Oregon Urban Growth Boundaries
Estimating Residential Densities: The Role of Indexes

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This study investigates how the characteristics of a jurisdiction and the amount of vacant land are related to residential densities within any given urban growth boundary (UGB) in the state of Oregon. Oregon's Land-use laws require cities to develop and implement land-use plans approved by the state. In an ideal world, one could develop an easily-understood and highly accurate formula identifying land need for any given UGB. Of course, this kind of deus ex machina is not feasible, so the first objective of this project is to illustrate how a compact set of factors can be used to calculate a relative index of land-use density (RILUD) with reliable statistical properties. The second objective is to demonstrate the feasibility of building an index and the practical uses such a tool provide.

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1. EXECUTIVE SUMMARY

At the center of the State of Oregon's Land Use regulations is the complex and ongoing issue of Urban Growth Boundaries. Intended to contain urban sprawl and accommodate population growth, Oregon is one of few states that require each jurisdiction to establish and maintain an Urban Growth Boundary (UGB). The UGB amendment process is a topic of debate and subjectivity. At the core of the problem is a lack of consistency and efficiency in how a jurisdiction identifies its land need and in how State institutions handle UGB amendment applications.

In identifying land need, jurisdictions have few reliable benchmarks to identify standing relative to other jurisdictions facing similar situations. An efficient system would allow for such comparisons in order to better formulate and evaluate land need. This study aims to illustrate how a compact set of UGB characteristics can be used to develop an index with the potential of providing benchmarks for UGB comparisons, scenario simulations, and predictive estimations. To accomplish this objective, we compile a list of strong explanatory variables for UGB residential density, create a predictive model with minimal variance, and demonstrate the model's ability to simulate factor shocks.

Data for our model comes primarily from Census and American Community Survey data as well as from UGB survey documents found in the public domain. Because current protocol for conducting land-use surveys is need-based, the data we use to construct our index is cross-sectional. Residential-zoned vacant acres, population level, total UGB acres, industry mix and region controls represent the core predictors of our model. This set of variables allows us to control for many of the idiosyncratic differences between jurisdictions, resulting in an empirical model that can explain much of the variation in residential densities.

With such an empirical model, reliable inferences can be made about how residential density tends to respond to different figures of vacant residential acres and industry mix. While this study demonstrates the development of a relative index of land-use density (RILUD), indexes also have the potential to benefit the field of urban development by explaining other variables including income, land pricing, and spatial characteristics.

2. INTRODUCTION

Urban growth management is an ever-evolving set of techniques used by city planners and by government officials; it is also an issue of increasing concern in many areas of the United States. According to the “smart growth theory” which has been adopted by many policy makers across the United States, Canada, and much of Europe, approaches to urban growth management take a few forms: (1) Charges and fees, including impact fees, toll roads, system connection charges, among others; (2) management of infrastructure through the use of programs that concern integrated land use, transportation, and capital use; and (3) Land use regulations that include urban growth boundaries and zoning regulations. In this paper, we focus on the third approach in urban growth management, specifically the use of the urban growth boundary (UGB).

By using the third approach to urban growth management, land use regulations, an optimal allocation of land must be defined in order to avoid two main consequences that are likely to arise. Apportioning too little land for urban use is likely to result in inflated land and housing prices, while assigning too much land for urban use may result in urban sprawl.

In this paper, we investigate how the amount of vacant land in a residential area is related to residential density within an urban area in the state of Oregon. This study will help reveal to city planners and government officials how vacant land inside current UGBs should be considered in forming and evaluating UGB expansion proposals. Our results may help provide an objective yardstick for vacant land which could mitigate some of the political and legal struggles that have rendered the UGB process inefficient and costly. Additionally, our results could provide an index of what relative pressures on density exist across cities.

Goal 14: Urbanization (OAR 660-015-0000(14)) requires cities to develop and implement land-use plans approved by the state's Department of Land Conservation and Development. As part of that process, each city establishes an approved UGB. The UGB is intended to guide compact, efficient land use, curtailing urban sprawl while accommodating economic prosperity and population growth. As circumstances change over time, cities propose changes in their UGB, and each city is unique. Uniqueness and changing circumstances make the process of UGB revision and approval grueling for all and inevitably subjective.

The difficulties and frustrations surrounding the current status of the system are well-represented in an article written by Peter McCallum titled "Oregon Land-Use System Needs Overhaul". In the article, McCallum, a thirteen-year member and current president of the City of Woodburn's city council, discusses the ten-year long struggle and ultimate inability of the City of Woodburn to acquire new industrial land. Calling on Oregon legislators to "immediately undertake a comprehensive modernization of our land use system", McCallum stresses that ambiguous law and land-use processes result in a system that takes years to resolve fundamental planning functions[1]. Improved efficiency and consistency in the areas of land-need identification and external review would greatly reduce the frequency of situations similar to Woodburn's that have negative impacts on residents.

Few reliable benchmarks are available to jurisdictions and state legislators that can

[1] McCallum, Peter. "Woodburn Councilor: Oregon land-use system needs overhaul." Statesman Journal: n. page. 8 June 2014. Web. 8 June 2014.

provide information on the relative standing of a jurisdiction. In an ideal world, one could develop an easily-understood and highly accurate formula for the one appropriate UGB for each city. Of course, this kind of deus ex machina is not feasible, so the first objective of this project is to illustrate how a compact set of factors can be used to calculate a relative index of land-use density (RILUD) with reliable statistical properties. The RILUD is intended as a first attempt at a metric for relative density and efficient land use, given a compact set of easily observed attributes for each city, such as existing UGB, population, residential patterns, locale, and economic composition. Again, no metric can be a reliable as a deus ex machine. Instead, we offer the RILUD as an initial illustration of what might be possible in developing a metric to use as a benchmark placing the many idiosyncratic features and plans of each city in relative context.

Our second objective is to demonstrate the feasibility of building an index and the practical uses such a tool provides. In doing so, we aim to develop suggestions for similar efforts in the future for workgroups found in organizations such as ECONorthwest and for state policymakers.

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3. BACKGROUND

Land use controls largely originate in 19th century England, where concerns began to arise regarding unregulated urban growth. In 1973, the first UGB in the United States was set up by Tom McCall, then-governor of Oregon. It was placed under Senate Bill 100, legislation centered on statewide land-use planning. Oregon state law now requires all jurisdictions to have UGBs, comprehensive plans, and zoning policies. One of three states in America that requires cities to establish and maintain urban growth boundaries, Oregon is unique because of its vast amount of forest and farm land. Agriculture and forest products have been Oregon's second and third largest industries since 1980, when high tech became the single largest industry in the state.

