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Climate Change and Housing Prices: Hedonic Estimates for Ski Resorts in Western North America

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ABSTRACT

We apply a hedonic framework to estimate and simulate the impact of global warming on real estate prices near ski resorts in the western United States and Canada. Using data on housing values for selected U.S. Census tracts and individual home sales in four locations, combined with detailed weather data and characteristics of nearby ski resorts, we find precise and consistent estimates of positive snowfall effects on housing values. Simulations based on these estimates reveal substantial heterogeneity in the likely impact of climate change across regions, including large reductions in home prices near resorts where snow reliability already is low.

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I. INTRODUCTION

Worldwide average temperatures have been rising since the mid-20th century and are likely to continue rising well into the future (IPCC 2007a). This warming trend is expected to lead to a substantial reduction in snowpacks in the mountainous regions of western North America, a process that has already begun (Knowles et al. 2006). In this paper, we assess the impact of these climatic shifts on the price of an important asset—residential properties—in areas where the local economy relies heavily on winter sports tourism, most notably downhill skiing and snowboarding.

Our application is closely connected to two distinct literatures that provide assessments of the potential economic effects of climate change. In its substantive focus, it relates most closely to existing studies that investigated the effects of climate change on tourism and outdoor recreational activities, including the ski industries in Europe and North America (e.g., Loomis and Crespi 1999, Mendelsohn and Markowski 1999, Elsasser and Burki 2002, Scott et al. 2006, OECD 2007, Bark-Hodgins and Colby 2007, Wall 1992, Madison 2000, Pendleton and Mendelsohn 1998). In its methodological approach, our paper follows previous work that utilized a hedonic framework to assess the effects of climate change on the agricultural sector, measured in terms of land values (e.g., Mendelsohn, Nordhaus, and Shaw 1994; Schlenker, Hanemann, and Fisher 2005, 2006; Ashenfelter and Storchmann 2006). We take a similar approach to estimate the effect of climate change on residential property prices that are linked to conditions for downhill skiing and snowboarding. To our knowledge, this paper represents the first attempt to use the hedonic framework to estimate the effects of global warming on asset prices that are closely linked to the tourism industry, which has been suggested as a research strategy in other recent work (Shaw and Loomis 2008).

Our analysis requires combining data along three primary dimensions: home prices and characteristics, weather readings, and ski resort characteristics. Our data on house prices come from two different sources: U.S. Census tract data on average values, measured from the 1970, 1980, 1990, and 2000 Censuses; and detailed data on transaction prices for homes sold in four market regions in the U.S. and Canada, covering the period from about 1975 through 2005. Each of these data sources also has information on other home characteristics that affect prices, thereby providing the basic requirements for our hedonic specification. To assess the impact of changing weather conditions, we use detailed data on daily weather observations culled from weather stations located at 18 different widely dispersed points located near ski resorts (in terms of location and altitude) in the western U.S. and Canada. These data enable us to form annual measures of "snowfall intensity," or the percent of precipitation falling as snow over the winter months, which is a key determinant of the quality of snow and hence skiing conditions. Finally, as additional controls for housing demand in resort areas, we use data on the characteristics of ski resorts that are located near the homes in our data. Our analyses and results are bolstered by the complementary strengths of the two housing data sources: the availability of multiple observations per Census tract enables fixed-effects estimation that purges the results of tract-specific, unobservable determinants of house values, while the estimates using the four-market individual sales data are based on a tighter connection between house prices and characteristics and higher frequency variation in weather and other observables than is afforded by the tract data.

Our hedonic regression models of changes in house prices with respect to medium-run changes in the snowfall composition of winter precipitation yield precise and consistent estimates of positive snowfall effects on housing values in both data sources, which are largely robust to alternative specifications. We use our estimates to simulate the impact of likely warming on house prices in coming decades and find substantial variation across resort areas based on climatic characteristics such as longitude, elevation, and proximity to the Pacific Ocean, which determine the extent to which a given degree of warming will reduce snowfall intensity. Some resort areas will be largely unaffected, while others face potentially large reductions in home prices. As discussed in our conclusions, these results are subject to some caveats, notably the possibility of shifts towards warm-weather tourism and reallocation of demand across destinations, but they are suggestive of very large adverse effects of climate warming on winter tourism in western North America.

II. ECONOMIC EFFECTS OF CLIMATE CHANGE

The current scientific consensus regarding global climate change has identified a trend towards rising worldwide average temperatures since the mid-20th century that is likely to continue well into the future (IPCC 2007a). Substantial controversy remains over the exact role of various contributory factors and hence appropriate human responses, but scientists generally expect that global surface temperatures will increase by 1.1 to 6.4 °C (2.0 to 11.5 °F) between the years 1990 and 2100. We will refer to this prediction interchangeably as climate change or by its common name, “global warming.” This warming is expected to alter the seasonal patterns of precipitation in mountain ranges in western North America and Europe, with an increase in the share of rainfall in total precipitation (IPCC 2007b).

Some empirical research that attempts to quantify the economic impacts of climate change in North America through econometric estimation has focused on the agricultural sector, a resource-intensive industry that is likely to be directly affected by changes in both temperature and precipitation. This research has largely relied on hedonic estimation approaches, which assess the effects of climate variation on land values or property prices (e.g., Mendelsohn, Nordhaus, and Shaw 1994; Schlenker, Hanemann, and Fisher 2005, 2006).

Researchers also have recognized the potential impact of global warming on tourism, particularly skiing/snowboarding, the segment that is likely to suffer the largest adverse impacts. A number of studies have examined adaptation strategies in areas where the local economy is likely to be adversely affected by the impact of warming on ski resorts, including studies of Canada (Wall 1992, Scott et al. 2006), the European Alps (Elsasser and Burki 2002, OECD 2007) and Arizona (Bark-Hodgins and Colby 2007). These studies generally conclude that warming is likely to substantially undermine the viability of ski resorts in those areas, with adaptation strategies such as snowmaking providing an uncertain but probably small degree of offset. Moreover, this work has pointed to a high degree of variability in the sensitivity to climate change across geographic regions. For example, in OECD (2007) it is projected that for a 1° C warming, Germany will experience a 60% decline in the number of naturally snow-reliable ski resorts, versus only a 10% decline in Switzerland; for a 4° C warming, snow reliability will decline by nearly 100% in Germany, versus about 50% in Switzerland.

Other studies regarding the effects of global warming on skiing have examined changes in recreation demand more generally (e.g., Loomis and Crespi 1999, Mendelsohn and Markowski 1999). These studies found potentially large losses in number of skier days arising from increased temperatures. Additionally, several largely qualitative assessments have pointed out that increased temperatures will create less favorable conditions for this pastime (see U.S. Climate Change Science Program 2008 for an extensive review).

None of the work to date on global warming and winter sports has attempted direct estimation of likely changes in the value of assets such as real estate, which was suggested as a research strategy by Shaw and Loomis (2008). The current paper is intended as the first contribution along these lines.

Our particular focus is on ski resorts in the western part of North America. Scientists already have identified warming in the mountainous parts of this broad region, and continued warming as expected will significantly reduce snowpacks in the region, primarily as a result of the shift in the share of rainfall in total precipitation (Knowles et al. 2006, Bales et al. 2006).[1] This effect will be most pronounced in areas where temperatures are already close to the critical value of 0° C, the freezing point for water.[2] The ski resorts in this broad swath of North America exhibit substantial diversity in regard to their proximity to this critical value, as average temperatures are influenced by geographic factors such as latitude, elevation, and proximity to the warming influence of the Pacific Ocean. As a result, this region provides a good quasi-experimental setting for assessing the impact of climate change. We focus exclusively on the West rather than including resorts in other parts of parts of North America, such as the U.S. Northeast, because the ski resorts in our sample tend to be "destination" resorts in which property values are likely to be determined largely by the resorts themselves and are largely independent of unrelated economic conditions in nearby urban and suburban areas.

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[1] Much of this research, including Knowles et al. (2006) and Bales et al. (2006), has been motivated by concerns over the implications for water resource management.

[2] The physical alteration of precipitation around a temperature of 0° C functions as a nonlinear turning point for the impact of warming on ski conditions, much like the nonlinearity around optimal temperatures for growing various crops in Schlenker and Roberts (2008).

III. DATA AND METHODS

III.A. Data

Our data set consists of three main components: house prices and characteristics, weather conditions, and ski area characteristics. The linkages between these components are based on geographic proximity, with housing locations and ski areas falling within a minimum distance of weather measurement stations and each other. We describe these components in turn.

(i) Home prices and characteristics

We have two sources of data on home prices and characteristics.

The first source is data on average owner-assessed home values and characteristics for U.S. Census tracts from the GeoLytics/Urban Institute database that links data reported in the decennial Censuses since 1970.[3] We chose tracts that are within 50 kilometers (31 miles) of the ski resorts that met our inclusion criteria and within 100 km (62 miles) of a weather station that is located above 4000 feet (1219 m) in altitude (see below for discussion of the weather station and ski area data).[4] Along with restriction to observations with non-missing values of our primary variables, these criteria produced a sample of about 690 Census tracts, with roughly 60 percent available for the Census years of 1970 and 1980 and the full sample available for 1990 and 2000 (see Appendix Figure 1). The tracts are located near mountainous areas with ski resorts in the western states of Arizona, California, Colorado, Idaho, Montana, Nevada, New

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[3] This data source is referred to as the Neighborhood Change Database; details are available at http://www2.urban.org/nnip/ncua/ncdb.html. We interpret the owner-assessed values as reliable indicators of sale prices on average. Census housing value and rent data have been used to assess the relationship between racial segregation and house prices/rents (Card, Mas, and Rothstein 2008), market valuation of environmental and locational amenities (Greenstone and Gallagher 2007; Gyourko, Mayer, and Sinai 2006), and the price effects of intercity variation in supply restrictions (Glaeser, Gyourko, and Saks 2005).

[4] The minimum altitude restriction is intended to capture stations where it is cold enough to snow throughout our sample region.

