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Forest pests and home values: The importance of accuracy in damage assessment and geocoding of properties

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ABSTRACT

We examine the impact of measurement errors in geocoding of property locations and in the assessment of Mountain Pine Beetle-induced tree damage within the proximity of a given residence on estimated losses in home values. For our sample of homes in the wildland-urban interface of the Colorado front range and using a novel matching estimator with Bayesian regression adjustment we find that both types of errors can lead to substantial biases in estimated losses. Our results confirm that the Forest Service's Aerial Detection Survey is generally too coarse to be informative for property valuation that depends on highly localized spatial data.

Introduction

The accuracy of address-based geocoding (ABG), as used in many geographic information system (GIS) software packages, has been subject to scrutiny in recent years by spatially focused disciplines such as geography and epidemiology. The emerging consensus in these areas is that ABG can lead to measurable positional errors, when compared to ground-truthing or interpretation via aerial imagery. Furthermore, these errors tend to be more pronounced in rural areas with lower population density.

For example, Cayo and Talbot (2003) examine 3000 addresses of residential properties in upstate New York and find a median error, in terms of the Euclidean distance between the true and the presumed location of the actual housing structure, of 38 meters (m), 78 m, and 201 m in urban, suburban, and rural settings, respectively. Schootman et al. (2007), in turn, report a mean error of 42 m and a median deviation of 31 m for 299 addresses in urban St. Louis, Missouri. Zandbergen (2007), considering over 100,000 addresses in urban/suburban Orange County, Florida, discovers a mean error of 66 m, with a standard deviation of over 430 m.

As mentioned in Burra et al. (2002), and discussed in detail in Zandbergen (2007) these positional errors can introduce serious bias into an underlying statistical analysis if they are systematic in nature, which is often the case in a given empirical application. For example, in Zandbergen (2007)'s context ABG generally "moves" residential locations closer to major traffic arteries than they really are. This leads to an over-estimation of the number of children exposed to traffic-related air pollution. Similar biases are reported in Harada and Shimada (2006) and in Hay et al. (2009) in the context of spatial densities and hot spots for crime locations.

Somewhat surprisingly given the recent proliferation in spatially explicit property valuation studies, the potential inaccuracy of ABG has largely been ignored in the applied economics literature. As we illustrate in this study, pinpointing the accurate location of a private residence can be very important if the effect of environmental changes in the immediate vicinity of a home constitutes the central focus of a given analysis.

In our application we consider tree mortality induced by the Mountain Pine Beetle (MPB) within a close perimeter of a given residence in the wildland-urban interface (WUI) of the Colorado front range. The MPB (*dentroctonus ponderosae*) is a native forest pest that has shown explosive population growth in recent years, with annual forest destruction rates in North America and Canada comparable to that of all wildfires combined (Carroll et al., 2004; Bentz et al., 2010; Sims et al., 2010; Man, 2012).

This poses a second spatially explicit risk of bias in estimated real estate capitalization rates if tree mortality itself is assessed with systematic error. Specifically, we examine the home-level accuracy of MPB damage as determined by the U.S. Forest Service's Aerial Detection Survey (ADS) relative to case-by-case photo-interpretation by a remote sensing expert.

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Using a novel econometric approach based on nonparametric matching with a Bayesian regression adjustment we find that both types of measurement error – imprecise geocoding and erroneous damage assessment – can lead to substantial biases in estimated losses of home values. Specifically, we show that both sources of imprecision can introduce sample attrition by entirely omitting actually affected homes from the analysis, and "swapping errors" by falsely classifying an impacted home as damage-free and vice versa, thus sorting them into the wrong bin for our matching model. This leads to damage estimates in terms of lost property values that can deviate from the expert benchmark by a very large margin.

The next section provides details on remote sensing strategies and econometric modeling. This is followed by an empirical section that discusses data and estimation results. Section four concludes.

Methodology

Remote sensing approaches

We consider four different combinations of remote sensing tools to determine the geocoded location of a property, as well as MPB damage in the proximity of a given home. Our flagship approach is based on visual inspection of both home location and surrounding tree health by a remote sensing expert. This provides benchmark estimates for MPB effects on home values that we assume are largely free of spatial measurement errors. The specific steps for this combination of expert photo-interpretation and visual geo-coding (*PI, vis*) are as follows:

1. Use 2011 maps of the National Agriculture Imagery Program (NAIP) with three color bands (red, green, blue) and a spatial resolution of one meter covering our housing market areas of interest.
2. Add preliminary geocodes for each property in our sales data using ESRI's "StreetMap premium for ArcGIS" package (2012, release 2), which is based on home addresses.
3. Use Google Earth (GE), Bing Maps (BM), and GIS imagery provided by local county assessor's offices to visually determine the correct location for a given address. Update geocodes as needed.[1]
4. Using ArcView, create a 100 m buffer around each corrected geocode.[2]
5. Visually inspect tree mortality within this buffer using a combination of all available imagery (NAIP, GE, BM, assessor maps) and declare a home as impacted (that is "treated") if *any* tree damage is detected, irrespective of intensity. We then assign a binary code of 0 (1) to damage-free (impacted) properties. This is essentially the same approach as taken by Backsen and Howell (2013), who use NAIP maps of the same type and resolution as ours to assess MPB damage in the Black Hills of South Dakota in 2010. Using ground-truthing to verify the reliability of this method, they find the photo-interpretation results to be 90–95% accurate using a binary "impacted / not impacted" rule such as ours.[3]

