Assessing Patterns in the Conversion of Rural Lands to Residential Use

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Introduction

Scientists, researchers, policy-makers, natural resource managers, producers, and individuals throughout the world are trying to better understand the causes and consequences of landscape change. Increasingly, the resilience of economic and ecologic systems is tied to landscape attributes affected by change (Turner et al. 2007). Economists continue to revisit questions related to the influences of public policies and other factors on landscape patterns and the efficiency of alternative landscapes at meeting economic and ecologic objectives (Irwin et al. 2009, Nelson et al. 2008). Spurred by advances in data resources, computing technologies, and statistical methods, economists have helped to provide a greater understanding of the causes and consequences of landscape change (Plantinga and Irwin 2006; Irwin et al. 2009).

This paper develops an empirical economic model to examine development patterns in Oregon, USA. Of particular interest are development patterns in rural areas where forestry and agriculture remain important economic activities, but may not always be consistent with the expectations of residents in newly developed areas. A unique panel dataset assembled by the Oregon Department of Forestry and USDA Forest Service, Pacific Northwest Station shapes our empirical analysis of development of non-federal land from 1973 to 2005. The dataset permits examination of the conversion of both farm and forest lands to residential use at the relatively fine spatial scales necessary for weighing the potential compatibilities and incompatibilities between commercial forestry and agricultural operations and existing development. Rather than describing development using discrete land use categories (e.g. forest, agriculture, and development) the data set records the actual number of structures (or buildings) at sampled locations across the landscape. This feature presents both particular challenges as well as opportunities that are relatively novel in econometric land use modeling research literature.

Drawing from theoretical and empirical modeling frameworks proposed by recent economic studies of land use change (Plantinga and Irwin 2006; Irwin et al. 2009), this paper combines building count data with data describing the relative returns to different land uses to estimate a reduced form model explaining the variation in changes in building counts. The structure of the dataset supports a variety of count-based modeling approaches to analyze patterns in the conversion of lands to developed use. We explore the utility of a hurdle modeling approach (Mullahy 1986, Winkelman 2000, Creel and Loomis 1990) to model both the passing of a development threshold (1 additional building) and the intensity of the conversion (counts of additional structures).

Conceptually, the hurdle approach is appealing for several reasons. First, the hurdle model offers the potential to improve our econometric estimated over those obtained from other count models (e.g. Poison, negative binomial) by better accounting for excess zeros which are a feature of our dataset owing to the presence of significant areas of Oregon that remain unpopulated by people. Second, the associated intuition of this threshold is appealing in the context of rural land-use change. While extensive research has been completed in regions undergoing dramatic residential growth, the appropriateness of these models for describing more remote areas experiencing limited growth or perhaps declines in developed lands is questionable. For a variety of reasons, including regulatory and infrastructure networks, distinctions in development processes are likely across the urban to rural continuum (Newburn and Berck 2006). Distinguishing the initiation of change in an area from the ultimate intensity of new building allows for consideration of research questions aimed at understanding whether or not the same set of factors influence the initiation of changes in development from the ultimate intensity of those changes in development.

Literature Review

Spurred by advances in data resources, computing technologies, and statistical methods, economists have helped to provide a greater understanding of the causes and consequences of landscape change (Plantinga and Irwin 2006). Spatial data and modeling tools are driving numerous theoretical and empirical advances in land-change science; these changes are occurring across numerous disciplines and are stimulating higher-quality cross-disciplinary research (Turner et al. 2007). Valuable insights about development processes and policy impacts are following from micro-level, economic studies of conversions to residential use (Towe et al. 2008, Cunningham 2007, Lewis and Plantinga 2007, Lynch and Liu 2007, Newburn and Berck 2006, Irwin et al. 2003). Buoyed by access to parcel-data, the aforementioned set of studies are able to control elegantly for ownership and public policy effects, striving to identify the specific impacts of various factors on the conversion process. Collectively, these studies demonstrate the potential of economic theory and intuition to explain patterns in the conversion of undeveloped lands to residential use and intimate patterns of new residential development are influenced strongly by variation in the expected returns to residential use.

Lacking access to parcel data, we make use of plot-based data describing the intensity of development as numbers of structures within a defined area over space and time and employ an alternative empirical modeling strategy to that used in other studies. Accordingly, our data and analysis are constrained by a lack of knowledge of ownership boundaries, and are thus more similar to those advanced by researchers using aggregate housing data (e.g., county-scale), data based on census geography (Theobald 2005) and remotely-sensed land-cover information (Turner et al. 1996) to describe land change. Previous work based on the same data employed here (Kline et al. 2003, Kline 2005, Kline et al. 2007) focused on areas with positive changes in building counts and often excluded information on plots with zero change. This analysis incorporates plots with zero change by using a hurdle modeling approach to describe change and therefore our sample extends to a broader range of the urban-rural continuum.

We draw insights from previous studies of rural land-use change in Oregon based on these same data and other studies completed in this region (Cho et al., 2003, Nelson et al. 2008). Previous research of building changes in western (Kline et al. 2003, Kline 2005, and Kline et al. 2007) and Eastern (Kline et al. 2006) Oregon identified several trends in associations between building activity and land features. Higher changes in construction activity—measured in terms of increasing structure counts—were correlated with higher base building counts, greater access to market centers, and lower slope and elevation values. Oregon's Statewide Planning Goals and Guidelines, which were made operational in 1975 and adopted in subsequent years by communities, seemed to be steering changes to areas zoned for developed uses (i.e., urban areas within urban growth boundaries and rural areas zoned for developed use) but increases in building counts were also observed in areas zoned for agricultural, forest, and range uses.

