temperature leads to a small positive increase in house price instead of a reduction. First, as long as average winter temperature falls between 20°F and 32°F where snow quality is maintained for winter activities, minor increases in temperature could make the activities more enjoyable. In fact, a very low temperature creates icy ski conditions. Thus, a slightly higher temperature will create better snow quality. Second, a shortened winter season may mean a longer summer season so that individuals will be able to increase their utility from summer recreation (Rendanz, 2002). If the ski resorts offer winter and summer recreation activities, the increase in homeowner's utility during the summer months may compensate for their reduction in utility during the winter months. Note that given our results, when average winter temperature is too high, it will decrease house prices unambiguously because people can no longer enjoy winter activities. Thus, there is a limit to substituting summer recreation with winter recreation activities.

5.2 Valuing Consumer Surplus

We use the implicit values derived in Table 2 to calculate consumer surplus by estimating the inverse demand for average winter temperature in equation (13). Table 5 summarizes the estimates for the inverse demand for average winter temperature. Unlike the hedonic price function, the implicit marginal value of average winter temperature in one location is not affected by neighboring implicit marginal values as shown by the insignificant spatial correlation coefficient. Income is negative and significant which indicates that homeowners with more income place a relatively lower value on average winter temperature since they may care more about other characteristics related to their house. Population density negatively affects the value placed on average winter temperature but it is only significant in the West and Northeast regions. Average winter temperature coefficients are negative and significant in most regions illustrating a decline in the marginal value of average winter temperature as it increases.

Figure 1 illustrates the inverse demand curve for each region using estimates from Table 5.[4] Consumer surplus is positive when the average winter temperature is low. However, a crossing point temperature exists where the consumer surplus is zero and becomes negative as average winter temperature rises. Thus, a low crossing point temperature implies more sensitivity to increases in average winter temperature. The crossing point temperature is highest in the West at 46°F and lowest in the Midwest at 8°F. In the Mountain and Northeast regions, the crossing point temperatures are similar at about 26°F.

Table 6 summarizes the estimated consumer surplus in the four regions in the United States. Among the regions, only the Midwest has a crossing point temperature below its average winter temperature in 2010. Thus, we would expect the consumer surplus to be negative in the Midwest and positive for the other regions holding average winter temperature constant. The consumer surplus estimates in the West and Midwest have the largest absolute magnitudes since their crossing point temperatures are furthest from the average winter temperature. However, if we account for climate change over time using equation (14), two regions, the Midwest and the Northeast have negative consumer surplus. This is because in the Northeast, the crossing point temperature (24.71°F) is very close relative to the average winter temperature level (24.26°F) where a steady increase in average winter temperature over time would lead to a negative consumer surplus by the seventh year of homeownership. The unadjusted average homeowner consumer surplus for the Northeast is \$1321. If we account for a mean increase in average winter temperature over their stay in the house given a

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[4] The inverse demand curve is derived using the formula, $P_{ci} = \frac{\beta_0}{1-\gamma\sum_n \omega_{ns}} + \frac{\beta_i}{1-\gamma\sum_n \omega_{ns}} Z_{ic}^W + \frac{\beta_y}{1-\gamma\sum_n \omega_{ns}} \bar{y} + \frac{\beta_n}{1-\gamma\sum_n \omega_{ns}} \bar{n}$ where $\bar{y}$ and $\bar{n}$ are average income and average population density respectively.

low discount rate, the adjusted consumer surplus is actually -$1223, a negative value. Given the same assumptions, the West region has the largest consumer surplus at $19,637 followed by the Mountain region at $6686. The largest loss is in the Midwest at -$8,358.

Not accounting for an increase in average winter temperature due to climate change can severely overestimate the approximation of consumer surplus. The overestimation is larger if the average winter temperature is less than the crossing point temperature but close to it and if the increase in average winter temperature due to climate change occurs in the upper range of climate change predictions. By *not* accounting for a mean change in average winter temperature based on climate prediction estimates from USGCRP (2009), the calculated consumer surplus can be overestimated by as low as 9% or as high as 146% assuming a 6% discount rate. At a lower interest rate and at the maximum mean change prediction of average winter temperature, the overestimation in consumer surplus ranges from 8% to 237%.

The aggregate consumer surplus is a vertical summation of individual consumer surplus. Given the population of homeowners in each region, the highest aggregate consumer surplus is in the Western region at about $6 billion assuming a 2% discount rate. In contrast, the lowest consumer surplus is in the Midwest where about $3.5 billion is lost assuming the same discount rate level.