Our second remote sensing approach, labeled "*PI, ABG*" follows steps (1.) and (2.) from above, but skips the geocode verification process in step (3.). Instead, the 100 m buffers are drawn around the generic address-based geocodes provided by StreetMap. Tree mortality is then assessed via visual inspection within that buffer. Thus, this strategy exposes our home sales analysis to the risk of measurement error due to "misplaced properties," as discussed below in more detail.

The third approach, "*ADS, vis*" corrects generic geocodes via expert interpretation as in the benchmark strategy, but uses results from ADS fly-overs to mark a property as impacted (binary code of "1") or not (binary code of "0"). Specifically, a home is declared as affected by tree mortality if its (corrected) 100 meter buffer intersects with a damage polygon from any of the 2007–2010 ADS outings if the sale occurred before June 1, 2011, and any of the 2007–2011 ADS fly-overs if the home sold after May 31, 2011.[4] Since 2007 marks the year in which MPB infestations turned large-scale in the Colorado front range, and each annual fly-over only captures newly diseased trees, this strategy can be expected to cover all relevant cumulative damage surrounding a given property. However, due to the lack of precision of ADS polygons at this refined spatial level as noted in Johnson and Ross (2008), Backsen and Howell (2013) and confirmed by Cohen et al. (2016) this strategy poses the risk of measurement error for our home sales analysis due to erroneous damage assignments.[5]

The fourth and final remote sensing interpretation, labeled "*ADS, ABG*," deviates from the benchmark in both dimensions – geocoding and damage assessment. It combines generic StreetMap geocoding with ADS-informed damage assessment, and is such susceptible to both types of potential measurement errors.

Econometric approach

Our general estimation approach relies on matching techniques, that is a direct comparison of sales price between "treated" homes (with impacted trees within 100 m) and matched "control" homes (without impacted trees within the 100 m buffer). In theory, if a matched control home is identical in relevant observed and unobserved dimensions to a treated home except for tree damage, the difference in price must reflect the damage effect. In practice, controls will rarely be a perfect match for a given treated home. However, residual differences in observables can be controlled for with an auxiliary regression, as shown in Abadie and Imbens (2011) and explained below in more detail. In our case this auxiliary regression also controls for unobservable spatial and seasonal effects via inclusion of corresponding binary indicators.

Overall, this matching approach with regression correction is a robust alternative to a full-fledged hedonic regression model relating sales price to housing attributes and tree damage. Such hedonic

[1] Specifically, the location of a given home was viewed on the NAIP map simultaneously with BM or GE imagery. This minimizes the risk of residual georegistration errors imported via BM or GE, since NAIP has reliable image georegistration.

[2] The 100 m buffer was chosen based on Cohen et al. (2016) who do not detect any significant impacts on home values from MPB-induced tree mortality beyond the 100 m perimeter.

[3] We only consider imagery with known acquisition date. For each home sale, we use the image(s) closest to the sales date to determine tree damage.

[4] This strategy is based on in-person discussions with expert entomologists, according to whom new MPB damage should be clearly visible by June of a given year. Specifically, an attacked tree's needles turn red within the first year of infestation, and gray within three to four years. Either type of discoloration was considered evidence of impacted trees in our imagery-based damage assessment. In contrast, the ADS focuses on new damage (red needles) in a given fly-over year. In our analysis we use cumulative damages from all recent years of fly-overs to implicitly capture trees in all stages of discoloration.

[5] Johnson and Ross (2008), using ground-truthing for 233 sample plots in 2005 find that the ADS accurately characterized the presence of MPB damage in only 61% of cases. They consider these classification errors "to be excessive for use at fine spatial scales" (p. 216). Similarly, Backsen and Howell (2013) assess the accuracy of ADS to detect recent MPB damage at only 25% at the plot level, and at 65% at a larger, 300 foot buffer level. That notwithstanding, Price et al. (2010) use ADS results to determine the number of MPB-affected trees within different perimeters of homes sold between 1995 and 2006 in Grant County, CO, and generally find negative marginal per-tree effects on home values. In contrast, Cohen et al. (2016), for their sample of home sales between 1999 and 2011 in Larimer and Boulder County, CO, were not able to obtain meaningful results using ADS data. Instead, they settle on a repeat-sales analysis using host tree GIS layers to determine MPB-induced real estate effects.