Theoretical Model

Micro-economic theoretical models of conversions to developed uses start with decisions of individual landowners. A convenient representation of such decisions (Irwin and Bockstael 2002; Irwin et al. 2003) considers a profit maximizing landowner who owns an undeveloped land parcel and makes a discrete choice in every time period regarding conversion to developed use. The individual landowner chooses to either convert the parcel to a developed use or maintain the parcel in an undeveloped use. Conditional on the land parcel being undeveloped in the initial period, the landowner's decision is a binary discrete choice of converting the parcel to developed use or maintaining the parcel in an undeveloped use, such that the present discounted sum of all future expected returns from the land is maximized.

The landowner's decision becomes a dynamic optimization problem. Conversions to developed uses are expected when the expected present discounted value of the parcel in developed use net of conversion costs and opportunity costs is maximized over an infinite time horizon. Under several (strong) assumptions about the dynamics of growth pressures and conversion costs, Irwin and Bockstael (2002) demonstrate that the resulting optimal conversion rule posits that parcel j will be converted in the first period in which the following conditions hold:

$$V_{jdT|u} - \sum_{t=0}^{\infty} V_{jUT+1}\, \delta^{T=t} > 0;\ V_{jdT|u} - V_{juT|u} > \delta(V_{jdT+1|u})$$

where V_{jrt} represents the net expected return from converting parcel j (which is currently in undeveloped land use u) to developed use d at time t and δ is the discount rate. The first condition intimates that parcel j will be converted from use u to use d in time period T, which is the first time period in which the net returns from this conversion are greater than the present value of the foregone returns associated with land use u over the infinite time horizon. The second condition suggests that parcel j will be converted in period T only if the expected returns from converting net the one period opportunity cost of conversion is greater than the discounted net returns from converting in period T+1.

Employing these two conditions as the basis of an empirical model, researchers let the net expected returns from developing parcel j, V_{jdT}, be a function of a variety of parcel-level features, including location, biophysical, and neighborhood attributes. Recognizing uncertainty and imperfect/incomplete knowledge of these net returns and assuming that that the second condition associated with the optimal conversion rule above is the one that is binding, the landowner's binary conversion rule can be rewritten in probabilistic terms as:

$$P_{jdT} = P(V_{jdT|u} - V_{juT|u} + \varepsilon_{jT} > \delta V_{jdT+1|u} + \varepsilon_{jT+1} \quad)$$

where the ε terms represent the unobserved components associated with parcel j in time periods T and T+1 and $P_{jdT|u}$ is the probability that parcel j is converted from undeveloped use, u, to developed use, d, in time period T. If landowners' expectations over the net returns in period T+1 are myopic and terms are re-arranged to isolate the unobserved components, then the binary probabilistic conversion rule can be expressed as:

$$P_{jdT} = P\big((\varepsilon_{jT+1} - \varepsilon_{jT}\big) < (1-\delta)V_{jdT|u} - V_{juT|u} \quad).$$

Intuitively, land parcel j is more likely to be converted in period T the greater the wedge between the net return from developing in T and the net return from maintaining land in an undeveloped state.

Without land parcel boundaries, we employ a different decision and organizational unit of analysis. Assuming individual landowner decisions will follow this general pattern of net return maximization, we expect the land attributes that influence the return to conversions to also explain variation in development activity within our units of observation - 80 acre buffers.

Data

This paper develops an empirical economic model to examine development in Oregon, USA. A unique panel dataset assembled by the Oregon Department of Forestry and USDA Forest Service, Pacific Northwest Station shapes our empirical analysis. The data track development of non-federal land around sample points over 5 time periods or 4 changes in time (1973 to 1982; 1982 to 1994; 1994 to 2000; and 2000 to 2005). Structure (or building) counts in 80 acre buffers (centered on individual points) are recorded for 37,003 points and stored in a spatial database. The sample points monitored to create these data are those also used in the periodic forest inventories conducted by the USDA Forest Service's Forest Inventory Analysis (FIA) Program. An advantage of the building count data over other land use data sources is their ability to directly link building counts with other data collected for sample points by the FIA Program. This feature enables empirical analysis of relationships between building counts and, for example, the prevalence of particular private forest management activities such as timber harvesting, thinning, and tree planting. The combination of data sets can be used to not only examine the development process, but also examine what, if any, influence that process might have on private forestry.

While the points are distributed extensively over space (see Figure 1), they do not represent a random sample of locations in Oregon. Accordingly, we are tracking change on only a subset of Oregon's landscape. Instead, they are better suited to describe changes in rural, forest communities. The dataset permits examination of the conversion of both farm and forest lands to developed use at the relatively fine spatial scales necessary for weighing the potential compatibilities and incompatibilities between commercial forestry and agricultural operations and existing development. In this paper, our focus is changes over time. As a first pass, we independently explore changes in structure counts from 1973 to 1982, 1982 to 1994, 1994 to 2000, and 2000 to 2005. The dependent variable is an integer count of the change in number of buildings constructed in a set time period within the 80 acre point-centered buffer. For example, CH7305 represents change in buildings from 1973 to 2005. Variables describing the baseline counts of buildings by buffer are recorded for 1973 (C73), 1982 (C82), 1994 (C94), 2000 (C00), and 2005 (C05).