6. Conclusion

This paper estimates the amenity value of climate change by analyzing the impact of changes in climate variables on house prices near ski resorts using a hedonic price method that accounts for the spatial dependence between housing prices. We find that higher average winter temperatures will increase house prices near ski resorts at a decreasing rate. As long as average winter temperature falls within the preferred range of winter temperature activities, a slight increase may benefit individuals engaging in winter activities as reflected by changes in the housing value during the short or medium run. This may also reflect people enjoying summer recreation since a shorter winter season may imply a longer summer season. However, as average winter temperature continues to increase, this will not only lead to a shorter winter season but poorer snow conditions. Thus, the marginal contribution of average winter temperature is unambiguously decreasing house price in the long run.

We also estimate consumer surplus from average winter temperature changes during the medium run. The calculation of consumer surplus from the inverse demand equation for average winter temperature needs to account for potential changes in average winter temperature over time. The crossing point temperature where consumer surplus changes from positive to negative is lowest in the Midwest and Northeast regions. Both regions have negative consumer surplus for the average home owner during the duration of her stay in the house. In contrast, the consumer surplus for the West and Mountain regions are positive. Thus, similar to the agriculture and climate change literature, we show that the amenity value of climate change related to the ski resort industry also varies across regions.

Our results also have important policy recommendations for the ski resort industry and policymakers. Ski resort owners might consider transforming their business to a multi-purpose resort. Adding summer recreation on site would attract more visitors and act as a buffer from the effect of climate change. Policymakers should also be aware of the variable effect of climate change within the region even in the ski industry. An increase in average winter temperature may be beneficial in the short run for some regions but it will eventually lead to lower consumer surplus and even negative consumer surplus if such effects are not stopped or reversed.

References

Acharya, G., & Bennett, L. L. (2001). Valuing open space and land-use patterns in urban watersheds. *The Journal of Real Estate Finance and Economics*, *22*(2-3), 221-237.

Burakowski, E., & Magnusson, M. (2012). *Climate impacts on the winter tourism economy in the United States*. Natural Resources Defense Council.

Butsic, V., Hanak, E., and Valletta, R. G. (2011). Climate change and housing prices: Hedonic estimates for ski resorts in western North America. *Land Economics*, 87(1), 75-91.

Cho, S. H., Poudyal, N. C., & Roberts, R. K. (2008). Spatial analysis of the amenity value of green open space. *Ecological Economics*, *66*(2), 403-416.

Cho, S. H., Kim, S. G., Roberts, R. K., & Jung, S. (2009). Amenity values of spatial configurations of forest landscapes over space and time in the Southern Appalachian Highlands. *Ecological Economics*, *68*(10), 2646-2657.

Deschenes, O., & Greenstone, M. (2007). The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather. *The American Economic Review*, 354-385.

Dubin, Robin A. (1988). Estimation of regression coefficients in the presence of spatially autocorrelated error terms. *The Review of Economics and Statistics*, 466-474.

Emrath, P. 2011. "How Long Buyers Remain in Their Homes." Special studies for Housingeconomics.com available at: http://www.nahb.org/generic.aspx?genericContentID=110770&channelID=311.

Fukushima, T., Kureha, M., Ozaki, N. et al. (2003). Influences of air temperature change on leisure industries: Case study on ski activities. *Mitigation and Adaptation Strategies for Climate Change,* 7(2), 173-189.

Gatzlaff, Dean H., and Ling, David C. (1994). Measuring changes in local house prices: An empirical investigation of alternative methodologies. *Journal of Urban Economics,* 35(2), 221-244.

Geoghegan, J., Wainger, L. A., & Bockstael, N. E. (1997). Spatial landscape indices in a hedonic framework: an ecological economics analysis using GIS. *Ecological economics*, *23*(3), 251-264.

Geoghegan, J. (2002). The value of open spaces in residential land use. *Land use policy*, *19*(1), 91-98.

Greenstone, M., and Gallagher, J, (2008). Does hazardous waste matter? Evidence from the housing market and the superfund program. *The Quarterly Journal of Economics.*

Hamilton, J. M. (2007). Coastal landscape and the hedonic price of accommodation. *Ecological Economics*, *62*(3), 594-602.

Irwin, E. G. (2002). The effects of open space on residential property values. *Land economics*, *78*(4), 465-480.

Ketkar, K. (1992). Hazardous waste sites and property values in the state of New Jersey. *Applied Economics,* 24(6), 647-659.