UGBs have two underlying purposes. First, boundaries provide a partition between urban and rural land use, protecting forested lands and national parks. Second, boundaries are intended to provide a 20-year supply of land to accommodate population growth in a jurisdiction. Boundaries are intended to contain and control urban sprawl in a way that prioritizes the efficient use of land. Efficient land use can be partly defined as meeting public demand for housing, employment opportunities, and public facilities. These include schools, street and sewer systems, parks, and other services that create a thriving place to live, work and play. Oregon's land-use system is intended to make development choices intentional and public rather than driven by private interests and profit.

UGBs are established and maintained through a complex political and legal process designed to equate the ever-growing demand for land in a jurisdiction with its land supply. Jurisdictions begin to identify land needs by adopting 20-year population and employment growth forecasts every five years. Forecasts estimate what growth will occur in an area based on historic population growth and assumptions about what future demographic and economic trends may occur. Jurisdictions identify the available supply of land by conducting buildable land inventory assessments. These assessments identify categories of committed, protected, developable (vacant) and developed lands within a boundary. Jurisdictions combine buildable land inventories, population and employment growth forecasts and other economic analyses to form comprehensive land use plans. In these documents, jurisdictions determine whether current UGBs are adequate to accommodate future needs for housing development, commercial development and economic growth.

Jurisdictions argue for the expansion of their UGBs in a very specific manner specified by the state. Goal 14 of the Oregon Department of Land Conservation and Development (DLCD) statewide planning goals outlines urbanization goals and guidelines concerning UGBs. Jurisdictions establish a need for UGB expansion by first demonstrating admissible needs for additional land. Admissible needs include accommodations for long range urban population including housing, employment opportunities, livability or uses such as parks, schools or other public facilities. Jurisdictions must then demonstrate that such needs cannot be accommodated within current boundaries. Comprehensive plans adhering to planning goals are reviewed by Oregon's Land Conservation and Development Commission (the seven-member volunteer citizen board that guides DLCD) and become controlling documents for areas only when officially approved. This process has experienced significant legal and political struggles that have resulted in, and continue to result in, lengthy court processes that waste millions of dollars and countless hours of time. [2] [3] [4]

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4. LITERATURE REVIEW

Of the studies that examine UGB issues, few address how the characteristics of a jurisdiction affect residential density. For this reason our literature review focuses on papers that provide justification for assumptions used to develop our hypothesis, as well as the explanatory variables.

We draw on the work of various environmental protection organizations including the

[2] Christensen, Nick. "State Regulators Recommend LCDC Partially Remand 2011 UGB Expansion." *Metro*. N.p., 12 Apr. 2012. Web. 23 May 2014.

[3] Christensen, Nick. "State Regulators Lay out Legal Path for Possible UGB Approval." *Metro*. N.p., 8 June 2012. Web. 23 May 2014.

[4] Fehrenbacher, Lee. "Newberg given Time to Readdress UGB Expansion Plans." *Daily Journal of Commerce*. N.p., 20 Mar. 2014. Web. 23 May 2014.

EPA[5], Sierra Club[6], and Smart Growth America[7] to help us define “efficient land use”, which can be used interchangeably with “smart growth”. Several overarching guidelines are present in each organization’s theory. Cities should provide for the increase in population by increasing city density (plus revitalization of older suburbs and downtown areas), while reducing urban sprawl into open space, especially farmland. Communities should have transportation and housing choices near jobs, shops, and schools. As mentioned in the introduction, UGBs are a specific regulatory tool to achieve this definition of efficient land use.

In “Urban Sprawl: Diagnosis and Remedies”, Jan K. Brueckner addresses the growing national concern over urban sprawl, which he defines as “excessive spatial growth of cities”.[8] City growth becomes excessive when it encroaches on nearby agricultural land, destroys the aesthetic benefits of vacant land, or creates traffic congestion (and thus more air pollution). Other measures of excessive fringe growth could be a lower rate of redevelopment near city centers, or a decrease in social interaction in the residential fringe areas.

Brueckner argues that urban spatial expansion naturally results from a growing population, rising incomes, and falling commuting costs. He finds that if adjacent resource land is valuable, there will be bidding competition between developers and agricultural users. More broadly, this paper rests its assumptions on the interplay between supply and demand in spatial location.

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[5] "About Smart Growth." *EPA*. Environmental Protection Agency, n.d. Web. 01 June 2014. <http://www.epa.gov/smartgrowth/about_sg.htm>.
[6] "What Is Smart Growth." Sierra Club, n.d. Web. 03 June 2014. <http://www.sierraclub.org/sprawl/community/smartgrowth.asp>.
[7] "What Is "smart Growth?"" *Smart Growth America*. N.p., n.d. Web. 03 June 2014. <http://www.smartgrowthamerica.org/what-is-smart-growth>.
[8] Jan K. Brueckner, “Urban Sprawl: Diagnosis and Remedies”, (International Regional Science Review: Sage Publications, 2000) p.162.

When Brueckner examines commuting costs, he reasons that more investment in highways allows people to live less expensively in suburbs by reducing travel time and fuel costs. If greater access to highways causes more commuting, then intuitively city density will decrease. Proximity to highways could also lead to "job suburbanization", due to a change in the transportation orientation of businesses. If a lower rent suburban location also has access to cheaper means of transportation by highway, then a business may locate in the suburb rather than an expensive city location with transportation by port or rail.

"Urban Densities in England and Wales: the significance of three factors" by A.G. Champion is a regression analysis used to examine the relationship between urban density, population size, social class, and population change – with social class shown to be the most important of the three.[9] Multicollinearity between the variables made the results ambiguous despite the significance of the independent variables. This is a phenomenon in which two or more explanatory variables are correlated with each other, making it difficult to determine their individual effects on the dependent variable (residential density in our case). Multicollinearity increases the standard errors of the coefficients, reducing the chance these coefficients will be significant.

In "Urban Spatial Structure" (1998), Alex Anas, Richard Arnott, and Kenneth A. Small develop a model that has the ability to predict the pattern of residential location by income.[10] The model finds, "That rich households will have flatter bid-rent functions than poor households and hence will locate more peripherally." (Anas, Arnott, Small, 1436) This means that urban

[9] A.G. Champion, "Urban Densities in England and Wales: the significance of three factors", (Area: The Royal Geographical Society, 1972) p.187.
[10] Anas, Alex, Richard Arnott, and Kenneth A. Small. "Urban Spatial Structure." *Journal of Economic Literature* XXXVI (1998): 1436+. Web.
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sprawl increases with income.