The set of independent variables includes measures of distance to employment centers (DBCITY), established residential settlements (DNPLACE), transportation infrastructure (DHWAY), the Oregon Coast (DCOAST), Native Reservation Lands (DNATIVE), and Federal land holdings (DFLAND). Recognized as positive contributors to returns in residential use, a negative relationship is expected between building growth and distance to urban employment centers (DBCITY), highways (DHWAY), and US Census Bureau designated places (DNPLACE). All else equal, proximity to Oregon's stunning coastline is also expected to increase the return to housing, resulting in an expected inverse relationship between distance to the Oregon coast (DCOAST) and building growth. Our priors are less clear about the relationship between building growth and proximity to Native Reservation (DNATIVE) and Federal land holdings (DFLAND).

We employ categorical variables describing elevation and slope to proxy for land suitability for development and costs of converting from agricultural and forested use to developed use. All else equal, lands with higher slope values (SLOPE_HIGH and SLOPE_MED relative to SLOPE_LOW) are expected to be more costly to convert and therefore are expected to be negatively associated with building counts. Likewise, all else equal, lands with higher elevation values (ELEV_HIGH and ELEV_MED relative to ELEV_LOW) are expected to be more costly to convert and therefore are expected to be negatively associated with building counts. Because lands located at higher elevations may also have better views and increase returns to residential use, our priors are more mixed regarding the influence of elevation.

A final set of variables address Oregon's progressive land use laws. We control for variation in the amount of time these laws were in place by creating locally based measures of zoning changes using community-specific acknowledgement dates of policy approvals by Oregon's Department of Land Conservation and Development Commission (DLCD). The resulting estimates (PLAW) capture variation in the adoption of these zoning and land use regulations over space and time. Descriptions of zoning are done at two spatial scales and distinguish lands zoned as developed (urban and rural), agriculture, and forest lands. One set of measures characterize the zoning category of the sample point used to define the location of the FIA plot (ZDEV (ZURB AND ZRUR), ZFARM, ZFOR); the second set describes the percentage of the 80 acre buffer falling into the different categories (PZDEV, PZFARM, PZFOR). All else equal, we expect more additions to the stock of buildings in areas zoned for development. Interaction terms, created by multiplying PLAW and the relevant zoning variables (ZDEV, ZFARM, ZFOR), capture potential differences in these regulatory changes across different land categories. We employ an indicator variable to distinguish Eastern and Western Oregon (WEST).

Tables 1 and 2 present respectively variable definitions and descriptive statistics.

Empirical Model

The empirical analysis described in this paper summarizes the first step in a multi-step analysis of these Oregon building counts data. Specifically, this paper provides an overview of a basic extension of previous work by Kline et al. 2003, Kline 2005, Kline et al. 2006, Kline et al. 2007. Using a similar set of independent variables, we develop models of changes in building counts employing a hurdle modeling approach. Drawing insights from the theoretical model developed earlier, the change in building counts is modeled as function of independent variables capturing variation in the net returns from additional building activity. As demonstrated in Table 2 and Figure 2, our changes in building count data include many zero values. The distributions of our dependent variables intimate the data are overdispersed relative to the Poisson distribution, a standard distribution assumed to model count data. We opt to employ a hurdle model (Mullahy 1986, Winkelmann 2000, Creel and Loomis 1990) in response to these excess zero values.

The hurdle model can be interpreted as two-part model, where the first part involves modeling of a binary outcome and the second is a truncated count model (Cameron and Trivedi 1998). In the context of this analysis, the first part describes the probability of a single additional building being constructed in the 80 acre buffer. This can be thought of as a development threshold. In contrast, the second part models variation in the (positive) building counts. Hurdle models are finite mixture models created by integrating the zeroes produced by one density and positive values produced by a second zero-truncated density:

$$P[y = 0] = f_1(0);$$

$$P[y = j] = \frac{1 - f_1\ (0)}{1 - f_2\ (0)} f_2\ (y), j > 0;$$

where $f_1(0)$ is the probability of a zero outcome (no change in buildings; y=0) and f2(y) is the probability of positive amounts of new buildings conditioned on the outcome being greater than zero. Specification of hurdle models allows for flexibility in terms of selecting the binary and count regression models. We experimented with a variety of combinations for the binomial and truncated count models. The results summarized in the next section combine a binary logit model and Poisson truncated count model.

Results

We estimate models of changes in building counts over four time frames: 1973 to 1982; 1982 to 1994; 1994 to 2000; and 2000 to 2005[1]. The two-part hurdle models integrate a binary logit model explaining whether or not an additional structure was built in the buffer and a poisson count model of the number of additional buildings. We began by estimating conventional poisson and negative binomial models and conducting formal tests of overdispersion (Cameron and Trivedi 1998) (Table 3). In all instances, statistical tests suggested overdispersion and supported use of a negative binomial model over a

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[1] We recognize the opportunities presented by the panel nature of these data. Some previous work by Kline has exploited the panel nature of these count data. We are constrained by our lack of information about land attributes and other covariates that have changed over time.

poisson model (Table 3). Next, we estimated the hurdle models including all independent variables in both the hurdle and event/count stages of the model. The set of independent variables changes slightly over time because of the timing of zoning changes. Communities throughout Oregon were required to change their zoning and land use regulations to meet the State's guidelines. Acknowledgement dates, which document when OR DLCD approved of these changes, range from 1976 to 1986. Accordingly, the variable measuring the proportion of time period meeting the DLCD laws (PLAW) is equal to 1 for all areas after 1986 and therefore is not included in the specifications modeling changes after 1994.