Kim, J., and Goldsmith, P. (2009). A spatial hedonic approach to assess the impact of swine production on residential property values. *Environmental Resource Economics*, 42(4), 509-534.

Kockelman, K. M. (1997). The effects of location elements on home purchase prices and rents: Evidence from the San Francisco Bay Area. *Transpotation Research Record: Journal of the Transportation Research Board No. 1606*, 40-50.

Konig, U., and Abegg, B. (1997). Impacts of climate change on tourism in the Swiss Alps. *Journal of Sustainable Tourism*, 5(1),46-58.

Lipski, S., and McBoyle, G. (1991). The impact of global warming on downhill skiing in Michigan East Lakes geographer, 26, 37-51.

Loomis, J. (2004). Do nearby forest fires cause a reduction in residential property values?. *Journal of forest economics*, *10*(3), 149-157.

Maddison, D. (2003). The amenity value of the climate: The household production function approach. *Resource and Energy Economics*, *25*(2), 155-175.

Nelson, J. P. (2010). Valuing rural recreation amenities: hedonic prices for vacation rental houses at Deep Creek Lake, Maryland. *Agricultural & Resource Economics Review*, *39*(3), 485.

O'Byrne, P. H., Nelson, J. P., and Seneca, J. J. (1985). Housing values, census estimates, disequilibrium, and the environmental cost of airport noise: A case study of Atlanta. *Journal of Environmental Economics and Management,* 12(2),169-78.

Pace, R. Kelley, and Otis W. Gilley. (1997). Using the spatial configuration of the data to improve estimation. *The Journal of Real Estate Finance and Economics,* 14(3), 333-340.

Rehdanz, K. (2002). Hedonic pricing of climate change impacts to households in Great Britain. *Hamburg University, Hamburg Centre for Marine and Climate Research.*

Roback, J. (1982). Wages, rents, and the quality of life. *The Journal of Political Economy*, 1257-1278.

Schlenker, W., Hanemann, W. M., & Fisher, A. C. (2005). Will US agriculture really benefit from global warming? Accounting for irrigation in the hedonic approach. *American Economic Review*, 395-406.

Schlenker, W., & Roberts, M. J. (2009). Nonlinear temperature effects indicate severe damages to US crop yields under climate change. *Proceedings of the National Academy of Sciences*, *106*(37), 15594-15598.

Scott, D., McBoyle, G., and Minogue, A. (2007). The implications of climate change for the Quebec ski industry. *Global Environmental Change, 17(2), 181-190.*

Se Can, Ay, and Isaac Megbolugbe. (1997). Spatial dependence and house price index construction. *The Journal of Real Estate Finance and Economics,* 14(1), 203-222.

Soguel, N., M.-J. Martin, and A. Tangerini. 2008. "The Impact of Housing Market Segmentation between Tourists and Residents on the Hedonic Price for Landscape Quality." Swiss Journal of Economics and Statistics 144(4): 655–678.

Stetler, K. M., Venn, T. J., & Calkin, D. E. (2010). The effects of wildfire and environmental amenities on property values in northwest Montana, USA. *Ecological Economics*, *69*(11), 2233-2243.

US Global Change Research Program (USGCRP). 2009. Global Climate Change Impacts in the United States. Available at: http://nca2009.globalchange.gov/.

Williams, A. M. (2001). The impact of surface coal mining on residential property values: A hedonic price analysis. *Pursuit-The Journal of Undergraduate Research at the University of Tennessee*, 3(1), 6.

Wolfsegger, C., Gossling, S., and Scott, D. (2007). Climate change risk appraisal in the Austrian ski industry. *Tourism Review International, 12(1), 13-23.*