The authors suggest this could be because of deteriorating central housing quality, racial preferences, or the working out of Tiebout Mechanisms. In the Tiebout Model[11], individuals move between communities until they find one that provides their utility maximizing bundle of public goods. Wealthier residents have higher demands for local public goods, so they form exclusive neighborhoods around these goods and pay higher tax rates.

Policymakers have commissioned third parties, often economic consulting firms, to create smart growth indices to judge the relative health and sustainability of their cities. The Metropolitan Sprawl Index (MSI)[12] for San Francisco (2002) uses 22 variables to define four factors of urban sprawl (one of the core problems facing policymakers discussed in our introduction). The authors choose residential density and street accessibility for two of the four factors, along with neighborhood mix of homes, jobs, and services; and strength of activity centers. The MSI defines residential density by the Census Tract.

A limitation the creators of the MSI found is that in reality, certain areas of lower residential density do not indicate sprawl. These could be areas preserved for parks, natural habitats, or industrial areas. Residential areas with very low densities (6-7 homes per acre) can sometimes even support convenience stores, schools, and transit services. Since the 6-7 homes can access these services without lengthy car trips, they fall outside the author's definition of sprawl.

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[11] Tiebout, C. (1956), "A Pure Theory of Local Expenditures", *Journal of Political Economy* **64** (5): 416–424.

[12] Ewing, Reid, and Rolf Pendall. "Measuring Sprawl and Its Impact." *Smart Growth America* (n.d.): n. pag. Web. 24 May 2014. <http://www.smartgrowthamerica.org/documents/MeasuringSprawl.PDF>.

This introduces the problem of zoning. There are many times when residential zones are mixed with other uses, usually commercial. For example, a building with a business on the bottom floor and apartments above is a common structure. If we exclude the structure we are falsely decreasing density, but if we include it we are not purely measuring the effects on residential density. However, we have taken measures to try and mitigate this problem by using UGB surveys to acquire more specific residential acreage information rather than the Census. These UGB surveys also allow us to exclude constrained land, "Vacant or partially vacant parcels with significant physical, environmental, or infrastructure limits to development".[13] This would be the parks and natural habitats mentioned by the MSI, as well as public facilities.

The MSI shows which metro areas are the most sprawling overall, and which factors make them that way. It shows that a correlational study with multiple regression analyses can successfully create a sophisticated land use index. The authors mention the challenge of controlling for confounding influences in this kind of research. We take their advice by measuring and controlling for many influences in our expanded model.

The SLEUTH Urban Growth and Land Use Change Model by the US Geological Survey is another index created with the intent to inform smart growth policies. The model gives city planners a tool where they can input the characteristics of their city, then see how these factors affect growth with visual output. This program uses layers of images as input for variables of slope (the incline or steepness of a surface), land use (urban, agricultural, rangeland, or forest), excluded (anything resistant to urbanization, like open bodies of water or national parks), urban (developed land), transportation (nearby road networks), and hillshade (mostly aesthetic, to

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[13] "Glossary." *Oregon.gov*. Oregon Department of Land Conservation & Development, n.d. Web. <http://www.oregon.gov/LCD/docs/publications/g9guidebook/appa_glossary.pdf>.

create a three dimensional appearance). The program then applies growth rules to simulate urban driven land cover change including: spontaneous growth (random urbanization), new spreading centers (random growth cells that spread outward), edge-growth (growth from existing spreading centers), and road-influenced growth (if a road exists in nearby cells).

The SLEUTH model has a similar method to our "distance to I5" variable to account for road-influenced growth, and the authors hold the same hypothesis that density will increase with greater access to roads.[14] SLEUTH uses a weighting scheme for roads to increase accuracy.[15] The model is initialized with the earliest road layer recorded for the city. As time passes, and the date for a more recent road layer is reached, the new layer is read in and development will proceed from there.

A 2003 study by the University of Maryland, Woods Hole Research Center, and Fels Center of Government[16] utilized the SLEUTH Index to analyze the effect of local urban development on the water quality of the Chesapeake Bay estuary. The model was calibrated to that specific area, and future growth was projected out to 2030 under three different policy scenarios: current trends, managed growth, and ecologically sustainable growth. It was discovered that the current trends scenario had likely negative impacts on the water quality, while the ecologically sustainable scenario produced patterns that were more constrained and used less natural resource land. The author's ultimately mention the critical need and potential of land use indexes, but that spatial accuracy and scale sensitivity are among issues that must be

[14] "Data Input (Transportation)." *Project Gigalopolis*. USGS, UCSB, n.d. Web. 03 June 2014. <http://www.ncgia.ucsb.edu/projects/gig/About/dtInput-Transportation.htm>.
[15] "Road Weighting." *Project Gigalopolis*. USGS, UCSB, n.d. Web. 03 June 2014. <http://www.ncgia.ucsb.edu/projects/gig/About/gwRoadWeight.htm>.
[16] Jantz, Claire A., Scott J. Goetz, and Mary K. Shelley. "Using the SLEUTH Urban Growth Model to Simulate the Impacts of Future Policy Scenarios on Urban Land Use in the Baltimore ^Washington Metropolitan Area." *Environment and Planning B: Planning and Design* 30 (2003): 251-71. Web.

addressed to make these more practical for policymakers:

"A modeling system that could provide regional assessments of future development and explore the potential impacts of different regional management scenarios would be useful for a wide range of applications relevant to the future health of the Bay and its tributaries." (Jantz, Goetz, Shelley, 251)

While none of these studies directly analyze residential density within UGBs, they are useful foundations for our assumptions. Below we explain our conceptual model, and speak more in depth about some of the assumptions and variables discussed here.

5. CONCEPTUAL MODEL

A simple economic approach suggests that land-use density (LUD) is the result of the complex interplay of demands for land uses. Demand is a factor of residential and commercial patterns, population, available supplies of buildable land, locale, and geomorphic features (streams, rivers, lakes, wetlands, ocean, slope gradients, and soil composition). Detailed measures for all of these are well beyond the scope of the current project, so we will focus on developing effective proxy variables in illustrating the potential for metrics like the RILUD. The metrics for our own success include the statistical power and reliability of the RILUD, as well as simplicity, ease of use, and transparency.

The RILUD is intended to predict residential densities relative to the mean based on the characteristics of Oregon jurisdictions. In this section we identify the components of RILUD and how they represent the interplay of demand for land use and their relationship with residential land. RILUD defines residential density as the number of dwelling units per acre of developed residential land in an UGB. The index's focus is on demand theory behind residential density as the supply of land is fixed in the dataset.