Results by time periods are presented in Tables 4-7. The parameter estimates displayed in the results tables can be interpreted as binary logit and poisson count parameter estimates respectively. Because of assumed nonlinear relationships, these parameter estimates are not marginal effects.

Reviewing the count results describing the intensity of changes in buildings, there are interesting consistencies and differences over time. A subset of trends remain constant in all four time periods - additional buildings are negatively associated with distance to a major city (DBCITY) (Portland, Eugene, Salem) and distance to a major highway (DHWAY) and positively associated with the number of buildings at the outset of the time period (LC), less steeply sloped lands (SLOW, SMED), and zoning encouraging development (ZDEV). Mixed findings are revealed for several other independent variables. For example, counts of housing are positively associated with the Western indicator variable in the early time periods (1973 - 1994) and negatively associated with this variable in the later stages. Generally, these findings are consistent with some of the broad trends documented in previous analyses of these data using conventional count models (see Table 3 for the negative binomial results).

Additional insights are gleaned from comparing the influence of variables in the hurdle and count models across and within time periods. We see greater consistency in the signs of relationships in the hurdle models over time. Crossing the development threshold is more likely in areas with higher numbers of building at the outset (LC), low and medium slope values (SLOW, SMED), low and medium elevation values (ELOW, EMED) and less likely in areas located further from Oregon's coast (DCOAST), highways (DHWAY), and federal land (DFLAND). Assessment of the impact of Oregon's land use regulations is complicated by the interaction terms in the first two specifications. In the first time period (1973 to 1982), during which not all communities had adopted the zoning changes, crossing this threshold is positively associated with a higher proportion of time meeting the zoning changes and crossings are more likely in developed and agriculturally zoned areas than those zoned for forestry. A similar ordering of associations with zoning is found in the second time period (1982 to 1994). Generalizing the relationship with PLAW in this second time period is made difficult by the mixed signs of the relevant parameter estimates. For the later periods (1994 to 2000; 2000 to 2005), lands zoned for development (ZDEV) and agriculture (ZFARM) are more likely to cross the building threshold than those zoned as forestlands (ZFOR).

Additional insights can be gleaned by two comparisons of results. Of some interest is the comparison and contrast of the roles of independent variables in the hurdle and count stages (see Table 8 for a summary comparison). A second valuable comparison is the results summarized in Table 3 versus the truncated count regression results summarized in Tables 4-7. These assessments will guide our subsequent modeling steps in characterizing patterns in the conversion of rural lands to residential use.

Conclusions

Our empirical research is partially motivated to support state and federal policy and management decisions that require forecasts of future housing levels and their location relative to productive forest and agricultural lands (e.g., Stein et al. 2005; Stein et al. 2007). Within Oregon, information about land use trends and future forest land development are of particular interest in devising policy and management strategies to mitigate climate change by sequestering carbon, and enhance the provision of ecosystem services, among other uses. The research project supporting this preliminary modeling is designed to inform Oregon policy-makers of patterns in the conversion of rural lands to residential use and help advance discussions among scientists of different disciplines (e.g. ecology, economics, hydrology, sociology) who are engaged in multidisciplinary research efforts to examine and model landscape change. As we explore the utility of various modeling approaches, we are learning lessons about the challenges and opportunities of working with different data sources and modeling approaches. The lessons learned from our research in Oregon likely will be transferable to other communities and regions.

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Figures and Tables

Figure 1. Sample Point Locations (Oregon, N=37,003)