Table 1: Summary statistics of variables used in the estimation

	All Regions		West		Midwest		Northeast		Mountain Region	
	Mean (Standard Deviation)	Range [min,max]	Mean (Standard Deviation)	Range [min,max]	Mean (Standard Deviation)	Range [min,max]	Mean (Standard Deviation)	Range [min,max]	Mean (Standard Deviation)	Range [min,max]
House Characteristics ($\boldsymbol{Z^H}$)										
Median House Price ($1000)	287.48 (328.22)	[25, 2500]	319.18 (211.32)	[73, 2500]	162.59 (71.82)	[25, 475]	188.60 (82.03)	[56, 425]	486.13 (534.08)	[121, 2500]
Area (Sqft)	1,790.82 (638.44)	[800, 4500]	1788.03 (694.30)	[944, 3880]	1,792.11 (374.10)	[1108, 3324]	1,552.80 (174.77)	[1152, 1991]	1,989.62 (948.13)	[800, 4500]
Number of Room	5.27 (0.85)	[3.1, 8.1]	4.87 (0.73)	[3.2, 6.8]	5.57 (0.70)	[4.2, 8.1]	5.49 (0.74)	[3.9, 7.2]	5.03 (0.98)	[3.1, 8]
Number of Bedroom	2.59 (0.34)	[1.55, 3.66]	2.49 (0.35)	[1.55, 3.40]	2.63 (0.26)	[2.07, 3.56]	2.61 (0.30)	[1.93, 3.24]	2.58 (0.42)	[1.61, 3.66]
Age	47.38 (11.87)	[25, 80]	43.47 (7.98)	[25, 58]	49.35 (10.37)	[27, 80]	56.86 (10.33)	[26, 74]	40.00 (10.84)	[27, 77]
Owner Income ($)	27,373.67 (7185.66)	[12294, 64381]	27397.13 (5192.90)	[20093, 38211]	26,580.14 (4878.48)	[18267, 37849]	25,925.28 (4735.41)	[19807, 40076]	29,437.92 (10893.69)	12294, 64381]
Ski Resort Characteristics ($\boldsymbol{Z^S}$)										
Vertical Drop (ft)	1,120.52 (964.28)	[100, 4406]	1424.00 (814.49)	[266, 3365	302.17 (145.77)	[100, 880]	738.32 (473.12)	[100, 2100]	2,136.90 (868.70)	[600, 4406]
Base Elevation (ft)	3,617.53 (3270.17)	[31, 10790]	5362.33 (1719.33)	[1200, 7200]	876.95 (422.21)	[31, 2593]	935.76 (516.51)	[100, 2100]	7,703.78 (1748.31)	[3842, 10500]
Ski Area (acres)	627.40	[7, 5500]	934.52	[10, 4800]	95.36	[7, 462]	108.70	[12, 347]	1440.17	[40, 5500]

	(995.50)		(1076.73)		(94.37)		(80.34)		(1244.77)	
Number of Month Open	5.08 (1.01)	[3, 9]	5.65 (1.07)	[3, 8]	4.56 (0.76)	[3, 6]	4.72 (0.83)	[4, 6]	5.58 (0.94)	[4, 9]
Summer recreation on site (indicator variable)	0.59 (0.05)	[0,1]	0.65 (0.12)	[0,1]	0.55 (0.06)	[0,1]	0.52 (0.07)	[0,1]	0.67 (0.07)	[0,1]
Climate Characteristics ($\boldsymbol{Z^C}$)										
Average Winter Temperature (°F)	24.46 (5.98)	[10.5, 46.33]	30.95 (5.36)	[18.75, 46.33]	21.20 (5.16)	[10.5, 32.33]	24.26 (3.83)	[15, 32.33]	23.88 (5.40)	[11.33, 37]
Average Variance of Winter Temperature	125.04 (61.61)	[28.66, 370.16]	114.77 (73.69)	[28.66, 259.86]	96.85 (19.95)	[53.6, 135.86]	113.88 (30.03)	[57.1, 201.06]	172.20 (75.68)	[53.46, 370.16]
Average Winter Precipitation (Inches)	2.58 (2.06)	[0.22,13.51]	4.81 (3.40)	[0.78, 13.51]	1.61 (0.73)	[(0.57, 3.7]	3.18 (0.50)	[1.95, 4.41]	1.65 (1.18)	[0.22, 6.49]
Average Variance of Winter Precipitation	0.39 (1.24)	[0.00001, 9.95]	1.46 (2.60)	[0.01, 9.95]	0.10 (0.12)	[0.001, 0.57]	0.23 (0.30)	[0.01, 2.11]	0.09 (0.32)	[0.00001, 2.39]
Average Summer Temperature (°F)	65.64 (5.21)	[52.33, 78.83]	64.20 (6.06)	[55, 77.5]	68.38 (3.36)	[60.33, 78.83]	67.18 (2.89)	[62.16, 75.83]	62.33 (5.70)	[52.33,75.21]
Average Variance of Summer Temperature	238.14 (131.10)	[60.8, 1087.6]	300.06 (139.57)	[60.8, 654.7]	160.21 (72.55)	[81.86, 673.36]	162.90 (68.44)	[80.26, 577.76]	345.29 (119.07)	[180.7, 1087.6]
Average Summer Precipitation (Inches)	2.79 (1.50)	[0.12, 5.46]	0.98 (0.92)	[0.12, 4.53]	3.98 (0.49)	[2.95, 5.20]	4.13 (0.43)	[3.06, 5.46]	1.58 (0.68)	[0.26, 4.006]
Average Variance of Summer Precipitation	0.32 (0.86)	[0.0016, 10.26]	0.47 (0.78)	[0.0019, 2.72]	0.12 (0.16)	[0.0016, 0.86]	0.13 (0.16)	[0.002, 0.71]	0.61 (1.43)	[0.003, 10.26]