Mexico, Oregon, Utah, and Wyoming. For many rural areas, the Census only began assigning tracts in 1990; our observation count therefore jumps substantially in 1990, due to the addition of many rural tracts. Panel A of Table 1 lists summary statistics for the Census tract sample. In addition to average home values (based on owners' self reports for owner-occupied housing), the files provide information on various tract and house characteristics, such as average household income, population density, average number of rooms (a rough measure of house size), and the share of single-family homes.[5]

The second source of data on home prices and characteristics is based on individual home sales in four different markets in the U.S. and Canada that also meet our criteria for being close to ski resorts. The specific regions are: Whistler, British Columbia (coastal Canada); Fernie, British Columbia (Canada; inland from Whistler); North Lake Tahoe (parts of Washoe County, NV and Placer County, CA); and South Lake Tahoe (parts of Eldorado County, CA).[6] These data, obtained from Dataquick for the U.S. markets and Landcor for the Canadian markets, provide information on the sale price and characteristics for homes sold beginning around 1975-1980 and extending through the year 2006 (Table 1, Panel B). In addition to the sale price and sale date (which captures general movements in housing prices), we have data on characteristics such as age, size, number of bathrooms, specific location relative to amenities, and other variables that are commonly used in hedonic home price equations (with inconsistent availability across the four market regions).

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[5] Prior to 1990, the housing price data pertain to single-family homes only. The incorporation of rural tracts and multifamily homes beginning in 1990 causes the sample real mean home price to decline between 1980 and 1990. These changes in sample composition do not affect our results because we control for the share of single-family homes in the regressions and restrict the Census regressions to tracts with multiple observations, focusing on changes over time using a fixed-effects framework.

[6] Although they share the same weather station, we treat North and South Lake Tahoe as different housing and skiing markets in the market analyses because it is often difficult to reach one from the other by car during the winter months.

(ii) Weather

For our study of the impact of changing weather conditions, precise and reliable weather data are critical. For the United States we rely on the U.S. Historical Climatology Network (USHCN), which provides daily and monthly records of basic meteorological variables from over 1000 observing stations across the 48 contiguous United States. Stations are chosen for inclusion in the USHCN only if the data meets specific criteria to assure data accuracy over the entire history of the station. We obtained similar data for the Canadian sites from the Canadian Government's Office of the Environment.[7]

From these two sources we culled daily observations on minimum and maximum temperatures and precipitation totals for 18 sites spread out across the West: 16 of these are in the United States and are used for our analyses of Census tract data (one is used for the individual market analysis for the Lake Tahoe region), plus the two in Canada for the individual market analyses. Despite the initial availability of data from a much larger number of U.S. weather stations, the number of stations that can be incorporated into our analyses is sharply limited by three factors: (i) the weather stations must be located near major ski resorts (see next subsection); (ii) they must be located at altitudes near ski area base levels (at least 4000 feet, as noted above); and (iii) the weather stations must provide daily temperature and precipitation readings for a complete set of winters back at least to 1960 in order to form our snowfall measure. The Canadian data are available for 1972-2005 for Whistler and 1970-2005 for Fernie.

Our primary measure of weather conditions relevant for assessing the quality of skiing conditions is the snowfall percentage of total precipitation observed during the winter months (referred to in the climate literature as the ratio of snowfall equivalent to total precipitation, or

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[7] Information on the U.S. data is available at <cdiac.ornl.gov/epubs/ndp/ushcn/newushcn.html>. Information on the Canadian data is available at <www.weatheroffice.gc.ca/mainmenu/about_us_e.html>.

SFE/P), which we will refer to as "snowfall intensity." An alternative to SFE/P is the direct snowfall measurement that accompanies most daily weather station readings. We prefer SFE/P for three reasons. First, for many observations direct snowfall measurements are absent from daily UHSCN data. This is especially true for early measurements, which were done manually. Second, recorded snowfall amounts are generally acknowledged to be "notoriously unreliable and observer dependent" (Knowles et al. 2006, Cherry et al 2005): measurement errors of up to 50% have been recorded (Yang et al. 1998), making the use of such data suspect. Finally, snowfall intensity appropriately accounts for the mix of precipitation between snow and rain. Locations and ski seasons with higher total snowfall may have higher total precipitation as well (including rain), which substantially reduces the quality of the skiing experience regardless of how much snow has accumulated. In contrast to total snowfall, snowfall intensity drops unambiguously as temperatures rise: locations and seasons with high snowfall but high rainfall as well will be identified as having less desirable conditions.[8]

Given the difficulties with direct observation of snowfall in the daily weather data, we construct a measure of snowfall intensity from the observed temperature and precipitation data. Our classification is similar to the definition used by Knowles et al. (2006), who analyzed weather patterns and found that a similarly defined variable provided an accurate and robust measure of snowfall conditions in their data. We use the rule that on any day recorded as having precipitation and a minimum temperature below 0 °C, all precipitation on that day is classified as

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[8] One drawback to the snowfall intensity variable is its lack of robustness to variation in total precipitation levels; it will not distinguish between two seasons in which the same share of total precipitation falls as snow but one season is much drier than the other. However, as a practical matter in our data the impact of variation in total precipitation matters less than does variation in temperatures and the consequent share of snow versus rain: as we demonstrate in the discussion of the robustness of our results, SFE/P is a significant explanatory factor in our house price regressions, whereas snowfall totals are not.

snow (measured in liquid-water equivalents).[9] While this represents an upper-bound to actual daily snowfall, our estimates suggest that this measure more accurately measures snowfall intensity than do measures based on alternative assumptions.[10]

For each of our 18 weather stations, we sum the daily observations on snowfall liquid-water equivalents (SFE) and total precipitation (P) across the months comprising the primary skiing season (December through March), then use these sums to calculate the ratio SFE/P for each annual ski season in the area of each weather station. In the Census regression analyses, we focus on the average SFE/P for the 10 years preceding the Census year (SFE/P-10) as the measure of snowfall intensity to which home values in surrounding ski resort areas may respond. Appendix Table 1 lists the values of this variable for each weather station in each decade, along with mean temperatures (plus ski area characteristics, as described below). In the individual housing market regressions, which include sales over a continuous period, we focus on the five-year moving average values of this series (SFE/P-5; see Figure 2a), in part because the 10-year average (SFE/P-10) would cause us to lose the early years of our Whistler sample; we assess the implications of this assumption in our robustness tests in Section IV.B.

The first two panels of Figure 2 display the 5-year average values of snowfall intensity and winter mean temperature for the individual market samples. Due to the nonlinear relationship between snowfall and temperature, which arises from variation around the critical value of 0° C, the annual variation in snowfall intensity generally exceeds the annual variation in

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[9] Knowles et al. (2006) used the rule that if some snowfall was actually observed at the station on the day in question, all precipitation observed on that day is classified as snowfall. Because not all of our stations record the type of precipitation, we modified the algorithm as described in the text.

[10] This includes the alternative extreme of classifying all precipitation on a day as snow only if the maximum temperature never exceeds 0 °C; this alternative representation generally has very little explanatory power when used in place of our preferred measure.

winter mean temperatures.[11] For example, for the Lake Tahoe weather station, mean temperatures were relatively constant from the mid-1980s until 2005 (Figure 2, Panel B), but substantial variation in snowfall intensity is evident during this period (Figure 2, Panel A).

Although we focus on the 10-year and 5-year measures of snowfall as our primary weather variables, we also examined the impact of other weather variables as part of our robustness checks on the main results (Section IV.B), including other lag structures for our measure of snowfall intensity. We also use a weather variable intended to capture one of the potential advantages of warming from the perspective of winter sports—the number of uncomfortably cold days, defined as days with a maximum temperature of -10°C (14° F) or less, averaged in the same manner as the snowfall intensity variable. This variable is displayed for the individual markets in the third panel of Figure 2. It exhibits substantial variation over our sample frame, with a downward trend generally evident, especially in recent years. Over the longer term, resorts in cold areas may benefit from a perceived improvement in skiing conditions (comfort levels) due to a reduction in the number of these days, creating the possibility that warming will raise demand for housing and home prices in some areas.

(iii) Ski resort characteristics

Because our analyses are aimed at uncovering a relationship between home prices and skiing conditions, we have limited our data to regions with relatively large ski resorts that are likely to play an important role in the local economy. To account for investments in ski resort expansions and alterations that may affect nearby land values and home prices over time and thereby bias the estimated impact of variation in snowfall intensity, we compiled data from the *White Book of Ski Resorts* (Enzel, various years), which provides detailed information on various

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[11] Whistler's weather station is located at relatively high altitude, closer to that ski area's peak than its base (see Appendix Table 2), which explains its high snowfall intensity and low temperatures.

resort characteristics.[12] For ski resorts that are within 100 km of the relevant weather station and met a minimum size threshold—lift capacity of at least 1000 persons/hour and at least 500 vertical feet (152 m) drop—we aggregated the data for all ski resorts in weather station regions to arrive at the regional values (see Appendix Table 2).

In the regressions reported here, we include two measures to capture investments in resort capacity and quality: total lift capacity and average vertical drop (weighted by capacity).[13] Appendix Table 1 provides summary statistics on these characteristics by region, as defined by weather stations.[14] It is important to note that lift capacity does not unambiguously measure a desirable expansion of skiable area; if resorts simply add lift capacity without expanding terrain, these investments could increase congestion and lower resort quality from the perspective of the typical skier or snowboarder. Thus, although such investments could increase resort revenues, they may not increase the value of local residential properties. An increase in vertical drop is a quality improvement for many users, because it provides the potential for longer runs and access to more varied terrain. However, our measure is an imperfect quality indicator; for example, because this variable is calculated on a capacity-weighted basis, its value will decline if resorts with vertical drops that are less than the average in their region expand capacity (e.g., ski areas associated with the Alta and Tahoe City weather stations in Appendix Table 1). Although the

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[12] See Mulligan and Llinares (2003) for an effective application of these data. Because this source does not provide pre-1976 data, we match the 1976 values with our 1970 Census tract and weather data. Also, we were unable to obtain these data for all years between 1976 and 2006, so some annual values are filled in from adjacent years in our market analyses.