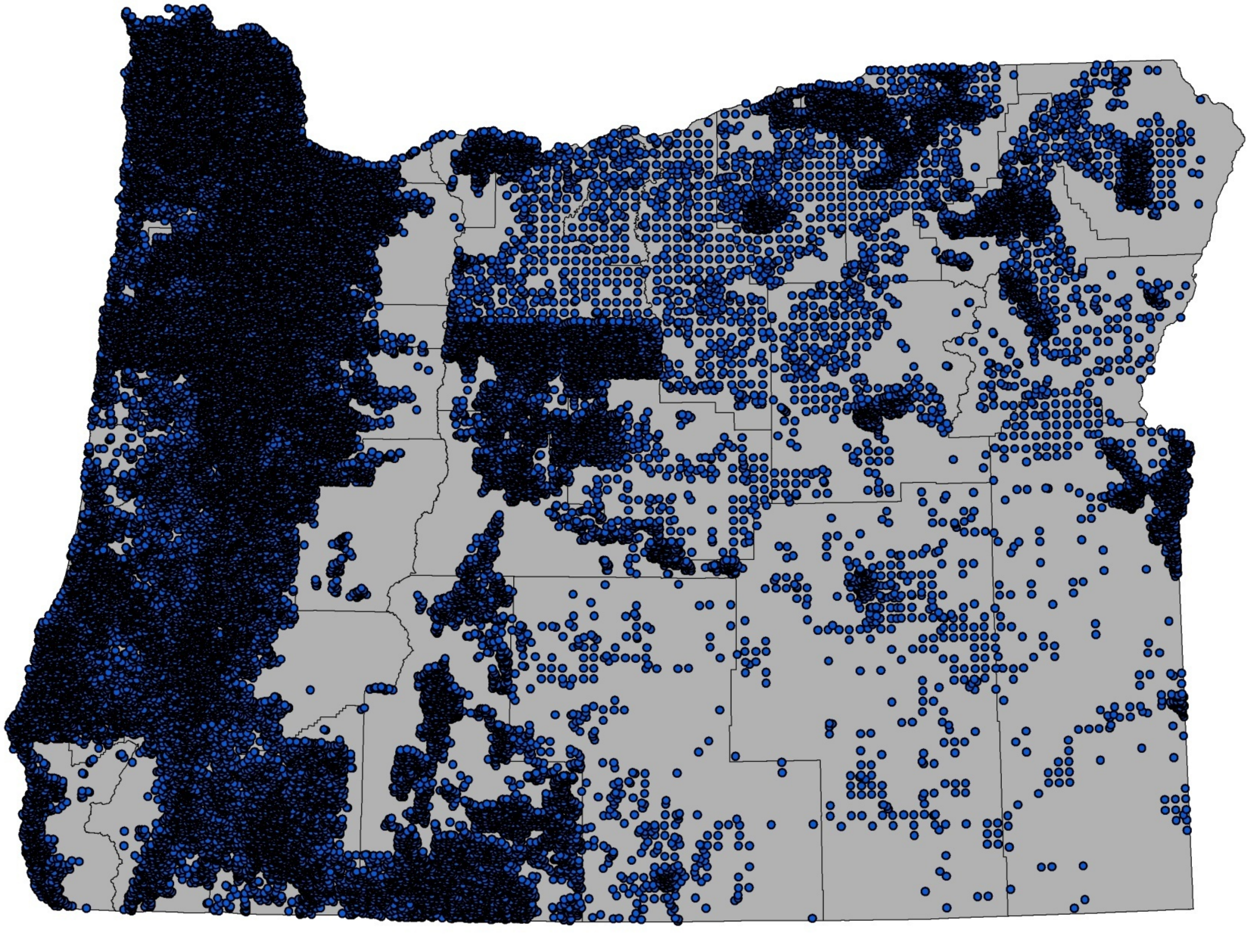

Figure 2. Change in Counts

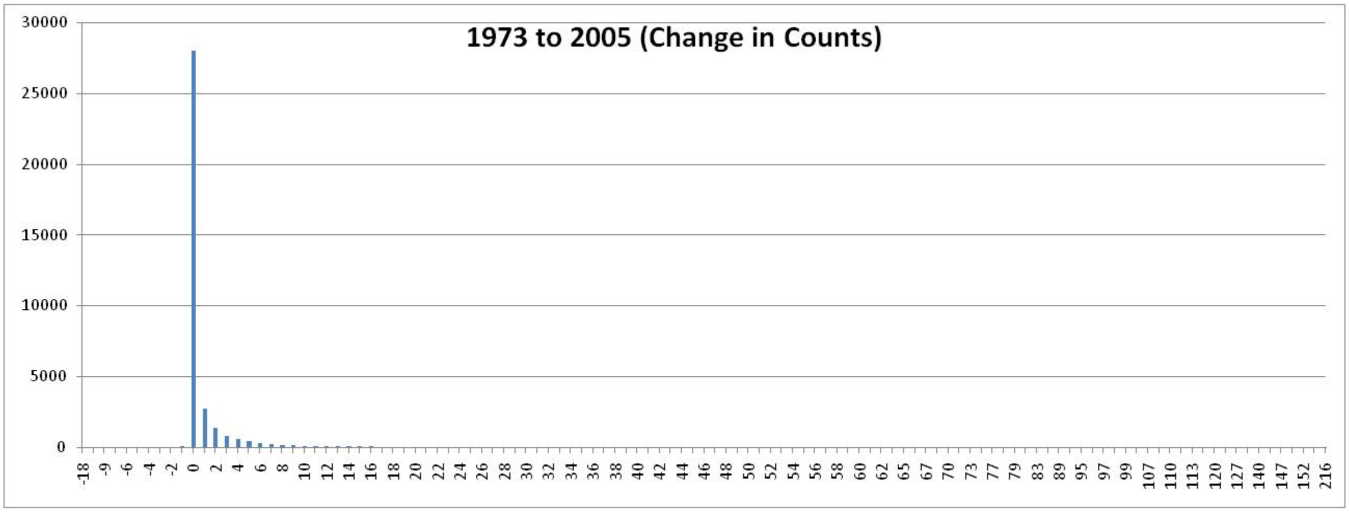

Table 1. Variable Names and Descriptions

Variable	Explanation	Units
CH7305	Change in housing count (1973 to 2005)	count
CH7382	Change in housing count (1973 to 1982)	count
CH8294	Change in housing count (1982 to 1994)	count
CH9400	Change in housing count (1994 to 2000)	count
CH9405	Change in housing count (1994 to 2005)	count
LC1973	1973 Housing count within 80 acre buffer	ln(count)
LC1982	1982 Housing count within 80 acre buffer	ln(count)
LC1994	1994 Housing count within 80 acre buffer	ln(count)
LC2000	2000 Housing count within 80 acre buffer	ln(count)
LC2005	2005 Housing count within 80 acre buffer	ln(count)
dbcity	Minimum distance to Eugene, Salem, Portland	000 km
dcoast	Distance to the Oregon Coast	000 km
deug	Distance to Eugene	000 km
dfland	Distand to nearest Federal Land	000 km
dhway	Distance to nearest highway	000 km
dnative	Distance to nearest Native Reservation Land	000 km
dnplace	Distance to nearest Census defined-place	000 km
dport	Distance to Portland	000 km
dsalem	Distance to Salem	000 km
dugb	Distance to nearest Urban Growth Boundary	000 km
elev_high	High elevation (> 5000 feet)	0/1
elev_low	Low elevation (0 - 3500 feet)	0/1
elev_med	Medium elevation (3501-5000 feet)	0/1
slope_high	Steep slope (above 40%)	0/1
slope_low	Small slope (0 - 25 %)	0/1
slope_med	Medium slope (26-40%)	0/1
ghu_00	Housing based gravity index (2000)	index
ghu_90	Housing based gravity index (1990)	index
gpop_00	Population based gravity index (2000)	index
gpop_90	Population based gravity index (1990)	index
plaw_0005	Proportion of time period meeting DLCD land use laws	proportion
plaw_7382	Proportion of time period meeting DLCD land use laws	proportion
plaw_8294	Proportion of time period meeting DLCD land use laws	proportion
plaw_9400	Proportion of time period meeting DLCD land use laws	proportion
pzdev	Percent of buffer zoned developed	percentage
pzfarm	Percent of buffer zoned as agricultural land	percentage

Table 1. Variable Names and Descriptions

Variable	Explanation	Units