Table 2: Determinants of Log House Price Using a Spatial Regression

	All Regions	West	Midwest	Northeast	Mountain Region
House Characteristics $(\boldsymbol{Z^H})$					
Log of house area	0.33***	0.30	0.43**	1.72***	0.19
	(0.09)	(0.19)	(0.19)	(0.32)	(0.12)
Log of average number of rooms	−0.32	-0.26	−1.74***	−2.56***	1.22
	(0.43)	(0.59)	(0.66)	(0.72)	(1.09)
Log of average number of bedrooms	0.43	1.11**	2.61***	1.36**	-0.76
	(0.42)	(0.48)	(0.92)	(0.70)	(1.19)
Log of average house age	−0.38***	-0.40	-0.07	-0.20	−0.60**
	(0.11)	(0.31)	(0.14)	(0.20)	(0.27)
Log of homeowner income	0.51***	0.13	0.86***	1.04***	0.70***
	(0.09)	(0.13)	(0.16)	(0.15)	(0.13)
Ski Resort Characteristics $(\boldsymbol{Z^S})$					
Log of vertical drop	0.16***	-0.22	0.25***	0.21*	0.75***
	(0.06)	(0.17)	(0.08)	(0.11)	(0.19)
Log of ski resort area	−0.04*	-0.01	0.00	0.01	−0.09*
	(0.03)	(0.09)	(0.04)	(0.08)	(0.06)
Log of number of months open	-0.12	0.42	-0.39	-0.12	−0.61*
	(0.17)	(0.43)	(0.24)	(0.26)	(0.33)
Log of elevation base	-0.02	0.43**	−0.10***	0.06	0.42**
	(0.05)	(0.19)	(0.03)	(0.05)	(0.21)
Summer Recreation dummy	0.15***	0.21*	0.11*	−0.14**	-0.11
	(0.05)	(0.12)	(0.06)	(0.07)	(0.07)
Climate Characteristcs $(\boldsymbol{Z^C})$					
Log of average winter temperature	10.52***	27.78***	13.48***	32.79***	6.00*
	(1.99)	(8.98)	(3.84)	(7.15)	(3.27)
Log of average winter temperature squared	−1.71***	−4.02***	−2.59***	−5.08***	−0.99*
	(0.34)	(1.30)	(0.65)	(1.16)	(0.57)
Log of variance of winter temperature	-0.18	0.38**	-0.15	-0.01	−0.30**
	(0.13)	(0.19)	(0.20)	(0.20)	(0.13)
Log of average winter precipitation	0.21***	0.42**	0.49**	0.11	0.14
	(0.08)	(0.19)	(0.21)	(0.28)	(0.12)

Log of variance of winter precipitation	-0.01	0.01	0.05	0.03	-0.01
	(0.02)	(0.05)	(0.05)	(0.04)	(0.02)
Log of average summer temperature	43.53*	47.86	308.84***	-84.88	158.91***
	(25.73)	(40.68)	(120.80)	(185.81)	(36.98)
Log of average summer temperature squared	−5.27*	-6.23	−35.94**	9.98	−19.40***
	(3.09)	(4.87)	(14.34)	(21.97)	(4.43)
Log of variance of summer temperature	0.17	−0.48***	-0.14	0.47***	-0.06
	(0.12)	(0.18)	(0.13)	(0.18)	(0.19)
Log of average summer precipitation	−0.31***	−0.65***	−0.87**	−1.32***	−0.36*
	(0.11)	(0.18)	(0.37)	(0.46)	(0.21)
Log of variance of summer precipitation	0.00	-0.10	0.01	0.02	0.12**
	(0.02)	(0.08)	(0.01)	(0.03)	(0.06)
Spatial coefficient	0.55***	0.46**	−0.82***	0.15	0.37***
	(0.11)	(0.24)	(0.28)	(0.38)	(0.10)
Constant	−106.85**	−136.69**	−667.06***	116.18	−340.01***
	(53.02)	(88.83)	(253.05)	(390.20)	(76.71)
State Fixed Effects	Yes	Yes	Yes	Yes	Yes
No. Obs.	216	40	66	50	60
Adjusted R-squared	0.81	0.88	0.85	0.83	0.91

Note: *** significant at 1%, ** significant at 5%,, * significant at 10%,. All standard errors are calculated using Huber-White robust standard errors.