[13] Lift capacity was summed to obtain regional total capacity. Vertical drop is calculated as the weighted-average value across ski resorts in the region, using each ski resort's lift capacity as its weight. This source also provides relatively consistent information regarding lift ticket prices, but this variable likely is endogenous in our setting.

[14] The data are not shown separately for North and South Lake Tahoe, because these two areas share the same weather station; however, as indicated in Appendix Table 2, different resorts are used to form the ski area characteristics for these markets in the individual market regressions reported in Table 3.

capacity and vertical drop variables are not ideal, other variables that would help identify resort quality and adaptability to climate change—such as total skiable terrain and snowmaking capability—cannot be reliably used because they are frequently missing in the source data over our sample frame.

III.B. Hedonic Estimation

Our regression equations for estimating the impact of snowfall intensity and other variables on resort-area home prices are derived from a standard hedonic framework (see e.g. Rosen 1974, Freeman 2003). For both data sources, we estimate the hedonic price equation in reduced form using a log-log specification (the key results are similar when the model is estimated in semi-log form). The model estimated for the data on individual homes takes the form:

$$\ln(price_{it}) = \beta_0 + \beta_1 S_{it} + \beta_2 Q_{it} + \beta_3 N_{it} + \beta_4 T_{it} + \varepsilon_{it} \tag{1}$$

where $price_{it}$ is the sale price of property i at time t, S is a vector of structural attributes, Q is a vector of environmental attributes, N is a vector of locational attributes, and T is the time of sale. We assume that the error term ε_{it} is composed of an i.i.d. component and a component that is common to sales occurring in the same year (i.e., in the estimation the standard errors are clustered by year). The β's are parameters to be estimated. This equation is estimated separately for each of the four regions for which we have data on prices of individual homes sold.

In our Census tract data, we estimate similar equations, except that the variables are tract-level averages and we have multiple observations per Census tract, allowing for the estimation of tract-level fixed effects:

$$\ln(average\,value_{jt}) = \gamma_0 + \gamma_1 S_{jt} + \gamma_2 Q_{jt} + \Omega_j + \mu_{jt} \tag{2}$$

where *(average value$_{jt}$)* is the log average owner-assessed home value for tract *j* in period *t*, *S* and *Q* are defined as above, and Ω_j is a time-invariant tract-specific fixed effect for tract *j* (the vector of property-specific locational attributes, N, disappears as this is assumed to be time-invariant and subsumed in Ω_j). The error term μ_{jt} is composed of an i.i.d. component and a component that is common to Census tracts in the same property market, which is assumed to be the county (i.e., in the estimation the standard errors are clustered by county). The γ's are parameters to be estimated.

We are primarily interested in the coefficient on our measure of medium-term snowfall intensity (SFE/P, included in the vector Q). Strictly speaking, housing values should be affected by owners' and potential buyers' expectations of snowfall conditions over the usable life of the home. However, it is likely that resort-area homeowners and renters form expectations about long-term snowfall conditions based on observable variation over preceding periods.[15] Liquidity constraints for financing resort-area home purchases may also play a role, causing a need for consistent rental demand during the years immediately after purchase of the home (assuming that potential renters form their current-season snowfall expectations based on observed snowfall intensity in preceding years).

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[15] Forward-looking projections that incorporate global warming are unlikely to exert much influence during our sample frame because knowledge of the potential weather effects of global warming has been quite limited until recent years. Our exploratory investigation of the effects of climate change information on home prices—using trends in newspaper coverage of key words (e.g., "global warming" and "climate change")—did not yield significant estimates.

The identification of price effects for demand shifts associated with variation in weather conditions is contingent on the presence of some degree of housing supply inelasticity. In addition to geographic and zoning constraints which could restrict the expansion of supply in some markets as snowfall conditions improve, we expect significant downward rigidities in the housing stock as snowfall conditions deteriorate, as occurs over much of our sample frame.[16]

Our estimates of the effect of snowfall intensity on home prices rely on variation over time in the individual home data and variation across tracts and over time in the Census tract data. The presence of both types of variation in the Census data substantially strengthens our test by allowing us to apply fixed-effects estimation to account for time-invariant unobservable factors that may be important determinants of home values across resort areas. Moreover, the geographic heterogeneity present in the Census tract data provides additional identifying information, through the variations in snowfall intensity that are associated with elevation, latitude, and proximity to the Pacific Ocean; this heterogeneity is a fundamental characteristic of climate change in our setting, and it also provides useful variation for estimation purposes. Estimates using the market sales data offer complementary advantages, specifically a tighter connection between house prices and characteristics and higher frequency variation in weather and other observables than is afforded by the tract data.

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[16] Wheaton (2005) estimated determinants of ski resort real estate values in a setting that is largely unrelated to ours, focusing on supply expansion for a single resort in the northeastern United States. He finds that annual snowfall variation is an important determinant of prices for resort-area real estate, although in his sample its short-run impact is offset by housing supply responses in the longer term.

IV. EMPIRICAL ANALYSIS

IV.A. Regression Results

Regression results using the Census tract data are displayed in Table 2. In addition to controls for snowfall intensity, our basic specification also includes controls for population density, average number of rooms in the housing stock, three variables representing age of the housing stock (coefficients not reported), the share of single-family homes (not reported), total ski resort lift capacity, and capacity-weighted vertical drop. The dependent and explanatory variables are measured in log form, except for dummy variables. Due to the heavy influence of variation in unobserved factors that determine housing values in the cross section of Census tracts, we do not discuss panel estimates that rely on variation across tracts and over time and instead proceed directly to fixed-effects models that fully absorb the cross-section variation.

Table 2 reports four different versions of the fixed-effects regression model for two different samples: the odd-numbered columns display results for the full sample of Census tracts, whereas the even-numbered columns display results for a sample of regions where the altitude of the weather station is not located more than 2100 feet (640 m) below the average base of the area ski resorts.[17] Beyond this sample restriction, the different specifications reflect alternative assumptions about pure time effects on home values in our samples. In the first version of the model (columns 1 and 2), the dependent variable is measured in nominal terms. Each subsequent version of the model accounts for sample-wide movements in home values over time. In columns 3 and 4, home values are adjusted for inflation using the U.S. CPI (all urban)

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[17] This restriction on altitude differentials represents a straightforward but econometrically inefficient means for limiting a potentially important source of measurement error, namely the gap between weather conditions at the station and the ski resorts. It results in dropping 3 weather stations (Jemez Springs, Parowan, and Whiteriver) and nearby Census tracts that are associated with a few relatively small ski areas (see Appendix Tables 1-2).

index for shelter costs.[18] In columns 5-8 the inflation adjustment is implemented through the inclusion of a sample-wide time trend as an explanatory variable. In addition, the specifications reported in columns 7 and 8 include complete interactions between the time trend and dummy variables for each Census tract. The model in the final two columns constitutes a very strong test, by ensuring that our findings for the effect of SFE/P in these data is not a spurious reflection of unobservable factors that increased housing prices over time and are correlated with changes in SFE/P within selected Census tracts.[19] The estimates are clustered by county, to account for correlation in housing market conditions across Census tracts in the same housing market.

Turning first to the control variables, the results of the regressions are somewhat mixed but plausible on net. Higher population density is consistently associated with higher home values, with high statistical significance in all specifications. Higher household incomes also are associated with higher home values, although the effect is statistically significant only for the nominal regressions in the first two columns. The coefficient on the number of rooms is negative in general and statistically significant for the full-sample nominal regression in column 1, although this coefficient is consistently positive and statistically significant when household income is excluded from the regressions (not shown in the table). Results for the ski area characteristics generally are insignificant, suggesting that investments in ski area capacity and characteristics were not an important determinant of nearby home values over our sample frame; however, the effects of capacity expansion are positive and marginally significant in some cases,

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[18] We used a national inflation measure for this analysis, because regional measures of housing or shelter costs are not available for a sufficiently long period.

[19] We thank Orley Ashenfelter for suggesting this approach. We also estimated the models in columns 5 and 6 of Table 2 with unrestricted year (decade) effects rather than a time trend. The results of these regressions indicated that a substantial share of the variation in snowfall intensity across the decades in our sample is shared among weather stations, which precludes the estimation of reliable snowfall effects in that specification.

and expansions in vertical drop have a strong positive effect in the final two columns.[20] The comparison of the first two columns with subsequent columns indicates that inflation adjustment lowers the absolute values of some of the estimated coefficients by correcting for the effects of changes that are correlated with general housing price inflation. The adjusted R-squared's from all of these regressions, which account for the inclusion of tract-specific dummy variables, are quite high, in the range of 0.72 to 0.98. This indicates that our model explains a very high proportion of the variance in average price changes across the Census tracts in our sample.[21]

Most importantly, the results in Table 2 show precisely estimated elasticities of home values with respect to snowfall intensity over the ten years preceding the observation on home values, with higher (lower) snowfall intensity increasing (decreasing) home values. These estimates are significant at the 1% level in all specifications, including in the models in the final two columns that include separate time trends by Census tract. The estimated magnitude of the snowfall intensity effect is substantially larger in these final two columns than in the other columns, although the standard errors are also relatively large. The coefficients on snowfall intensity generally are larger and more precisely estimated in the altitude-restricted models, with the exception of the fully nominal models in columns 1 and 2. When we replace snowfall intensity (SFE/P) with a measure of total snowfall accumulation in our primary specifications, we obtain generally insignificant and in some cases wrong-signed coefficients, which reinforce

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[20] Because these variables were incorporated primarily to account for the omitted variable bias that might occur in their absence, the lack of a significant effect is not troubling. As discussed in the next section, the key results from these runs are not sensitive to the inclusion of the ski area characteristics.