<u>Vacant Buildable Residential Land</u>

Vacant buildable residential land exists because of low opportunity costs associated with developing it. If housing is demanded developers will build housing, if there's insufficient demand housing will not be built. Residential densities will decrease in the acres of vacant buildable land in an UGB. However, more vacant land may be a factor of jurisdiction size; larger jurisdictions will inevitably have greater amounts of vacant land on average. If firms cluster, workers minimize travel costs and there is a low opportunity cost of vacant land a jurisdiction will have more vacant land and a higher density.

<u>Population</u>

Champion (1972) used cities' population size to explain their densities. RILUD recognizes that densities and land needs analyses are factors of the dynamics of cities rather than statics (population growth vs population levels). Using population growth regions, as defined by Portland State University's Metropolitan Knowledge Network(PSU-MKN), will account for population dynamics observed from 2000-2010 rather than the statics. Also, Oregon cities use population growth forecasts in their land needs analyses; using growth regions minimizes the implicit and explicit costs associated with switching to our index. Higher population growth will increase demand for residential land. Since the supply of land is limited by UGBs density will increase.

That said, it is likely that a small jurisdiction with a high population growth rate will be denser than a highly populated jurisdiction with a low growth rate as there is an adjustment period in which the small jurisdiction will be substituting land for capital until an UGB expansion is approved. So, including measures of population levels will account for the size of the jurisdiction whereas MKN region is a proxy for the growth of the jurisdiction. Larger populations and regions with higher growth rates are expected to be correlated with higher densities.

Agricultural Regions

The Oregon Department of Agriculture (ODA) defines 6 regions in the state based on the dominant type of agriculture. Conveniently, agriculture of a similar nature requires a similar climate, soil composition and landscape, i.e., slope gradient etc. Determining how regional agriculture affects densities is beyond the scope of RILUD; however, we can use these regions to estimate the differences in densities across geographic regions. Brueckner proposed that valuable agricultural lands will increase densities in adjacent urban areas. Though RILUD does not exclude this possibility we have not assessed the value of the relevant agriculture and can say nothing about this relationship.

Industry Mix

Using empirical evidence that marginal disutility of access time to transit is greater than the marginal disutility of in-vehicle time and assuming housing is a normal good we build our theoretical framework.

In theory, certain industries benefit from clustering by either sharing a common input (labor, raw material, information etc.), or bringing comparison shoppers into the market. A larger proportion of such an industry in a jurisdiction will generate greater demand for labor relative to an industry that does not benefit from agglomerative economies. If trip costs are high and incomes low employees will want to minimize trip costs by minimizing access time (public transit users), so they will live in more dense areas where public transit systems are sustainable.

This will cause greater residential density near employment centers. Contemporaneously, residential densities may decrease faster in distance from the center relative to an employment center without economies of agglomeration. If this is the case, there could be large amounts of vacant land away from the center but residential density will be increasing because developers are building “up” rather than “out”.

Anas et al (1998) found evidence that sprawl increases with income. Employees in industries with high incomes relative to the cost of housing will be less bound by location. A worker with more purchasing power will demand more square feet of housing and will be less responsive to changes in travel time. So taking the assumption that larger jurisdictions have larger amounts of vacant land and combining it with an industry in which workers are paid relatively high wages, such as the information sector, larger proportions of the two variables will be correlated with lower residential densities. Despite the implications of economies of agglomeration these particular industry employees will not cluster.

Conversely, a greater proportion of an industry that does not benefit from agglomerative economies will have no effect on residential densities. Indeed, if a firm does not benefit from agglomeration its goal will be to minimize production costs by finding cheap land. Cheap land is found where demand for land is low. The local composition of the industry will consist of one to a few firms uniformly distributed across the UGB and will be correlated with low densities. Independent services such as wholesale or transportation and warehousing fall under this category.

Agglomeration may affect construction. A jurisdiction with a relatively high proportion of construction industry results from demand for new, accommodating structures. If this is true developers and homebuyers are consuming vacant land, so vacant land will decrease in the proportion of construction industry within a city and density will increase.

The interplay of vacant land and the proportion of construction in a city will behave differently; if there are economies of agglomeration and residents are trying to minimize travel time housing will be constructed as close to the employment area as possible. Thus, vacant land further from employment centers will not be used while land closer to the center will be developed. In this scenario density will decrease with higher amounts of vacant land and construction.

Distance from I-5

Firms will choose to locate in a way that minimizes the transaction costs of either producing or distributing its product. As Brueckner hypothesized, if rents and the price of interstate transportation are low relative to the price of rail transport then industry reliant upon transportation of inputs or outputs from or to an area outside of its region will locate near I5. This will cause a clustering of transportation dependent industries and greater quantity of labor demanded near I5. Greater amounts of labor demanded will incite greater quantities of housing demanded subsequently increasing residential density. The density will decrease in distance from I5.

6. EMPIRICAL MODEL

In the previous section we identified key characteristics that we hypothesize to vary with residential densities. Given the cross sectional nature of the data and that our goal is to minimize the error and uncover the statistical relationship between characteristics and residential densities we believe regression analysis using OLS is best. Analysis of various specifications led us to believe that there is nonlinearity in variables; characteristics affect density differently at different levels. Different specifications of the independent variables also revealed that the magnitude of some right hand side variables depends on the value of right hand side variables. We attempt to capture such relationships by taking the product of some independent variables. Our model is specified as follows:

$$\text{DENSITY}_i = \alpha + \beta_1\text{POP}_i + \beta_2\,\text{POP}_i^2 + \beta_3\text{VACR}_i^2 + \beta_4\text{UGB}_i + \beta_5\,\text{I5-}_i + \beta_6\,\text{VACR}_i + \sum \delta_h\text{POP}_i\text{MKN}_{h,i} + \sum \delta_k\text{VACR}_i\text{ODA}_{k,i} + \sum \delta_j\text{VACR}_i\text{INDUSTRY}_{j,i} + \sum \beta_j\text{INDUSTRY}_{j,i} + \varepsilon_i$$

α is the housing density of a city if all variables except the reference categories are zero. The reference categories are MKN region 1, ODA region 6 and the transportation and warehousing industry sector. It has little meaning by itself as there is no city with zero population covering zero acres.

POP_i is the logarithm of population in jurisdiction *i* in the year in which the land needs analysis survey for city *i* was conducted. Based upon the conceptual model the variable should have a positive coefficient; a greater population is correlated with higher density. The logged term implies that density increases at a decreasing rate with population.

POP_i^2 is the squared logarithm of population. It is included to account for the presence of a non-linear relationship between density and population. In squared logarithms a negative coefficient implies that density increases at a slower rate with larger populations. The coefficient is expected to be negative.

UGB_i is the logarithm of total acres in jurisdiction *i* in the year in which the land needs analysis survey for city *i* was conducted. Based upon the conceptual model the variable should have a positive coefficient. Residential acres, residential units and UGB acres are positively correlated (table below); however, UGB acres and density are slightly, but negatively correlated.