Table 3: The Effect of Average Winter Temperature on the Marginal House Price

	Elasticity	**Implicit marginal house price in $US**			
Region		Mean	Minimum	Maximum	Standard Deviation
All	-0.46	-2095.04	-52661.09	89205.71	13126.03
West	0.13	3050.34	-36766.21	59995.99	14754.62
Midwest	-2.33	-15654.77	-51374.60	14236.73	10988.18
Northeast	0.37	4872.28	-17585.92	41506.18	12489.47
Mountain Region	-0.31	-2190.65	-26687.32	48003.05	11341.23

Table 4. Alternative Hedonic Price Functional Form and Specifications

	All Regions		West		Midwest		Northeast		Mountain Region	
	[1]	[2]	[1]	[2]	[1]	[2]	[1]	[2]	[1]	[2]
House Characteristics (Z^{H})										
Log of homeowner income	0.70***		0.34		1.09***		0.88***		0.61***	
	(0.11)		(0.23)		(0.25)		(0.21)		(0.15)	
Log of population density	0.03		0.07		0.09		0.05		0.00	
	(0.02)		(0.08)		(0.07)		(0.06)		(0.02)	
Log of average number of rooms	0.02		0.93***		0.13		−1.06**		0.13	
	(0.27)		(0.34)		(0.58)		(0.51)		(0.37)	
Log of house area		0.48***		0.62***		0.88***		1.25***		0.02
		(0.12)		(0.21)		(0.27)		(0.48)		(0.13)
Log of average house age		−0.61***		-0.41		−0.85***		−0.57***		−0.43**
		(0.12)		(0.33)		(0.28)		(0.20)		(0.21)
Ski Resort Characteristics (Z^{S})										
Log of vertical drop	0.11**	0.08*	-0.11	-0.08	0.19*	0.13	0.14*	0.03	0.48***	0.65***
	(0.05)	(0.05)	(0.10)	(0.09)	(0.11)	(0.10)	(0.08)	(0.07)	(0.15)	(0.14)
Climate Characteristcs (Z^{C})										
Log of average winter precipitation	0.17***	0.26***	0.23	0.19**	0.13	0.33	0.93**	0.68**	0.25***	0.27**
	(0.07)	(0.06)	(0.15)	(0.10)	(0.31)	(0.27)	(0.46)	(0.32)	(0.08)	(0.11)
Spatial Coefficient	0.52***	0.83***	0.34	0.63***	-0.29	0.14	-0.05	0.36	0.47***	0.70***
	(0.12)	(0.10)	(0.26)	(0.20)	(0.40)	(0.36)	(0.39)	(0.40)	(0.15)	(0.16)

Constant	−2.46*	0.07	3.38	1.76	2.35	6.13	3.31	0.15	−3.85***	-0.01
	(1.29)	(1.68)	(3.27)	(3.21)	(4.41)	(4.64)	(4.08)	(6.22)	(1.55)	(2.35)
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. Obs.	216	216	40	40	66	66	50	50	60	60
Adjusted R-squared	0.70	0.69	0.49	0.53	0.48	0.45	0.57	0.52	0.79	0.74

Note: *** significant at 1%, ** significant at 5%, * significant at 10%. All standard errors are calculated using Huber-White robust standard errors.

Table 5: Determinants of the Implicit Value of Average Winter Temperature

	All Regions	West	Midwest	Northeast	Mountain Region
Income	−0.20*	−0.26***	−0.68***	-0.02	−0.29***
	(0.11)	(0.11)	(0.21)	(0.07)	(0.11)
Population Density	-0.35	−1.54***	-0.97	−0.92***	0.92
	(0.40)	(0.44)	(1.51)	(0.26)	(0.56)
Average Winter Temperature	−1359.54***	−1443.94***	-726.30	−2901.26***	−2091.58***
	(386.14)	(406.64)	(656.50)	(280.49)	(499.60)
Constant	40022.23***	76554.26***	23825.55***	73755.61***	67164.36***
	(10175.08)	(17601.13)	(9181.77)	(6997.58)	(17553.98)
Spatial Coefficient	0.46	0.37*	0.37	-0.21	0.05
	(0.34)	(0.22)	(0.34)	(0.24)	(0.38)
Estimated Crossing Point Temperature (°F)	25	46	8.45	24.71	27.88
State Fixed Effects	Yes	Yes	Yes	Yes	Yes
No. Obs.	216	40	66	50	60
Adjusted R-Squared	0.60	0.81	0.68	0.92	0.66

Note: *** significant at 1%, ** significant at 5%,, * significant at 10%,. All standard errors are calculated using Huber-White robust standard errors.