[21] We also ran regressions for the balanced panel of 384 tracts that appear in all four Census periods, which yielded results that are comparable in magnitude and precision to those reported in Table 2.

our use of SFE/P as our primary measure of snowfall conditions; these results are discussed in more detail along with other robustness checks in the next section.[22]

Our preferred estimates, which are conservative vis-à-vis the full range of results in Table 2, are the inflation-adjusted and trend-adjusted full sample results in columns 3 and 5. The average of the two coefficients on snowfall intensity in these columns is 2.16. For a one standard deviation decline in the value of the snowfall intensity variable SFE/P-10—based on its observed values and calculated separately for each of the 16 weather stations—this average coefficient implies a 0.7% to 8.8% decline in average housing values in nearby Census tracts. (These results will be used for a simulation of the effect of global warming in Section IV.C.) Applying the same exercise to the altitude-restricted sample results in columns 4 and 6 produces an average coefficient of 3.40 and an effect on home values for the 14 regions in this sample that ranges from 1.1% to 13.8%.

Table 3 lists results from the parallel analysis of prices on individual homes sold in our four specific market regions in the U.S. and Canada. These regressions pool multiple home sales per year occurring over 25-30 years. Given the likely correlation in home prices for homes sold in the same year, the standard errors are clustered by year. These regressions control for a relatively wide set of home characteristics, such as the age of the home, square footage, and the month/year of sale; the coefficients on these variables generally have the expected signs, are precisely estimated, and are relatively consistent across the different market regions. The coefficients on ski area characteristic variables are statistically significant in most cases, although their signs vary across the columns, suggesting that capacity expansions are desirable in some instances and are associated with ski area congestion in others.

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[22] We experimented with specifications that allow the impact of changes in SFE/P to vary across areas defined by different base levels of SFE/P but found very little evidence for such variation in our data.

Similar to the Census tract regressions from Table 2, the coefficients on snowfall intensity are positive and statistically significant in most cases in Table 3, again indicating that higher (lower) snowfall intensity increases (decreases) home prices. North Lake Tahoe is the exception, with a positive but relatively small coefficient that does not achieve conventional significance levels. The sizes of these coefficients are higher in the Canadian markets than in the Lake Tahoe area. Based on the observed variation in snowfall intensity (SFE/P-5) for the weather stations in these areas, the coefficients on this variable imply that a one standard deviation decline in SFE/P-5 will reduce home values by 2.2% to 6.0% in the Eldorado and Canadian samples. These magnitudes fall within the range of the corresponding magnitudes from the fixed-effects specification using the Census data (Table 2, columns 3 and 4).

IV.B. Robustness Checks

The results discussed in the preceding section focused on a particular specification of the relationship between housing prices and weather conditions, conditional on a particular set of housing and locational characteristics. The specifications used represent our best attempt to incorporate relevant weather conditions and control variables available in our two sources of housing data. However, given concerns about the robustness of the hedonic approach in some settings, and considering the novelty of our data and empirical design, some probing of the basic specifications is warranted. In this section we investigate the sensitivity of our results to the specification of the home price equations and the specific representations of our weather variables.

Tables 4 and 5 present the results of these robustness checks, for the Census tract and individual market data, respectively. In both tables, the coefficients listed are each from separate regressions that largely correspond to the specifications used in Tables 2 and 3, with variation in the specific control variables and measure of weather conditions as indicated (the stacked coefficients for the “cold days” and SFE/P-10 variables in Tables 4 and 5 are from the same regression). Panel A of Table 4 shows that in the Census tract regressions the coefficient on snowfall intensity is highly insensitive to the exact set of other controls used. This consistency also is evident for the individual market regressions in Panel A of Table 5, with the exception of Whistler, for which the coefficient achieves conventional levels of statistical significance only in the model with complete controls.

The robustness checks for ski area characteristics help address the potential concern that these characteristics, which measure ski area capacity, are endogenous to snowfall. If resort capacity is positively related to housing prices and expands in response to favorable snowfall conditions, the inclusion of resort capacity as a control is important to avoid overstating the independent effect of SFE/P. On the other hand, if unobserved market conditions simultaneously increase resort capacity and housing values, capacity and SFE/P are positively correlated, and capacity is measured with more error than SFE/P, the coefficient on SFE/P may be biased upward in equations that control for resort capacity.

As a practical matter, the size of these potential biases is minimal in our data, because the relevant correlations between resort characteristics and the other variables are low in general. As a result, in the Census tract sample, the coefficient on SFE/P is relatively insensitive to the inclusion or exclusion of resort characteristics in Panel A of Table 4 (coefficient=2.03 and SE=0.614 with resort characteristics, coefficient=1.88 and SE=0.855 without). In Panel A of Table 5, the results for the individual U.S. markets also show limited sensitivity to the inclusion of resort characteristics. A greater degree of sensitivity is evident for the individual Canadian markets, although the impact on the SFE/P coefficient is statistically meaningful only in the

Whistler sample. This market has experienced the most rapid expansion in ski capacity and the housing stock over the sample frame (see Table 1 and Appendix Table 1). The increased size and improved precision of the coefficient on SFE/P when we add location and resort characteristics in the Whistler equation suggests that these characteristics are negatively correlated with SFE/P and that it is important to control for them in the equation, although we cannot rule out the possibility that changes in unobserved market conditions are imparting an upward bias to the coefficient on SFE/P in that equation.

Panels B-D of Tables 4 and 5 display results for alternative weather variables other than our primary measures of snowfall intensity (SFE/P-10 and SFE/P-5). Panel B in both tables lists coefficients for a measure of total snowfall accumulation, which we estimate based on a method similar to that used to form SFE/P. Unlike our measure of snowfall intensity, in no case is the coefficient on total snowfall positive and statistically significant, and it is in fact negative and significant for the Tahoe-area market regressions in the final two columns of Table 5. This finding reinforces our reasoning for choosing snowfall intensity rather than total accumulation as our primary measure of skiing-related weather conditions: the statistically significant negative coefficients on total snowfall for the Tahoe market likely reflect the incidence of seasons with high total precipitation, including high snowfall totals mixed with substantial winter rain (the so-called "El Niño" pattern), which reduces the quality of skiing.

Panel C in both tables lists results from models that incorporate a control for very cold weather, measured as the number of days during the ski season for which the high temperature never exceeds -10°C (14° F) and averaged across ski seasons in the same manner as the snowfall variable. When included as the only measure of weather conditions, the coefficient on this variable is positive and marginally significant in the Census tract regressions (Table 4, Panel C;

similar results are obtained in the individual market regressions but are not reported in Table 5 due to space constraints). This occurs due to the high degree of collinearity between cold days and snowfall intensity over the ski season: when SFE/P is included in these regressions as well, the coefficient on cold days in the Census tract regressions remains positive but becomes statistically insignificant (Table 4, Panel C), while the coefficients on SFE/P are similar to the comparable coefficients in Panel A. By contrast, in the corresponding regressions that include both weather variables for the individual market samples (Table 5, Panel C), the coefficient on the cold days variable is consistently negative and statistically significant in most cases, while the coefficient on SFE/P remains positive and significant. Indeed, the inclusion of the cold days variable generally strengthens the coefficient on SFE/P in the individual market runs. On net, the results using the cold days variable support the robustness of our results for snowfall intensity, while also suggesting that warmer weather for skiing, to the extent that it does not undermine snow quality, may increase demand for ski resort real estate in some areas.

We also investigated the impact of alternative averaging periods for the measurement of the snowfall intensity variable SFE/P, as reported in Panel D of Tables 4 and 5. Substantial variation in the estimated effects of snowfall intensity are evident across the different averaging periods, but taken together the results generally support the interpretation that home values are affected by expectations of snowfall intensity formed adaptively over prior periods. In the Census tract runs (Table 4, Panel D), the coefficient is largest when snowfall is averaged over a 7-year period, although we regard the results based on the 10-year average as preferable because the longer time period corresponds to the interval over which we observe home price changes in this dataset. The results for the individual market runs (Table 5, Panel D) do not point to the superiority of any averaging period over our choice of 5 years, with higher coefficients obtained for longer averaging periods for the Canadian regions and higher coefficients obtained for shorter time periods for North Lake Tahoe. Indeed, the impact of snowfall intensity is positive and significant for North Lake Tahoe when it is averaged over three years, suggesting in contrast to Table 3 that home values in that region do respond to shorter-term weather conditions.

Our final robustness check focuses on the sensitivity of our results to the distance restrictions on Census tracts and ski resorts relative to weather stations. As discussion in Section III.A, our primary sample limits the distances to 100 kilometers. Panel E of Table 4 reports results for the alternative restrictions of 150 km and 50 km. As in our primary sample, the coefficients on SFE/P in these samples are positive and precisely estimated. The coefficient for the 150-km sample (1.99) is nearly identical to that for our primary sample (2.03). When we narrow the geographic area to 50 km, the coefficient rises somewhat, to 2.52, suggesting that the impact of variation in skiing conditions is larger for housing units that are closer to the weather measurement points and to ski resorts.

On net, the results discussed in this section point to substantial robustness in the magnitude and statistical significance of the estimated impact of medium-term variation in weather conditions (primarily snowfall intensity) on home values. The results discussed in the preceding section, as displayed in Tables 2 and 3, reflect what we regard as the most reasonable specification, with estimated weather effects that are relatively conservative. We therefore focus on those results for the simulations of the impact of global warming.

IV.C. Simulated Impact of Long-term Climate Change

Our data and regression framework enable direct simulation of the impact of specific degrees of warming on housing values in our samples. Because the Census tract sample covers a wider geographic area than the individual market samples, we rely on the Census results for our simulations. The simulations rely on calculations that transform observed values of the 10-year average snowfall intensity variable (SFE/P-10) into alternative values based on projected amounts of warming in average temperatures. Because annual values of SFE/P are calculated using daily observations on temperatures and precipitation during the winter months (see section III.A(ii)), the translation into simulated alternative values is straightforward. In particular, we added specific amounts of daily warmth to the average of observed temperatures from 1970-2000 for each weather station and once again applied our rule that on any day recorded as having precipitation and a minimum temperature below 0° C, all precipitation on that day is classified as snow. We then aggregated the simulated daily values as before to produce annual values of SFE/P, then took 10-year averages to obtain SFE/P-10. Because SFE/P and hence our simulations are not affected by total precipitation, we did not incorporate precipitation projections.