Thus, as UGB acres increase residential acres increase more rapidly than residential units. It is evident that larger jurisdictions, if only slightly, have residential units more widely dispersed than smaller jurisdictions on average. This may result from an income effect under the assumption that median incomes are higher in larger cities.This will result in a negative coefficient on UGB_i. Residential densities decrease in UGB acres.

	UGB Acres	Units/Res Acre	Res Units	Residential Acres
UGB Acres	1			
Res Units per Res Acre	-0.01	1		
Residential Units	0.95	0.09	1	
Net Residential Acres	0.94	-0.15	0.92	1

$VACR_i$ is the logarithm of vacant buildable acres in jurisdiction *i* in the year in which the land needs analysis survey for city *i* was conducted. Density decreases in acres of vacant land; the variable will have a negative coefficient. However, under the hypothesis that different pressures on LUD are embedded in the interaction of vacant land with other jurisdiction characteristics much of the variation from vacant acres will be explained by its interactions with industry. In this case, it is possible that the coefficient will be positive or zero. Also, a positive coefficient may indicate that vacant acreage is a proxy for size.

$VACR_i^2$ is the squared logarithm of vacant buildable land. It is included to test for a non-linear relationship between density and vacant land. A positive coefficient indicates that density increases more rapidly with larger amounts of vacant buildable land.

$POP_iMKN_{h,i}$ is the logarithm of population for city *i* in MKN region *h* relative to MKN region 1, Northwest Oregon. MKN are population growth regions as defined by PSU-MKN. For example, the coefficient of $POP_i MKN_{6,i}$ is the effect of populations in region 6, Eastern Oregon, relative to the effect of population sizes in region 1. The terms are included to test for differential effects of population and across population growth regions. We expect that larger populations should have no differential effects across regions.

$VACR_i ODA_{k,i}$ is the second regional variable. The coefficient will be the average relationship of vacant residential acres in a jurisdiction in region *k* on density. ODA 6, Southeast Oregon, is the reference category. A coefficient δ_k is the average difference of ODA *k* from ODA 6. The sign of delta is expected to be negative; more vacant land is correlated with lower densities in the given region. ODA 1 is the entire coastal region.

$INDUSTRY_{j,i}$ is the proportion of industry *j* in jurisdiction *i*. As explained in the conceptual model, industries that benefit from agglomeration will cluster creating greater demand for labor and incite greater residential densities relative to transportation and warehousing. All jurisdictions have a base level of transportation and warehousing. As the jurisdiction grows the proportion of transportation shrinks. Jurisdictions with greater proportions of all other industries will have higher residential densities than those with higher proportions of transportation; β_j will be positive.

$VACR_i INDUSTRY_{j,i}$ is the product of industry proportion *j* and vacant residential acres in city *i*. Transportation and warehousing is the reference category. Higher amounts of vacant land with greater proportions of industries that benefit from agglomeration compared to transportation and warehousing are expected to have negative coefficients. The magnitude of these coefficients will approximate the degree of clustering. Higher coefficients in absolute value imply more clustering and less land used. From the conceptual model we infer that industries with higher wages will demand more housing over decreasing trip costs. δ_j for these industries will have a greater negative coefficient.

ε_i is the error term for jurisdiction *i*. It is the difference in density between RILUD predictions and our observations. The goal of RILUD is to minimize ε_i for each observation.

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7. DATA

<u>Selected Summary Statistics:</u>

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
Log Pop	64	8.944	1.128	6.957	11.96
Res Units/ Res Acre	57	1.016	0.656	-1.041	2.555
Log of Vacant Res	62	6.069	1.298	2.493	9.360
Log of Distance to I5	64	2.959	1.815	-1.204	5.926
Log of UGB Acres	64	8.044	1.101	5.472	10.67

The dependent variable is a measure of residential density. We collected characteristic data from 64 Oregon jurisdictions' housing surveys conducted by ECONorthwest and various city government and supplemented missing data with American Community Survey data relevant to the study year. The surveys are historical analyses and growth forecasts specific to UGB jurisdictions and include Housing Needs Analyses (HNA), Buildable Land Inventories (BLI), and Economic Opportunity Analyses (EOA), referred to as "UGB documents"). The UGB documents were provided by our community partner institution, the Department of Land Conservation and Development (DLCD) and Bob Parker of ECONorthwest.

To calculate jurisdiction and city densities, total acreage of the 64 UGBs were extracted from a comprehensive Oregon government UGB amendments table. This table recorded all UGB expansions from 1981 through 2011.[17] We found developed residential acreage in an urban growth boundaries in the UGB documents for about two thirds of the jurisdictions and directly contacted city planning commissions for the other third. The Lane Council of Governments provided data for three cities within its jurisdiction.

For those UGB documents that did not contain housing data we found residential units information in the American Community Survey Five Year Estimates.

The independent variables are net vacant buildable acres, population,UGB acres population growth region, distance from Interstate 5, agricultural region, and industry mix.

The Oregon Department of Agriculture(ODA), and Portland State Population Research Center (PSU-MKN) divide the state into different regions. The ODA categories are (1) Coastal Oregon, (2) the Willamette Valley, (3) Southern Oregon, (4) the Hood River Valley, (5) the Columbia Basin, and (6) Southeast Oregon.

PSU-MKN divides Oregon into six categories based on population growth from 2000 through 2010.[18] These include (1: +6.6%) Northwest, (2: +13.6%) Metro, (3: +11.5%) Valley,

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[17] Lazarean, Angela. "UGB Amendments Data Table." (n.d.): n. pag. *Governor's Natural Resource Office*. Oregon Government. Web. 23 May 2014. <www.oregon.gov/gov/GNRO/docs/Current%20Initiatives/UGB%20amendments%20data%20table_Hx.pdf>.

[18] "Oregon Regions." Metropolitan Knowledge Network. Portland State University Population Research Center. Web.

(4: +8.5%) Southwest, (5: +30.5%) Central, and Eastern (6: +3.7%).

Total city population was gathered from PSU and the Census.[19] Google Maps was used to measure the road miles from a city's center to I5.[20]

The data for net vacant buildable acres comes from the UGB documents provided by the DLCD and ECONorthwest, primarily Housing Needs Analyses and Buildable Land Inventories. The net vacant buildable acres of a city are composed of vacant buildable acres plus re-developable acres, minus constrained acres. Total net vacant buildable acres are often divided into residential, commercial, and industrial categories – of these we focused on residential in our model.

Industry mix data was gathered either from EOAs or from the American Community Survey Five Year Estimates, each category is measured as a percent of the city's overall industry.