pzfor	Percent of buffer zoned as forest land	percentage
zdev	Point falls in land zoned as developed	0/1
zfarm	Point falls in land zoned as agriculture	0/1
zfor	Point falls in land zoned as forest land	0/1
zrur	Point falls in land zoned as rural developed	0/1
zurb	Point falls in land zoned as urban developed	0/1
west	Western Oregon as defined by ODF	0/1

Table 2. Descriptive Statistics

Variable	Mean	Std. Dev.	Minimum	Maximum	N
CH7305	1.111	5.346	0.000	216.000	35719
CH7382	0.420	2.772	0.000	224.000	36026
CH8294	0.344	2.381	0.000	119.000	35850
CH9400	0.250	2.509	0.000	214.000	35867
CH0005	0.210	2.170	0.000	112.000	35824
C73	1.104	4.427	0.000	171.000	36189
C82	1.431	5.404	0.000	257.000	36026
C94	1.711	6.033	0.000	171.000	35945
C00	1.913	6.906	0.000	216.000	35877
C05	2.054	7.388	0.000	216.000	35825
LC73	0.234	0.618	0.000	5.142	36189
LC82	0.293	0.702	0.000	5.549	36026
LC94	0.334	0.762	0.000	5.142	35945
LC00	0.358	0.797	0.000	5.375	35877
LC05	0.380	0.817	0.000	5.375	35825
DBCITY	1.892	1.271	0.006	6.019	37003
DCOAST	1.603	1.490	0.000	6.276	37003
DEUG	1934.040	1204.280	8.874	5809.570	37003
DFLAND	54.776	65.472	0.000	361.617	37003
DHWAY	0.063	0.064	0.000	0.670	37003
DNATIV	702.478	411.792	0.000	2250.490	37003
DPLACE	0.155	0.139	0.001	1.588	37003
DPORT	2.300	1.308	0.008	6.144	37003
DSALEM	2.004	1.276	0.006	6.019	37003
DUGB	143.204	149.969	0.000	1573.190	37003
GPOP90	0.121	0.776	0.000	51.532	37003
GPOP00	0.157	0.967	0.000	62.408	37003
ELOW	0.783	0.412	0.000	1.000	37003
EMED	0.186	0.389	0.000	1.000	37003
EHIGH	0.031	0.174	0.000	1.000	37003
SLOW	0.740	0.439	0.000	1.000	37003
SMED	0.148	0.355	0.000	1.000	37003
SHIGH	0.112	0.316	0.000	1.000	37003
PL7305	0.616	0.267	0.315	1.000	35772
PL7382	0.329	0.409	0.000	1.000	37003
PL8294	0.499	0.427	0.000	1.000	37003
PL9400	1.000	0.000	1.000	1.000	37003
PZDEV	11.242	29.007	0.000	100.000	36999
PZFARM	37.578	46.279	0.000	100.000	36999

Table 2. Descriptive Statistics

Variable	Mean	Std. Dev.	Minimum	Maximum	N
PZFOR	49.722	48.148	0.000	100.000	36999
ZFARM	0.376	0.484	0.000	1.000	37003
ZDEV	0.114	0.318	0.000	1.000	37003
ZFOR	0.495	0.500	0.000	1.000	37003
WEST	0.646	0.478	0.000	1.000	37003