Our baseline climate change scenario for this exercise is the IPCC's "High A2" emission scenario in conjunction with its "Ensemble Average" of general circulation models (GCM). Temperature changes under this scenario and alternatives are available on a precise geographic basis from various sources; we used the IPCC projections on the "ClimateWizard" web site (http://www.climatewizard.org/; the underlying source is Maurer et al. 2007). We relied on the climate change projection through the mid 21st century; the simulations are based on the projected increase in average December-February temperatures between the years 1971-2000 and 2040-69. The projected temperature increases are in the range of 1.6° to 3.1° C across the regions (weather stations) in our sample, with Montana and the coastal states of California and Oregon near the low end of the range and parts of Utah and Colorado towards the high end.

As expected, these warming scenarios reduce the values of SFE/P-10 for all areas, with substantial heterogeneity evident across areas. However, the declines in SFE/P are not always closely aligned with the temperature increases, because areas differ in regard to their baseline temperatures. In particular, the decline in SFE/P ranges from about 5 percentage points in parts of Colorado to nearly 30 percentage points in parts of New Mexico; despite the relatively large temperature increase projected for Colorado, the decline in SFE/P there is limited because its existing baseline temperatures are relatively cold. The heterogeneity in the SFE/P changes will produce substantial variation in the regional impact of climate change in our simulations, despite our econometric estimate of a single shared effect of SFE/P on housing prices for the whole sample. Moreover, given the heterogeneity of observed weather data in our sample, the simulation relies on relatively little out-of-sample variation, with 81% of the simulated SFE/P observations found in the data.[23]

We use the earlier regression results to predict housing values if the values of SFE/P-10 change by the simulated amounts, holding constant the parameter estimates and values of the other covariates; as in the preceding section, we use the average of the inflation-adjusted and trend-adjusted coefficients from columns 3 and 5 of Table 2, which provides a relatively conservative estimate of impacts.

The results of this exercise are displayed in map form in Figure 2. The figure shows: (i) potentially large negative effects of warming on house values in areas near ski resorts; (ii) substantial heterogeneity in the size of the likely impacts. Most tracts in our sample will experience at least a 15% decline in home values. Only a few high-altitude areas, in Montana, Wyoming, and Colorado, will see declines of 14% or less, with single-digit declines projected for parts of those states. The most highly affected areas in our sample—New Mexico, Utah,

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[23] The out-of-sample predictions are for Jemez Springs (New Mexico), White River (Arizona). and Hollister (Idaho, Nevada).

Idaho, Nevada, and to a lesser extent Arizona and California—are projected to experience about a 44-55% reduction in home values.

Alternative simulation scenarios (not displayed) largely preserve the relative rankings of these regions in regard to price declines but show substantially smaller or larger price declines on average. Under a low emissions scenario (B1) with a low-sensitivity GCM model (CSIRO-MK3.0), which produces the smallest projected temperature increase, the decline in home prices is limited to 20%, with most areas experiencing single-digit declines. Under the opposite extreme (A2 emissions scenario using the MIROC3.2 GCM), 20% declines are the approximate lower bound, with about half of the areas projected to see declines in home prices of more than 50%.

V. DISCUSSION AND CONCLUSIONS

"I would think the Sierra Nevada is going to be faced with the transition to golf and mountain biking sooner than other areas."
- Lisa Sloan, Professor of Earth Sciences, UC Santa Cruz (quoted in Mason 2007)

Our results provide direct statistical evidence that global warming is likely to reduce home prices around major ski resorts in the western U.S. and western Canada. These results were uncovered by applying hedonic home price regressions to data on Census tracts in ten states and separate data on individual home sales in four market regions. The impact on housing values of variation in snowfall intensity (the snowfall share of precipitation during winter months) exhibits substantial consistency across our two data sets. Home prices respond to medium-term (3-10 year) variation in snowfall conditions over our sample period, suggesting that owners and potential buyers form demand and price assessments from backward-looking adaptive expectations.

Despite relative consistency in the average impact of snowfall intensity across our data sources, considerable heterogeneity exists in the likely impact of warming on conditions at different ski resorts, hence demand for housing in those areas. Some areas, such as high altitude or northerly resorts in Colorado, Montana, and Wyoming, will see very little adverse impact of warming on home prices, while areas that are already warm, especially parts of New Mexico, face the possibility of substantial reductions in the quality of snow and corresponding sharp declines in home prices around those ski resorts. These price changes may begin to occur in anticipation of the predicted temperature increases, as information from climate models becomes more generally available to the public. Over the longer term, as ski conditions deteriorate, second-order effects may include declines in resort area employment that could further reduce property values.

Our results are subject to common caveats that apply to hedonic estimation of the impact of climate change, most notably the possibility of adaptation, including changes in production functions and investments for alternative recreation activities. Wintertime adaptations such as snowmaking offer little potential offset because they require cold temperatures in order to be successful. By contrast, conditions for warm-weather activities such as golf and mountain biking may improve in areas near ski resorts as average temperatures rise; this effect may be reinforced by the access to cooler mountain temperatures in regions where hot summers become less tolerable as the climate warms (Bark-Hodgins and Colby 2007 suggest this possibility for Arizona resorts). To the extent that the conditions for such activities improve as temperatures rise, owners of commercial property may invest in recreational facilities such as golf courses and mountain biking conveyances and paths at higher altitudes, which may offset the decline in residential home values resulting from the deterioration of skiing conditions. Such changes will provide an unknown but potentially significant degree of offset to our simulated price declines.

Another factor that may offset the decline in housing prices in some locations is the potential reallocation of demand away from the warmest areas and towards areas that remain relatively cold. In particular, our estimates suggest that all ski resort regions will see some decline in home values, while in fact the areas that remain the coldest in relative terms may absorb the demand declines from warmer areas and experience increased demand on net. This potential demand increase for some areas is reflected in the negative impact of our measure of cold days on housing prices for two of the individual market samples (Fernie and North Lake Tahoe), in specifications that include snowfall intensity as well; these results imply that conditional on snow conditions, global warming may increase home values around some ski resorts. A similar effect may be observed in regard to the development of new ski areas, which may shift over time towards colder locations that become more viable as global temperatures warm. Systematic investigation of such positive effects of warming in relatively cold areas is a worthy topic for further investigation.

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Figure 1: Annual weather series
(sales market locations, 5-year average values)