8. METHODOLOGY

Given the data for this study is cross sectional, we use the Ordinary Least Squares (OLS) framework. Based on previously stated assumptions, we employ the use of an OLS regression to determine the relationship between the outlined characteristics and residential density. Our dependent variable is the logarithm of residential units divided by the residential acres in an UGB. A list of included variables and all results of the regressions can be found in Appendix A, and all defined equations are listed in the empirical model section.

[19] "Oregon State & County QuickFacts." United States Census Bureau. Web.
[20] "Oregon". Map. Google Maps. Web.

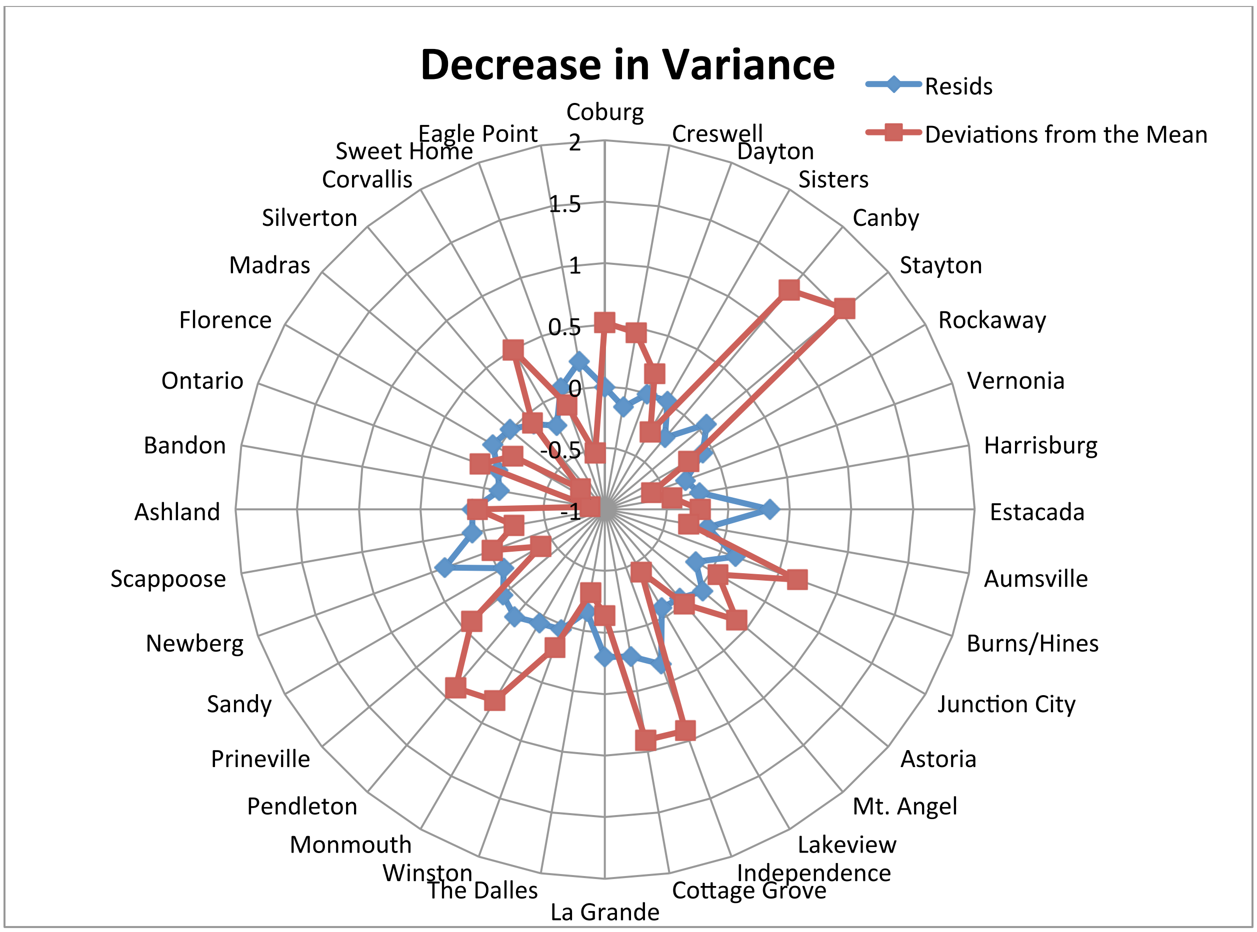
It is assumed that the model is linear in parameters. OLS is the best, linear, unbiased estimator to evaluate the relationship between characteristics and residential density. Given the constraints of cross sectional data, only correlations, not causality will be drawn from using this methodology. It also important to note that only the core variables in the regression have coefficients with inherent meaning, all other variables including dummy variables and interaction terms are only to be interpreted by their signs, if they have statistical significance.

We began with a core model including only population, UGB acres, distance from I5 and vacant buildable residential acres. From the core model we added additional variables in attempt to minimize the root mean square error (rmse). Two criteria were considered in the addition of variables. First, analyse the theory behind their inclusion (extensively covered in section 5). Second, analyze the effect of the variable on rmse and cross check the improvement in fit using Bayesion Information Criteria (BIC) as well as Aikike Information Criteria (AIC). This process resulted in the model outlined in section 6.

9. ECONOMETRIC RESULTS

Residential units divided by net residential acres in a jurisdiction is the dependent variable, thirty-four of the forty independent variables tested are statistically significant. For RILUD, statistically significant coefficients are less important than finding pivotal variables that explain the variation in residential density. As explained earlier, the method was to find a model that minimized the root mean square error. Most of the variables are included to control for variation, as well as to aid in the construction of a representative index. All forty variables included collectively contribute in the explanation of total residential density. Our econometric methodology requires no interpretation of the significant coefficients; however, out of interest we analyze the coefficients of significant core variables. As for the remaining variables, the dummy variables and interaction terms are useful in the interpretation of their signs (positive or negative).

Before interpreting the individual variables of the model, we will discuss the overall impact this regression has on determining residential densities for a jurisdiction. The figure below is an illustration of how RILUD reduced the variance in the dependent variable, log of residential density. Without this model, the standard deviation of the log of residential density is .679 (red). The root mean square error or RILUD, which can be interpreted much like the standard error, is .307 (blue). The model's predicted values decrease the variation by more than half indicating the independent variables are instrumental in determining residential density.



The core variables included are UGB acres, distance from Interstate-5, population (and squared population), and vacant residential acres (and squared vacant residential acres). All variables listed are found to have statistical significance.