Table 3. Negative Binomial Models of Changes in Structure Counts

	1973 - 1982		1982 - 1994		1994 - 2000		2000 - 2005	
Variable	**Parameter**	**b/Std. Error**	**Parameter**	**b/Std. Error**	**Parameter**	**b/Std. Error**	**Parameter**	**b/Std. Error**
Constant	-3.241	-29.592	-4.769	-16.162	-4.024	-14.266	-3.603	-11.661
DBCITY	0.001	0.044	0.016	0.780	-0.213	-9.807	-0.062	-2.351
LC73	0.996	36.962	1.119	49.846	1.082	42.510	0.867	42.304
SLOW	1.009	16.508	1.221	15.578	1.039	10.586	0.723	7.269
SMED	0.489	6.833	0.711	7.675	0.884	8.189	0.534	4.673
ELOW	0.249	4.581	1.442	5.455	1.412	5.779	1.007	3.753
EMED	0.016	0.028	1.202	4.518	1.150	4.580	1.023	3.795
PLAW	0.805	18.037	1.809	2.975				
ZFARM	2.022	29.121	0.776	13.833	0.399	8.524	0.515	9.441
ZDEV	0.076	0.131	1.852	30.857	1.706	32.287	1.542	24.406
PLAW*ZFARM	0.279	0.473	-2.226	-3.621				
PLAW*ZDEV	0.567	0.974	-1.886	-3.082				
PLAW*ZFOR	0.609	8.274	-1.708	-2.850				
WEST	-0.114	-4.822	0.286	3.159	-0.629	-7.846	-0.027	-0.294
DCOAST	-11.729	-32.499	-0.122	-3.967	-0.089	-2.709	-0.296	-6.291
DHWAY	-0.003	-11.739	-8.423	-19.608	-10.742	-19.204	-8.672	-15.918
DFLAND	4.813	43.308	-0.004	-11.447	-0.004	-10.743	-0.004	-8.724
ALPHA	-3.241	-29.592	5.042	41.717	5.199	37.417	6.325	39.263
lnL	-18,108.80		-15,261.59		-11,486.28		-11,559.01	
AIC	1.0097		0.8562		0.6415		0.6471	
BIC	1.0137		0.8605		0.6448		0.6504	
N	35,904		35,692		35,854		35,769	
g=mu(i)	9.020		5.699		2.577		2.380	
g=mu(i)^2	13.615		6.288		3.007		2.640	

Table 4. Poisson Hurdle Model of Changes in Structure Counts (1973 - 1982)

	Binary Hurdle (Change > 0)				**Count**			
Variable	**Parameter**	**Std. Error**	**b/Std. Error**	**P[|Z|>z]**	**Parameter**	**Std. Error**	**b/Std. Error**	**P[|Z|>z]**
Constant	-4.035	0.168	-24.082	0.000	0.875	0.047	18.603	0.000
DBCITY	0.049	0.023	2.184	0.029	-0.107	0.004	-26.286	0.000
LC73	0.947	0.023	40.860	0.000	0.381	0.002	192.347	0.000
SLOW	1.087	0.107	10.127	0.000	-0.084	0.041	-2.053	0.040
SMED	0.600	0.122	4.935	0.000	-0.025	0.043	-0.573	0.567
ELOW	0.172	0.079	2.173	0.030	-0.161	0.014	-11.145	0.000
EMED								
PLAW	0.052	0.821	0.064	0.949	-0.501	1.395	-0.359	0.720
ZFARM	0.788	0.055	14.381	0.000	-0.075	0.017	-4.373	0.000
ZDEV	1.917	0.071	26.872	0.000	0.517	0.015	34.437	0.000
PLAW*ZFARM	0.154	0.823	0.188	0.851	0.485	1.395	0.347	0.728
PLAW*ZDEV	0.002	0.827	0.002	0.998	0.823	1.395	0.590	0.555
PLAW*ZFOR	0.576	0.823	0.700	0.484	0.385	1.396	0.276	0.783
WEST	0.753	0.102	7.407	0.000	0.005	0.018	0.302	0.763
DCOAST	-0.124	0.030	-4.091	0.000	0.021	0.006	3.731	0.000
DHWAY	-9.722	0.528	-18.427	0.000	-4.434	0.181	-24.549	0.000
DFLAND	-0.003	0.000	-8.405	0.000	0.001	.495008D-04	22.478	0.000
lnL	-22,047.83							
AIC	1.2299							
BIC	1.2375							
N	35,904							

Table 5. Poisson Hurdle Model of Changes in Structure Counts (1982 -1994)

	Binary Hurdle (Change > 0)				Count			
Variable	Parameter	Std. Error	b/Std. Error	P[|Z|>z]	Parameter	Std. Error	b/Std. Error	P[|Z|>z]
Constant	-5.827	0.407	-14.325	0.000	0.310	0.770	0.403	0.687
DBCITY	0.189	0.025	7.466	0.000	-0.130	0.004	-35.391	0.000
LC82	1.061	0.023	46.715	0.000	0.394	0.002	169.197	0.000
SLOW	1.253	0.124	10.144	0.000	0.208	0.058	3.554	0.000
SMED	0.816	0.139	5.877	0.000	0.228	0.061	3.753	0.000
ELOW	1.606	0.362	4.443	0.000	0.074	0.768	0.096	0.923
EMED	1.314	0.362	3.627	0.000	0.119	0.768	0.155	0.876
PLAW	1.178	0.668	1.764	0.078	1.055	0.221	4.779	0.000
ZFARM	0.844	0.071	11.844	0.000	-0.114	0.021	-5.290	0.000
ZDEV	1.384	0.091	15.142	0.000	0.375	0.021	17.711	0.000
PLAW*ZFARM	-1.382	0.674	-2.052	0.040	-1.321	0.222	-5.952	0.000
PLAW*ZDEV	-0.970	0.679	-1.428	0.153	-1.036	0.221	-4.689	0.000
PLAW*ZFOR	-0.786	0.657	-1.195	0.232	-1.592	0.212	-7.494	0.000
WEST	0.313	0.111	2.820	0.005	0.183	0.022	8.409	0.000
DCOAST	-0.217	0.033	-6.500	0.000	0.059	0.008	6.956	0.000
DHWAY	-6.291	0.561	-11.217	0.000	-3.768	0.203	-18.535	0.000
DFLAND	-0.004	0.000	-9.401	0.000	-.739013D-04	.543889D-04	-1.359	0.174
lnL	-18,458.92							
AIC	1.0363							
BIC	1.0443							
N	35,692							