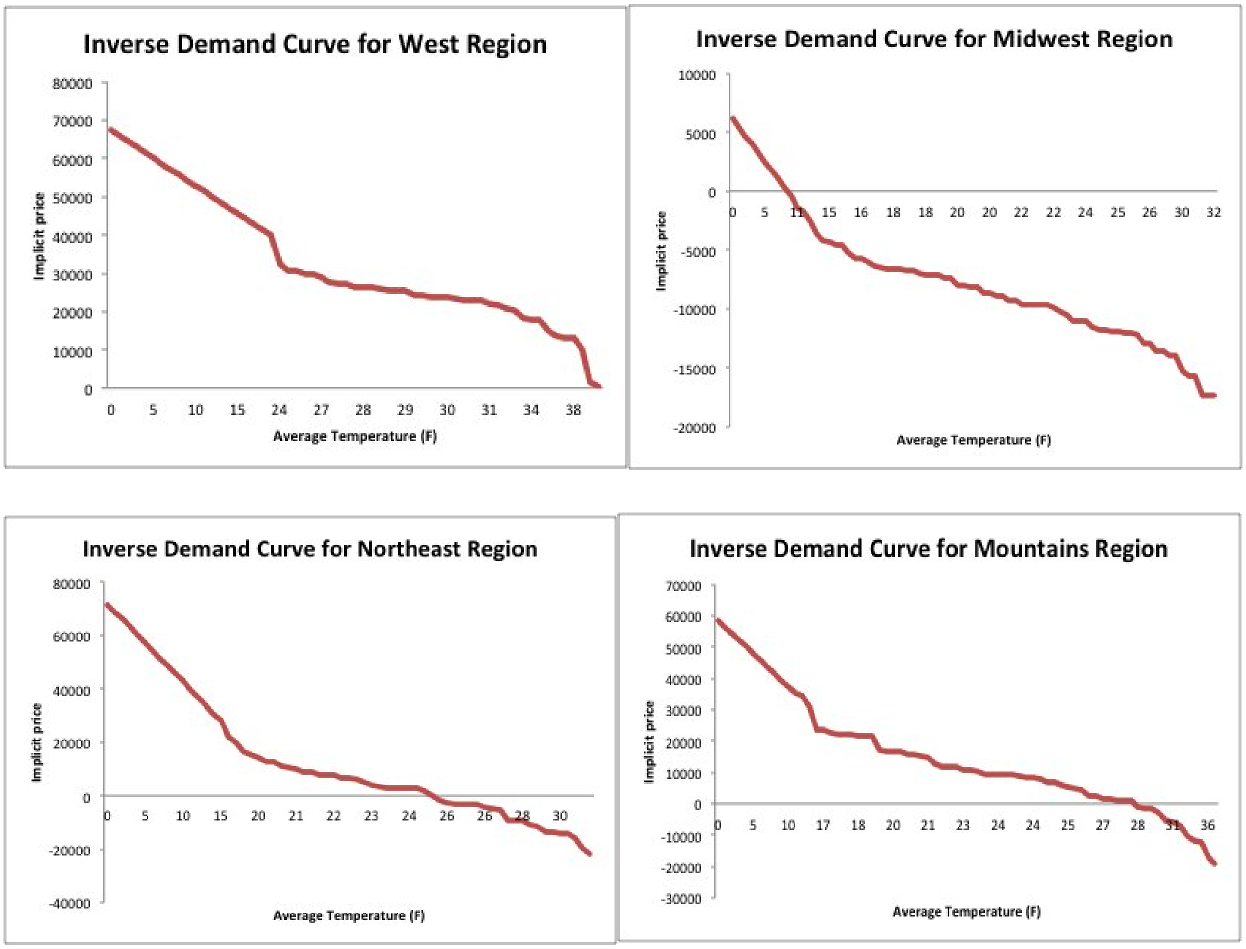
Table 6: Projected Consumer Surplus Across Regions in US$