One core variable that is significant is the distance from I-5. A 10% increase in the distance from I-5 leads to a 2.48% decrease in residential density. This variable is statistically significant at the 1% level. As hypothesized, the further a city is from a major arterial highway, density tends to decrease. It is important to note that this is not a causal relationship, but instead a correlation.

Another variable that is significant is the log of UGB acres. It is found that a 10% increase in UGB acreage for a jurisdiction is correlated with a 6.10% decrease in residential density. This variable is found to be statistically significant at the 5% level. As predicted by the model as UGB acres increase residential density falls. This is not a causal relationship, but rather a correlation.

Log of population within a jurisdiction is found to be statistically significant at the 5% level. The regression indicates that a 1% increase in population is correlated with a 3.589% increase in residential density. Intuitively this result makes sense; as population rises, so does density.

For the last core variable, vacant residential density, it is found that a 1% increase in vacant residential land correlates with a 19% increase in residential density. This result is consistent with the squared log of vacant residential land variable. Both are found to be significant at the 1% level. Intuitively, we expect density to be decreasing in vacant acres. Recall, in the conceptual model we argued that larger jurisdictions have more vacant land on average. Indeed, the top 22 jurisdictions by population comprise 68 percent of 22 jurisdictions with the largest amount of vacant acres. We believe the variable accounts for a measure of jurisdiction size that we have not found or included in RILUD and therefore carries a large positive coefficient. Effects of the variable are diminished by the interaction terms of vacant land with industry.

Also included in RILUD are the population growth regions labeled 'mkn.' The Northwest region is the reference category, thus it is excluded from the model. These MKN regions have been interacted with the natural log of population. The interaction term including region 6, which is Eastern Oregon, is found to be statistically significant at the 10% level. If population increases in region 6, there is a correlation that total residential density in region 6 increases in comparison to region 1 (the Northwest).

Agricultural regions are also included. Instead of including the regions as dummy variables by themselves, these regions are interacted with the logarithm of vacant residential acres. By including these interaction variables, it is an attempt to control for the coastal regions, ODA region 1. As mentioned previously, adding a control for the coastal regions is necessary due to variations in slope gradients related to vacant land. ODA regions 4 and 5 are statistically significant at the 10% and 1% level, respectively. Both regions have a negative coefficient; this is interpreted as when vacant land rises this is correlated with a decrease in residential density in comparison to ODA region 6. As vacant land increases, density in regions 4 and 5 fall with respect to region 6.

The next portion of variables within the regression is the interaction variables between industry mix and vacant residential acres. These interactions are between two continuous variables. All eleven interactions are statistically significant. The variable transportation and warehousing interacted with vacant land has been excluded from the regression, thus variables are interpreted in comparison to this excluded industry. All eleven terms have negative coefficients: the higher the amount of vacant land, the more negative the effect of agriculture, construction, information, and all other industries on residential densities. Similarly, the higher the proportions of these industries within a jurisdiction, vacant land will more negatively affect residential density. The results imply that all eleven industries are statistically different from transportation and warehousing as vacant land changes.

Lastly, the industry mix variables are included in the regression on their own. All included industries are statistically different from the excluded transportation and warehousing industry mix variable. Because they are not considered core variables we only discuss the sign. The results indicate that if any of the eleven industries increase in proportion, this is correlated with an increase in residential density. Once again, the results imply that all twelve industries are statistically different from transportation and warehousing.

The significance of the model at the 5 percent level ($F_{(40, 14)}=5.99$), the reduction in variance and the explanatory power of the independent variables show that RILUD can more accurately predict densities than a simple examination of the raw data. Furthermore, it serves as a tool in the planning process as demonstrated below.

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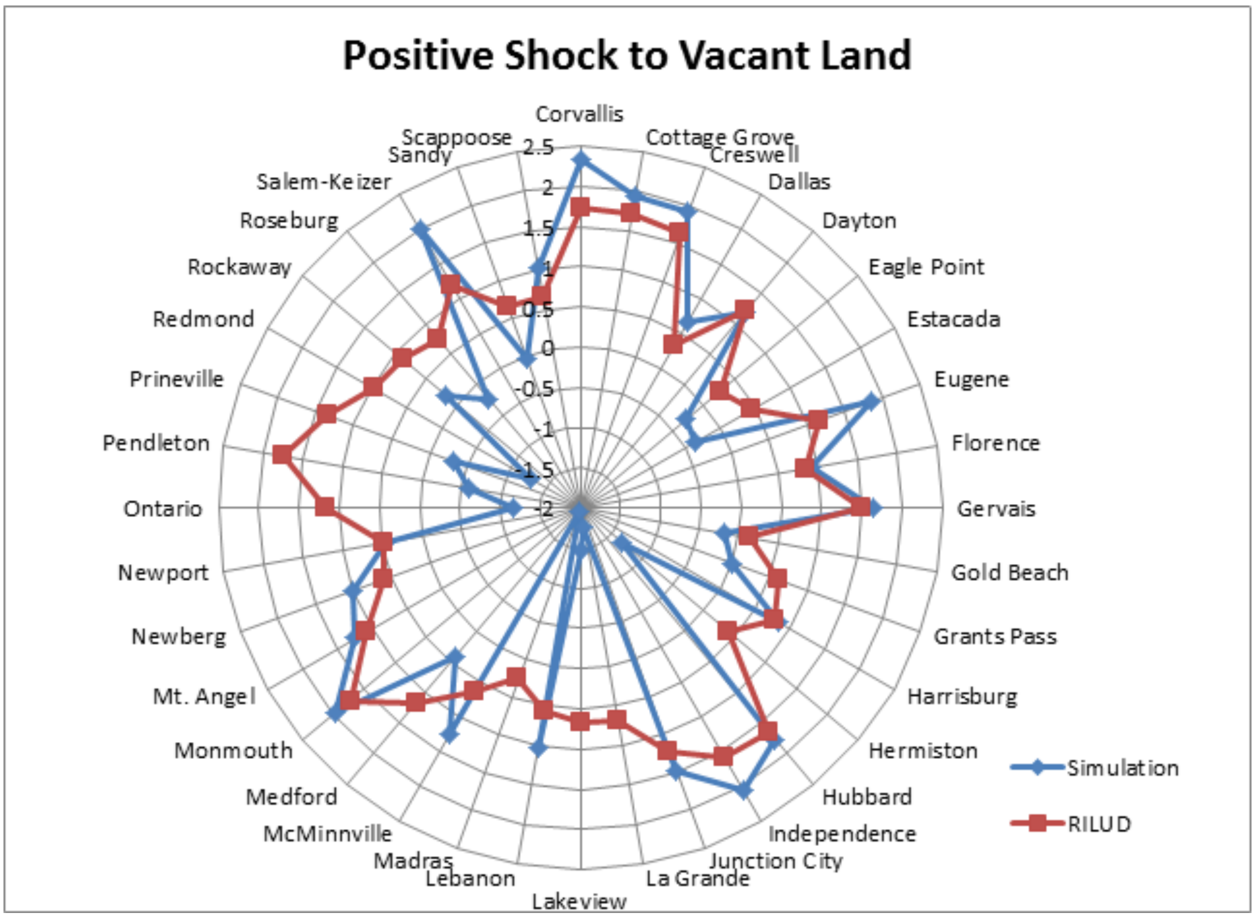
10. PRACTICAL USES