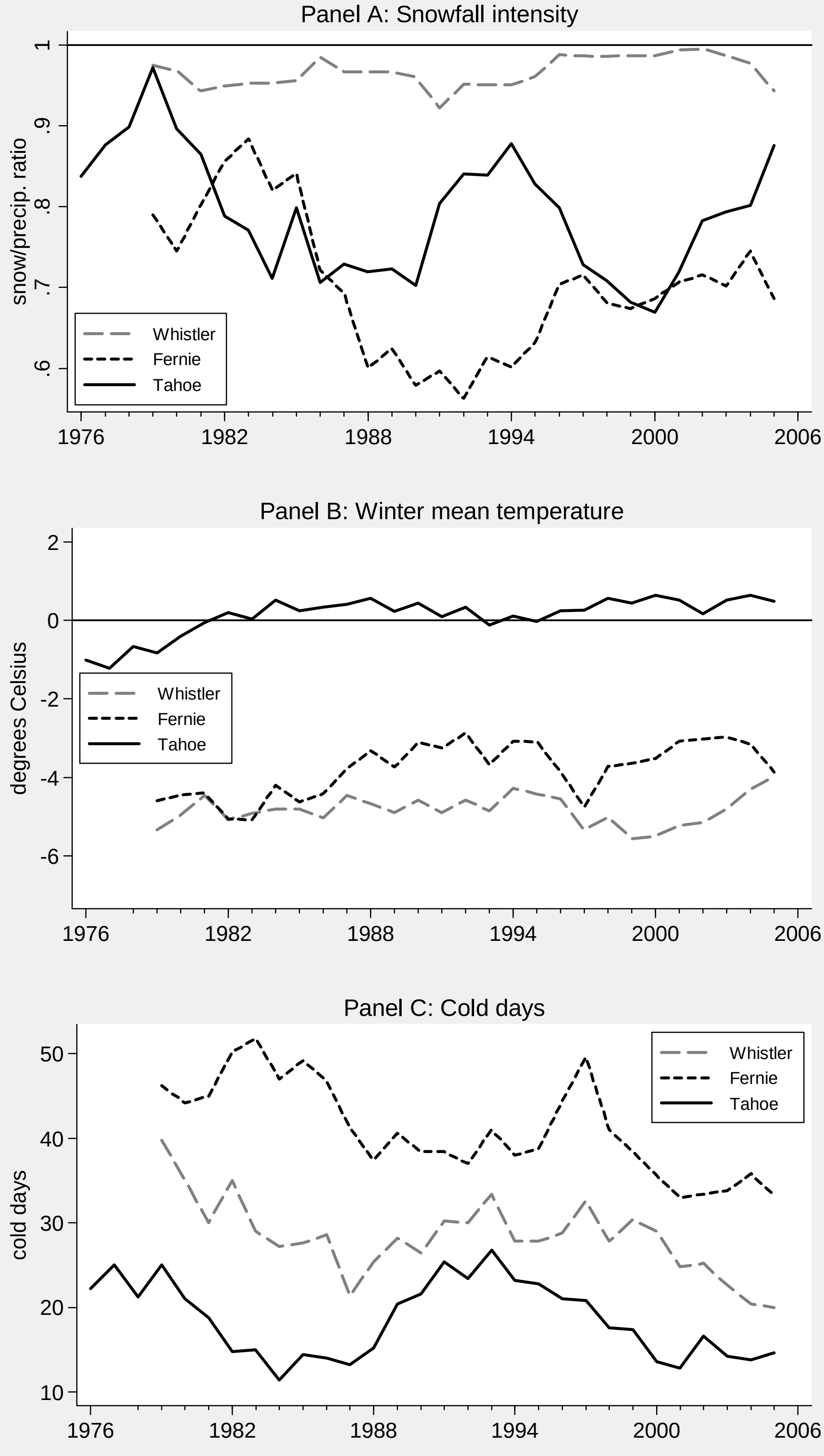
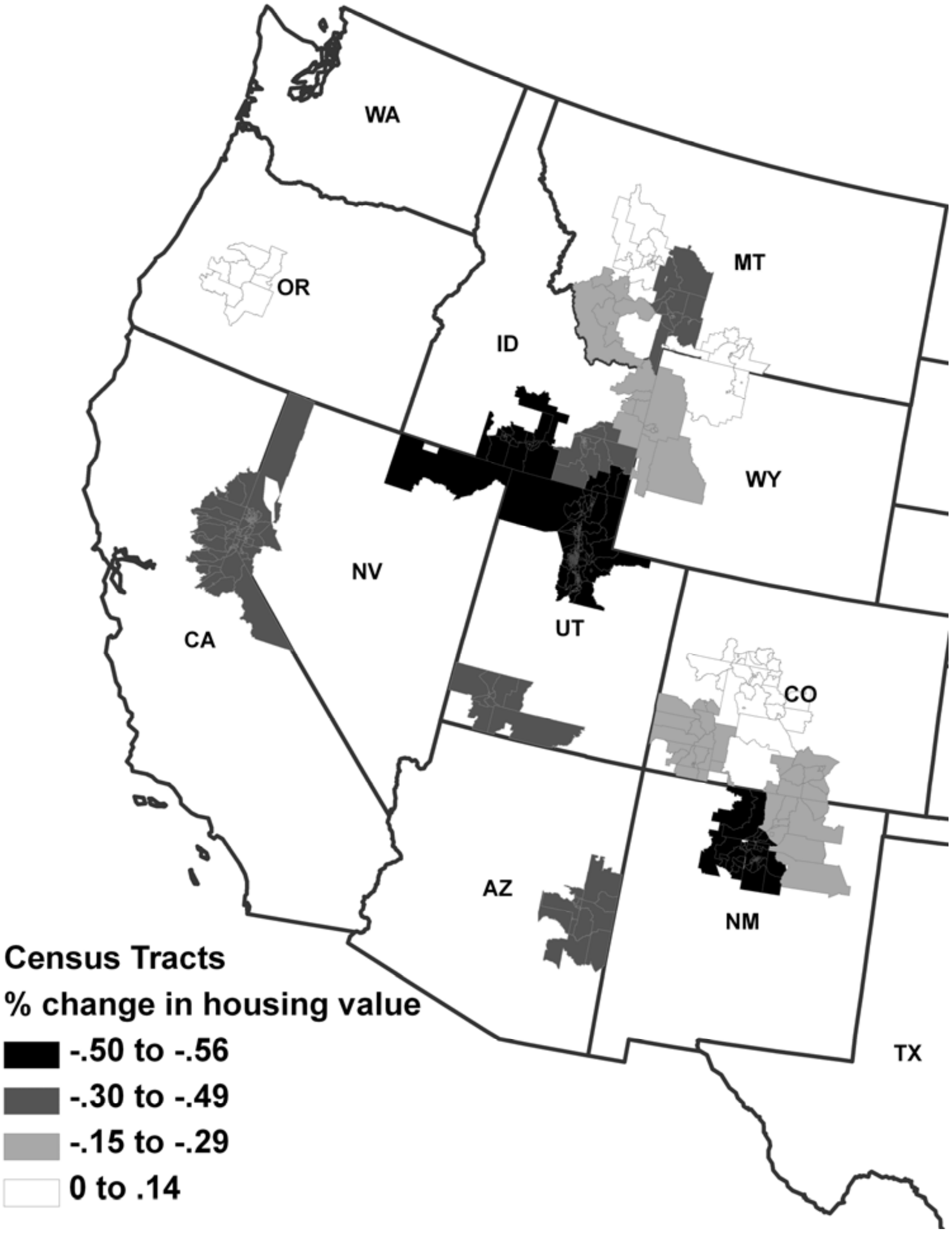


Figure 2: Simulated Change in Housing Values by 2050



Note: Based on IPCC ensemble average of general circulation models, high A2 emissions scenario.

Table 1: Housing and Location Characteristics

Panel A: Census Tract Data
Summary Statistics (means; standard deviations in parentheses)

	Years			
Variable	1970	1980	1990	2000
Mean home price (1999 $)	120578	232973	135664	191430
	(41837)	(360796)	(79704)	(110821)
Average household income (1999 $)	46565	49911	48732	57549
	(14417)	(15001)	(17726)	(22306)
Share of homes				
< 10 years old	0.40	0.46	0.24	0.04
	(0.23)	(0.25)	(0.16)	(0.05)
10-20 years old	0.25	0.19	0.32	0.17
	(0.14)	(0.12)	(0.14)	(0.11)
20-30 years old	0.14	0.14	0.10	0.23
	(0.10)	(0.11)	(0.11)	(0.13)
30+ years old	0.21	0.21	0.34	0.57
	(0.19)	(0.22)	(0.23)	(0.18)
Share of single family homes	1.00	1.00	0.83	0.81
	(0.00)	(0.00)	(0.24)	(0.22)
Average number of rooms	5.27	5.64	5.68	5.84
	(0.81)	(1.07)	(1.12)	(1.22)
Population density (per square mile)	2189	2767	2154	2491
	(2934)	(2892)	(2871)	(3217)
Number of observations	423	414	689	688

Note: Home price deflated using the national CPI for shelter costs, household income deflated using the overall national CPI (all urban); both measured in the year prior to the census year.

Panel B: Single Site Data (individual homes)
Summary Statistics (means; standard deviations in parentheses)

Variable	Whistler (BC) 1980-2006	Fernie (BC) 1980-2006	Washoe/Placer Cty. (NV/CA, N. Lake Tahoe) 1976-2006	Eldorado Cty. (CA, S. Lake Tahoe) 1981-2006
Sale price (nominal USD or CAD)	286573	105060	508797	279344
	(352821)	(79825)	(845904)	(347898)
Age of home (years)	7.23	29.52	21.89	25.11
	(7.64)	(31.12)	(13.60)	(14.45)
Square footage	1305	1531	1828	1536
	(1012)	(643)	(958)	(663)
Number of bathrooms			2.31	1.86
			(0.94)	(0.68)
Single family home (dummy)	0.19	0.72	0.60	
	(0.39)	(0.45)	(0.49)	
Nearest ski area (km)			11.61	14.89
			(6.77)	(6.98)
Distance to Lake Tahoe (km)			11.27	4.60
			(9.39)	(4.39)
Number of observations	14264	5049	12661	10344

Table 2: Fixed-effects Regression Results from Census Tract Data
Dependent variable: ln(average home value) (robust standard errors in parentheses)

	Nominal home values		Inflation adjusted (home values and household income)		Nominal home values		Nominal home values	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variable	Full sample	Altitude restricted	Full sample	Altitude restricted	Full sample	Altitude restricted	Full sample	Altitude restricted
ln (snowfall intensity)	2.76***	4.45***	2.03***	3.08***	2.29***	3.73***	7.51***	8.07***
(SFE/P-10)	(0.481)	(1.38)	(0.614)	(0.400)	(0.359)	(0.578)	(1.05)	(1.16)
ln(average household	0.915***	0.614*	0.451	0.302	0.243	0.074	-0.395	-0.363
income)	(0.166)	(0.379)	(0.543)	(0.623)	(0.392)	(0.515)	(0.632)	(0.668)
ln(population density)	0.107	0.118*	0.104	0.106*	0.050**	0.080*	0.079	0.079
	(0.065)	(0.067)	(0.063)	(0.063)	(0.025)	(0.047)	(0.058)	(0.054)
ln(avg. # rooms)	-0.527*	-0.113	-0.215	-0.040	-0.054	0.293	1.32	1.17
	(0.265)	(0.513)	(0.539)	(0.570)	(0.351)	(0.527)	(0.833)	(0.737)
ln(total lift capacity,	0.391*	0.611	0.208	-0.044	0.016	0.034	0.065	-0.035
ski areas in region)	(0.223)	(0.478)	(0.136)	(0.169)	(0.139)	(0.343)	(0.083)	(0.151)
ln(capacity-weighted	-0.455	0.177	-0.133	1.31	-0.468	0.591	5.14***	6.20***
vertical drop)	(0.603)	(0.829)	(0.430)	(0.911)	(0.581)	(0.874)	(0.561)	(0.427)
Time trend (decades)	--	--	--	--	0.639**	0.596**	0.731***	2.74***
					(0.302)	(0.288)	(0.108)	(0.648)
Tract-specific time trends	no	no	no	no	no	no	yes	yes
Adj. R^2	0.906	0.929	0.719	0.765	0.924	0.943	0.982	0.986
Number of obs.	2214	1900	2214	1900	2214	1900	2214	1900
Clusters (counties)	66	59	66	59	66	59	66	59

***Significant at 1% **Significant at 5% *Significant at 10%

Note: Standard errors clustered by county. Additional controls include share of single-family homes and 3 variables for percent of residences of various ages. Altitude restricted sample in (2), (4), (6), and (8) excludes four weather stations whose altitude is not close to adjacent ski area base altitudes (see text). Inflation-adjustment for house values in (3) and (4) based on the U.S. CPI (all urban) for shelter costs; household income is inflation adjusted using the overall CPI.