	West	**Midwest**	**Northeast**	**Mountain Region**
Unadjusted Average Consumer Surplus	22605.12	-9255.49	1321.67	8382.26
Adjusted Average Consumer Surplus				
Low discount rate and minimum projected increase in temperature	19885.30	-8231.98	-301.12	7005.34
Low discount rate and mean projected increase in temperature	19637.33	-8358.52	-1223.23	6685.59
Low discount rate and maximum projected increase in temperature	19392.31	-8452.26	-1822.61	6365.83
High discount rate and minimum projected increase in temperature	16138.79	-6244.50	-63.03	5713.54
High discount rate and mean projected increase in temperature	15956.42	-6329.36	-616.26	5478.38
High discount rate and maximum projected increase in temperature	15776.22	-6392.22	-975.86	5243.21
Aggregate Consumer Surplus ($1,000,000)				
Low discount rate and minimum projected increase in temperature	6110.28	-3573.96	-51.00	2897.39
Low discount rate and mean projected increase in temperature	6034.08	-3628.90	-207.17	2765.15
Low discount rate and maximum projected increase in temperature	5958.79	-3669.60	-308.68	2632.89
High discount rate and minimum projected increase in temperature	4959.06	-2711.09	-10.67	2363.11
High discount rate and mean projected increase in temperature	4903.02	-2747.93	-104.37	2265.85
High discount rate and maximum projected increase in temperature	4847.65	-2775.22	-165.27	2168.58

Note: Low discount rate is at 2% and high discount rate is 6%. The average number of years a homeowner stays in the house is assumed to be 13, 17, 22 and 13 years for the West, Midwest, Northeast and Mountain Region, respectively (Emrath, 2011). The range [minimum, mean, maximum] for the projected annual increase in average winter temperature is taken from the USGCRP (2009). For the West, Midwest, Northeast and Mountain Regions, we obtain the ranges [0.033, 0.0667, 0.1], [0.063, 0.09, 0.11], [0.06, 0.1, 0.126], and [0.043, 0.073, 0.103], respectively. The owner occupied housing unit population is 307,276; 434,156; 169,359 and 413,598 in the West, Midwest, Northeast, and Mountain region respectively (U.S. Census tract 2010).

Figures

Figure 1. Inverse demand curves for average winter temperature across regions in the United States.



Inverse Demand Curve for West Region

Inverse Demand Curve for Midwest Region

Inverse Demand Curve for Northeast Region

Inverse Demand Curve for Mountains Region

Appendices

Appendix 1. Data description and sources

	Definition	Source
House Characteristics (Z^H)		
Median House Price ($1000)	Median house price	Zillow real estate (2010)
Area (Sqft)	Area of the house	U.S. Census tract (2010)
Number of Room	Number of rooms in the house	U.S. Census tract (2010)
Number of Bedroom	Number of bedroom in the house	U.S. Census tract (2010)
Age	Age of the house	U.S. Census tract (2010)
Owner Income ($)	Income of house owner	U.S. Census tract (2010)
Ski Resort Characteristics (Z^S)		
Vertical Drop (ft)	The different between the summit elevation and base elevation of the ski resort	White Book of Ski Resort (2006)
Base Elevation (ft)	Elevation at the base of the ski resort	White Book of Ski Resort (2006)
Ski Area (acres)	Area of the ski resort	White Book of Ski Resort (2006)
Number of Month Open	Number of months the ski resort is in operation in a year	White Book of Ski Resort (2006)
Climate Characteristics (Z^C)		
Average Winter Temperature (F)	Average winter temperature from all cities in December, January and February	Weather Channel

Average Variance of Winter Temperature	The average calculated from the variance in each city	Calculated from Weather Channel
Average Winter Precipitation (Inches)	Average amount of snow/rain fall in December, January and February	Weather Channel
Average Variance of Winter Precipitation	The average calculated from the variance in each city	Calculated from Weather Channel
Average Summer Temperature (F)	Average winter temperature from all cities in June, July and August	Weather Channel
Average Variance of Summer Temperature	The average calculated from the variance in each city	Calculated from Weather Channel
Average Summer Precipitation (Inches)	Average amount of rainfall in summer months in June, July and August	Weather Channel
Average Variance of Summer Precipitation	The average calculated from the variance in each city	Calculated from Weather Channel

Appendix 2. List of States in each Region.

Region	States
West region	Alaska, California, Oregon, Washington
Midwest region	Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, Wisconsin
Northeast region	Connecticut, Massachusetts, Maine, New Hampshire, New Jersey, New York, Pennsylvania
Mountain region	Arizona, Colorado, Idaho, Montana, New Mexico, Nevada, Utah, Wyoming