Table 6. Poisson Hurdle Model of Changes in Structure Counts (1994-2000)

	Binary Hurdle (Change > 0)				Count			
Variable	Parameter	Std. Error	b/Std. Error	P[|Z|>z]	Parameter	Std. Error	b/Std. Error	P[|Z|>z]
Constant	-4.688	0.545	-8.608	0.000	0.590	0.476	1.238	0.216
DBCITY	-0.145	0.027	-5.421	0.000	-0.263	0.006	-45.023	0.000
LC94	1.067	0.024	44.653	0.000	0.344	0.003	123.274	0.000
SLOW	0.939	0.150	6.278	0.000	0.674	0.093	7.279	0.000
SMED	0.506	0.171	2.958	0.003	1.126	0.093	12.122	0.000
ELOW	1.867	0.507	3.680	0.000	-0.880	0.466	-1.888	0.059
EMED	1.693	0.509	3.326	0.001	-0.840	0.467	-1.800	0.072
ZFARM	0.363	0.061	5.964	0.000	-0.050	0.032	-1.568	0.117
ZDEV	1.026	0.069	14.816	0.000	0.869	0.030	28.819	0.000
WEST	-0.864	0.109	-7.957	0.000	-0.181	0.021	-8.482	0.000
DCOAST	-0.172	0.037	-4.587	0.000	0.100	0.009	11.322	0.000
DHWAY	-8.041	0.666	-12.074	0.000	-4.570	0.247	-18.534	0.000
DFLAND	-0.003	0.000	-6.891	0.000	0.001	.578791D-04	12.527	0.000
lnL	-15,500.15							
AIC	0.8660							
BIC	0.8722							
N	35,854							

Table 7. Poisson Hurdle Model of Changes in Structure Counts (2000 - 2005)

	Binary Hurdle (Change > 0)				**Count**			
Variable	**Parameter**	**Std. Error**	**b/Std. Error**	**P[|Z|>z]**	**Parameter**	**Std. Error**	**b/Std. Error**	**P[|Z|>z]**
Constant	-4.309	0.414	-10.399	0.000	1.317	0.487	2.703	0.007
DBCITY	-0.039	0.024	-1.582	0.114	-0.296	0.008	-36.775	0.000
LC00	0.569	0.022	25.495	0.000	0.570	0.003	219.448	0.000
SLOW	0.688	0.104	6.622	0.000	0.064	0.062	1.025	0.305
SMED	0.500	0.118	4.235	0.000	0.173	0.067	2.592	0.010
ELOW	1.146	0.388	2.955	0.003	-0.509	0.480	-1.059	0.290
EMED	1.138	0.389	2.925	0.003	-0.273	0.480	-0.569	0.570
ZFARM	0.515	0.052	9.834	0.000	0.106	0.034	3.162	0.002
ZDEV	0.949	0.068	13.900	0.000	0.760	0.033	22.913	0.000
WEST	0.370	0.109	3.388	0.001	-1.274	0.023	-55.244	0.000
DCOAST	-0.187	0.042	-4.483	0.000	-0.186	0.012	-15.465	0.000
DHWAY	-7.751	0.574	-13.506	0.000	-2.388	0.211	-11.329	0.000
DFLAND	-0.004	0.000	-9.776	0.000	0.002	.828064D-04	27.299	0.000
lnL	-19,468.50							
AIC	1.0893							
BIC	1.0924							
N	35,769							

Table 8. Comparing Significant ($p < 0.05$) Parameter Estimates

	Hurdle				Count			
	7382	8294	9400	0005	7382	8294	9400	0005
Constant	-	-	-	-	+	+		+
DBCITY	+	+	-		-	-	-	-
LC	+	+	+	+	+	+	+	+
SLOW	+	+	+	+	-	+	+	
SMED	+	+	+	+		+	+	+
ELOW	+	+	+	+	-		-	
EMED		+	+	+				
PLAW	+					+		
ZFARM	+	+	+	+	-	-		+
ZDEV	+	+	+	+	+	+	+	+
PLAW*ZFARM		-				-		
PLAW*ZDEV						-		
PLAW*ZFOR						-		
WEST	+	+	-	+		+	-	-
DCOAST	-	-	-	-	+	+	+	-
DHWAY	-	-	-	-	-	-	-	-
DFLAND	-	-	-	-	+	-	+	+