Table 3: Regression Results from Data on Home Sales (4 sites)
(Regression coefficients; robust standard errors in parentheses)
(Dependent variable: ln(sale value))

Variable	(1) Whistler (Canada)	(2) Fernie (Canada)	(3) Washoe NV/ Placer CA (North Tahoe)	(4) Eldorado, CA (South Tahoe)
ln(snowfall intensity)	3.20**	1.06***	0.296	0.758***
(SFE/P-5)	(1.39)	(0.341)	(0.216)	(0.235)
age of home (years)	-0.009**	-0.018***	-0.011***	-0.010***
	(0.004)	(0.002)	(0.002)	(0.001)
ln(square footage)	0.795***	0.514***	0.767***	0.724***
	(0.044)	(0.015)	(0.041)	(0.029)
sale date	0.005***	0.008***	0.008***	0.008***
(month/year trend)	(0.001)	(0.001)	(0.001)	(0.001)
ln(total lift capacity,	0.022	-1.02***	-0.814**	1.67**
ski areas in region)	(0.272)	(0.276)	(0.395)	(0.717)
ln(capacity-weighted	1.26	2.31***	-7.34***	3.99**
vertical drop)	(0.796)	(0.782)	(1.30)	(1.69)
ln(distance to nearest	--	--	0.002	-0.002**
ski resort in km)			(0.002)	(.001)
ln(distance to Lake	--	--	-0.011***	-0.016***
Tahoe in km)			(0.001)	(.002)
R^2	0.809	0.801	0.585	0.672
Number of obs.	14264	5049	12661	10344

***Significant at 1% **Significant at 5% *Significant at 10%

Note: Standard errors clustered by year of sale. Additional controls include a quadratic in age of home and:

Whistler--dummies for single-family home, period after announcement of Olympics, and neighborhood (5).
Fernie -- dummies for single-family home, neighborhood (12).
Washoe/Placer -- number of bathrooms, state dummy (California), state*(sale date), and dummies for single-family home and introduction of stricter land-use controls by the Tahoe Regional Planning Authority (TRPA).
Eldorado -- number of bathrooms, dummy for TRPA.

Table 4: Robustness Checks, Census Tract Regressions
Coefficient estimates for weather variables (standard errors in parentheses)

Panel A: Alternative contols

Variable	Demographics/economy	Add housing characteristics	Add ski characteristics (Table 2, col. 3)
ln(SFE/P-10)	2.03***	1.88**	2.03***
	(0.572)	(0.855)	(0.614)

Panel B: Alternative snow variable (ln(total snowfall))

Variable	Demographics/economy	Add housing characteristics	Add ski characteristics
ln(snowfall-10)	0.545	0.418	0.495
	(0.556)	(0.513)	(0.527)

Panel C: Additional weather variable (cold days)

Variable	Demographics/economy		Add housing characteristics		Add ski characteristics	
ln(cold days-10)	0.359*	0.046	0.336	0.072	0.521*	0.251
	(0.188)	(0.196)	(0.306)	(0.276)	(0.291)	(0.285)
ln(SFE/P-10)	--	1.97***	--	1.81***	--	1.81***
		(0.425)		(0.644)		(0.507)

Panel D: Alternative averaging for SFE/P

Variable	1-year	3-year	5-year	7-year
ln(SFE/P-n)	-0.087	0.456	1.42***	2.50***
	(0.209)	(0.883)	(0.415)	(0.630)

Panel E: Alternative distance restrictions on sample

Variable	150 km (N=2887)	50 km (N=1993)
ln(SFE/P-n)	1.99***	2.52***
	(0.673)	(0.573)

***Significant at 1% **Significant at 5% *Significant at 10%

Note: Except as indicated, regression specification and controls same as Table 2, column (3). Each regression coefficient is taken from a separate regression, except the stacked "cold days" and SFE/P-10 coefficients, which are from the same regression. In Panels A through C, specifications labeled "Demographics/economy" include population density and average household income; "Add housing characteristics" runs add the average number of rooms, share of single-family homes, and 3 variables for percent of residences of various ages; and the final column adds the ski area characteristics (to produce the specification from Table 3). The Panel D specification is identical to Table 2, except for use of the alternative snowfall variables indicated. The Panel E specification uses a different sample than Table 2, based on the distance restrictions (resorts to weather stations) and observation counts indicated.

Table 5: Robustness Checks, Individual Market Regressions
Coefficient estimates for weather variables (standard errors in parentheses)

Panel A: Alternative controls (coefficient on ln(SFE/P-5))

Regression controls	Whistler (Canada)	Fernie (Canada)	Washoe NV/ Placer CA (N. Tahoe)	Eldorado, CA (S. Tahoe)
Housing only	0.602	1.65***	0.470	0.856**
	(1.08)	(0.237)	(0.389)	(0.314)
Add location	1.74	1.75***	0.277	0.834***
	(1.28)	(0.233)	(0.300)	(0.286)
Add ski characteristics	3.20**	1.06***	0.296	0.758***
	(1.39)	(0.341)	(0.216)	(0.235)

Panel B: Alternative snow variable (ln(total snowfall))

Regression controls	Whistler (Canada)	Fernie (Canada)	Washoe NV/ Placer CA (N. Tahoe)	Eldorado, CA (S. Tahoe)
All	0.170	0.335	-0.327***	-0.580***
	(0.340)	(0.183)	(0.088)	(0.076)

Panel C: Additional weather variable (cold days)

Variable	Whistler (Canada)	Fernie (Canada)	Washoe NV/ Placer CA (N. Tahoe)	Eldorado, CA (S. Tahoe)
ln(cold days-5)	-0.058	-0.906**	-0.300*	-0.422**
	(0.289)	(0.402)	(0.170)	(0.132)
ln(SFE/P-5)	3.25**	1.48***	0.555*	1.10***
	(1.35)	(0.361)	(0.300)	(0.241)

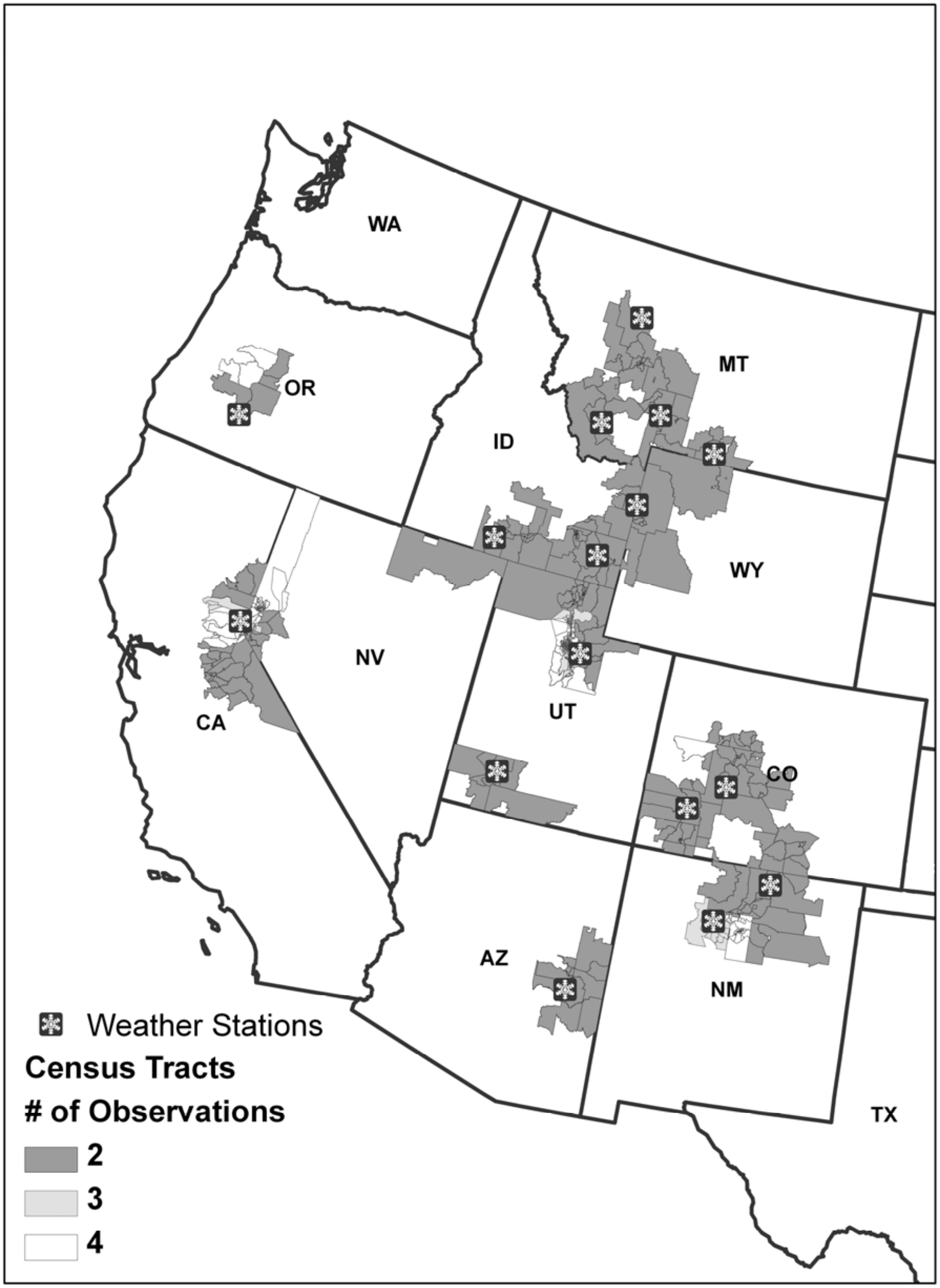
Panel D: Alternative averaging for SFE/P

Variable	Whistler (Canada)	Fernie (Canada)	Washoe NV/ Placer CA (N. Tahoe)	Eldorado, CA (S. Tahoe)
1-year	-0.673*	-0.139	0.249*	0.235*
	(0.387)	(0.117)	(0.135)	(0.118)
3-year	0.700	0.881***	0.504***	0.690***
	(0.774)	(0.257)	(0.157)	(0.198)
7-year	4.05***	1.12***	0.248	0.935**
	(1.29)	(0.352)	(0.375)	(0.385)
10-year	5.43**	1.35***	-1.86**	-1.91
	(2.46)	(0.489)	(0.722)	(1.16)

***Significant at 1% **Significant at 5% *Significant at 10%

Note: Except as indicated, regression specification and controls same as Table 3 for each market sample. Each regression coefficient is taken from a separate regression, except the stacked "cold days" and SFE/P-10 coefficients, which are from the same regression. In Panel A, the specification labeled "Housing only" include individual home characteristics only (age, size, etc.); "Add location" adds location variables such as neighborhood and time periods (post-Olympics announcement, etc.); and the final row adds the ski area characteristics (to produce the specification from Table 3). The panel B-D specifications are identical to Table 3, except for the alternative snowfall/weather variables indicated.

Appendix Figure 1: Census Tracts and Weather Stations



Appendix Table 1: Weather Station and Ski Area Data (decennial)
Summary Statistics (Means)

Weather Station	State	Variable	1970	1980	1990	2000
Alta 1NNW	ID-WY	Snowfall intensity (10-year avg.)	0.92	0.99	1.00	0.93
		Winter mean temp in C (10-year avg.)	-4.99	-5.86	-4.88	-4.54
		Total lift capacity (persons/hour)	9450	10300	13300	16622
		Avg. vertical drop (feet; capacity wtd.)	3316	3461	3614	3471
Augusta	MT	Snowfall intensity (10-year avg.)			0.96	0.93
		Winter mean temp in C (10-year avg.)			-1.54	-1.69
		Total lift capacity (persons/hour)			2000	3000
		Avg. vertical drop (feet; capacity wtd.)			1330	1330
Bozeman Montana State Univ.	MT	Snowfall intensity (10-year avg.)		0.94	0.90	0.91
		Winter mean temp in C (10-year avg.)		-2.89	-1.95	-1.65
		Total lift capacity (persons/hour)		5100	5100	7300
		Avg. vertical drop (feet; capacity wtd.)		2000	2000	2000
Crater Lake NPS HQ	OR	Snowfall intensity (10-year avg.)	0.94	0.96	0.99	0.93
		Winter mean temp in C (10-year avg.)	-2.77	-3.24	-2.58	-2.46
		Total lift capacity (persons/hour)			7100	8400
		Avg. vertical drop (feet; capacity wtd.)			1525	1563
Dillon WMCE	MT	Snowfall intensity (10-year avg.)	0.85		0.89	0.86
		Winter mean temp in C (10-year avg.)	-2.16		-1.83	-1.73
		Total lift capacity (persons/hour)	550		1200	700
		Avg. vertical drop (feet; capacity wtd.)	1990		1720	2020
Grace	ID	Snowfall intensity (10-year avg.)			0.80	0.84
		Winter mean temp in C (10-year avg.)			-3.67	-2.41
		Total lift capacity (persons/hour)			3300	3300
		Avg. vertical drop (feet; capacity wtd.)			2000	2000

(continued)

Appendix Table 1 (con.)

Weather Station	State	Variable	1970	1980	1990	2000
Gunnison 3SW	CO	Snowfall intensity (10-year avg.)	1.00	0.99	0.99	0.98
		Winter mean temp in C (10-year avg.)	-9.16	-9.37	-7.13	-7.54
		Total lift capacity (persons/hour)	32590	34815	48735	53680
		Avg. vertical drop (feet; capacity wtd.)	3076	3096	3038	3523
Hollister	ID-NV	Snowfall intensity (10-year avg.)	0.68	0.68	0.71	0.67
		Winter mean temp in C (10-year avg.)	0.01	0.40	0.18	1.40
		Total lift capacity (persons/hour)	1600	3600	3120	3740
		Avg. vertical drop (feet; capacity wtd.)	900	956	892	901
Jemez Springs	NM	Snowfall intensity (10-year avg.)	0.73	0.75	0.71	0.64
		Winter mean temp in C (10-year avg.)	1.97	2.66	2.99	3.20
		Total lift capacity (persons/hour)	4400	4400	11000	14300
		Avg. vertical drop (feet; capacity wtd.)	1650	1650	1512	1464
Parowan Power Plant	UT	Snowfall intensity (10-year avg.)	0.83	0.90	0.93	0.89
		Winter mean temp in C (10-year avg.)	0.76	-0.44	0.08	1.19
		Total lift capacity (persons/hour)	2800	2800	11200	10500
		Avg. vertical drop (feet; capacity wtd.)	1200	1200	1200	1320
Red Lodge 1NW	MT-WY	Snowfall intensity (10-year avg.)	0.99	0.99	0.99	0.98
		Winter mean temp in C (10-year avg.)	-2.99	-3.75	-2.39	-2.82
		Total lift capacity (persons/hour)	4080	4500	6400	10690
		Avg. vertical drop (feet; capacity wtd.)	2016	2016	2016	2400
Red River	CO-NM	Snowfall intensity (10-year avg.)	0.99	0.99	0.97	0.98
		Winter mean temp in C (10-year avg.)	-5.47	-4.10	-3.28	-3.03
		Total lift capacity (persons/hour)	7000	20550	31740	35540
		Avg. vertical drop (feet; capacity wtd.)	2287	1991	1934	2109

(continued)

Appendix Table 1 (con.)

Weather Station	State	Variable	1970	1980	1990	2000
Snake Creek PH	ID-UT	Snowfall intensity (10-year avg.)	0.82	0.91	0.87	0.85
		Winter mean temp in C (10-year avg.)	-3.26	-3.80	-2.60	-1.78
		Total lift capacity (persons/hour)	50405	56780	95960	157337
		Avg. vertical drop (feet; capacity wtd.)	2267	2256	2348	2697
Tahoe City	CA-NV	Snowfall intensity (10-year avg.)	0.74	0.85	0.75	0.75
		Winter mean temp in C (10-year avg.)	-0.28	-0.82	0.34	0.30
		Total lift capacity (persons/hour)	77215	103645	178274	187804
		Avg. vertical drop (feet; capacity wtd.)	2427	2211	2329	2293
Telluride	CO	Snowfall intensity (10-year avg.)	0.98	0.98	0.98	0.99
		Winter mean temp in C (10-year avg.)	-4.66	-3.95	-2.85	-4.19
		Total lift capacity (persons/hour)	10600	10626	22700	28546
		Avg. vertical drop (feet; capacity wtd.)	2566	2510	2687	2624
Whiteriver 1SW	AZ	Snowfall intensity (10-year avg.)	0.55	0.49	0.52	0.50
		Winter mean temp in C (10-year avg.)	4.59	4.70	5.46	5.36
		Total lift capacity (persons/hour)	3500	3500	15000	16000
		Avg. vertical drop (feet; capacity wtd.)	1400	1440	1700	1800
Whistler	BC	Snowfall intensity (10-year avg.)			0.96	0.97
		Winter mean temp in C (10-year avg.)			-4.70	-4.96
		Total lift capacity (persons/hour)	10200	22895	20395	29895
		Avg. vertical drop (feet; capacity wtd.)	1440	4182	5006	5020
Fernie	BC	Snowfall intensity (10-year avg.)		0.78	0.71	0.66
		Winter mean temp in C (10-year avg.)		-4.61	-3.87	-3.31
		Total lift capacity (persons/hour)	3200	3200	7000	12300
		Avg. vertical drop (feet; capacity wtd.)	2100	2100	2100	2811

Appendix Table 2: Ski Areas by Weather Station

Weather Station	State	Station Altitude (feet)	Ski Areas	Avg. Base Elev. (feet; cap. wtd.)[1]
Alta 1NNW	ID-WY	6430	Grand Targhee, Jackson Hole Ski Area	6898
Augusta	MT	4070	Great Divide	5880
Bozeman Montana State Univ.	MT	4856	Bridger Bowl Ski Area	6100
Crater Lake NPS HQ	OR	6475	Willamette Pass Ski Area	5131
Dillon WMCE	MT	5228	Maverick Mountain Ski Area	7133
Grace	ID	5550	Pebble Creek Ski Area	6330
Gunnison 3SW	CO	7640	Aspen Highlands, Crested Butte, Monarch, Snowmass	8663
Hollister	ID-NV	4525	Magic Mountain Ski Area, Pomerelle Ski Area	7515
Jemez Springs	NM	6262	Pajarito Mountain Ski Area, Ski Santa Fe	10123
Parowan Power Plant	UT	6000	Brian Head Ski Area	9700
Red Lodge 1NW	MT-WY	5850	Red Lodge Mountain Ski Area	7304
Red River	CO-NM	8676	Angel Fire, Cuchara Valley, Red River, Sipapu, Taos	8865
Snake Creek PH	ID-UT	6010	Alta, Beaver Mountain, Brighton, Deer Valley, Park City Mountain Resort, Powder Mountain, Snow Basin, Snowbird, Solitude, Sundance, The Canyons	7311
Tahoe City[2]	CA-NV	6230	**North Tahoe (Washoe/Placer):** Alpine Meadows, Boreal Ridge, Granlibakken, Homewood, Incline, Mount Rose, Northstar-at-Tahoe, Soda Springs, Squaw Valley, Tahoe Donner	6686
	CA-NV	6230	**South Tahoe (Eldorado):** Heavenly, Kirkwood, Sierra at Tahoe.	6754
Telluride	CO	8672	Purgatory Ski Area, Telluride Ski Area	8789
Whiteriver 1SW	AZ	5120	Sunrise Peak Ski Area	9275
Whistler	BC	6020	Whistler	2536
Fernie	BC	4498	Fernie	3501

[1] Varies across decades in the Census tract data and annually in the market-specific sales data; values in table averaged across time periods.

[2] North and South Lake Tahoe share the same weather station but are analyzed separately in runs using the market-specific sales data.