Uses of RILUD extend beyond the prediction capacity on which this paper has focused. For example, given a population forecast or projected industry growth, RILUD can execute density estimations. Also, with population and industry forecasts, a jurisdiction can estimate the rate at which vacant land should be used to maintain a benchmark density. The breadth of index applications is limited to the imagination and the included characteristics. Other applications of

RILUD include scenario analyses and contingency densities. In this section we simulate one such analysis, the implications of a shock to vacant buildable residential acres on residential density within the index.

To execute the simulation we multiplied the vacant residential land inventory for each jurisdiction by 2. We recalculated the interactions of vacant land with the industry variables and the agricultural regions (ODA) and imposed the estimated RILUD coefficients on the new data. Results are displayed below.



RILUD estimations are in red, simulation results are in blue. Let's examine two cities. Independence and Sandy have population densities of 2.8 people per UGB acre and 3.08 people per UGB acre respectively. As seen in the graph, a positive shock to vacant land increased the density in Independence while it decreased the density in Sandy. These two cities are similar in most measure, yet they differ significantly in their residential density, agriculture composition, and emergency health and social service industry. They are in the same agricultural region (ODA2) but different population growth regions (Independence: MKN3, Sandy: MKN2).

Consider two other cities, Cottage Grove, which increased in density in the simulation, and Madras, which decreased in density. Notable differences between these jurisdictions are the population density and residential density. Population densities for Cottage Grove and Madras are 2.99 and 1.71 people per acre. Their respective residential densities are 6.8 and 1.3 units per residential acre. [21]

These results suggest that the relationship between vacant land and residential density is not a straightforward, linear one. Rather, it shows that land-use density differs between jurisdictions and regions because of the different pressures from, and the complexities of land use demands. A rather intuitive implication of the simulation is that cities with higher initial densities are less susceptible to changes in vacant acres. More importantly, the simulation demonstrates that every jurisdiction reacts differently to factor shocks. Jurisdictions with characteristics similar to a jurisdiction in our sample might expect similar results from changes in vacant residential land.

This section demonstrates that an index such as RILUD can be used to inform a jurisdiction both in its own internal planning process and in its proposals for land use revisions subject to external review. Demonstratively, simulations on various UGB characteristics will emphasize the nature and possible results of changes in RILUD components.

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[21] Twenty-four jurisdictions out of the 55 jurisdictions in the sample increased in density an average of .35 points. This is approximately a 1.42:1 increase in residential units to residential acres. Twenty-three of the 24 regions that increased in density are located in ODA region 2. There are 30 jurisdictions in ODA2 in the simulation.

11. CONCLUSION

Urban growth boundaries are required for all Oregon jurisdictions with the purpose of containing urban sprawl and providing a twenty-year supply of land to accommodate growth. The identification of land need is an extremely important and complex process that is necessary for UGBs to continually serve their purpose. The inefficiency of the current process for UGB amendment is costly to the state and could be improved with the development of relative comparison indexes.

This study was constructed to demonstrate the potential of developing indexes to supplement the UGB expansion process. Using cross-sectional data, we constructed a relative index of land-use density (RILUD) controlling for the many idiosyncratic differences across Oregon UGBs. The objective behind building an efficient predictive model is to maximize goodness of fit by minimizing the root mean squared error. We were able to reduce the variance found in the raw data by half with our model as well as minimize the variance of model residuals. In other words, we developed a model with far more predictive power than possible using only raw data.

Using our model, factor shock simulations can be run that shed light on what impacts changes in factors might have for jurisdictions with certain characteristics. Changes in the level of a jurisdiction's industry mix, population or residential acres of vacant buildable land might particularly be of interest. Jurisdictions may also be interested in investigating, according to our model, what range of values variable characteristics should take in order to maintain certain residential densities.

The model we have constructed, along with our demonstration of its simulation functionality, indicates great promise for the development and use of future indexes. Future indexes could investigate and explain other factors, besides residential density, including spatial, income, and pricing characteristics. Subsequent investigations could streamline the UGB expansion process by informing Oregon jurisdictions in their own internal planning processes as well as in their proposals for land use revisions.

Because our index is built with cross-sectional data, its functions are constrained to developing benchmarks for UGB comparisons and running scenario analyses. While these functions are useful in informing land use planning, we see even greater function potential in indexes with time-series data. Such indexes could be used to make causal claims and have the ability to make literal predictions. The applications for these predictions are in the hundreds, from accurately estimating future factor levels to investigating the effectiveness of population forecasts. Current protocol for conducting land-use surveys is, however, problematic to the development of effective time-series data.

Efficiency of such indexes could be greatly improved if more consistent data on Oregon UGBs was collected. Two forms of consistency could make a large difference. Core data necessary for UGB analysis could be collected on a time-consistent basis across jurisdictions. This way, trends could be identified with far more precision and stronger predictive models backed by time-series data constructed. Data collected in each jurisdiction could also be made more uniform with more strict specifications. This would result in stronger consistency of data collected, allowing for enhanced precision and validity in analysis. Uniform storage of UGB survey documents would also be a boon to the efficient development of future studies.

In this study we focus on factors of demand, but an extension of our analysis could incorporate, and may find, that prices are equally indicative of a jurisdiction's density. As mentioned earlier, the opportunity cost of vacant land is largely to do with the land use demand and, subsequently, land value. Land prices could be a predictive variable of density; relatively higher-priced land is a result of high demand and proffers relatively high-density development. On the other hand, buyers looking to install land-intensive elements will seek out low-priced land and, thus, low-priced land is likely correlated with lower densities. A possible investigation might include a comparison of the price differential between downtown and suburban prices across jurisdictions.

Given more time, we would want to develop more in-depth controls for our model to better account for the literally thousands of idiosyncratic differences between Oregon jurisdictions. A stronger proxy for slope constraints in Oregon UGBs is one such control. Accounting for slope constraints could shed more light on what defining geological characteristics separate Oregon UGBs in their need for expansion. We would also be interested in examining how the inclusion of additional Oregon UGBs would improve the ability of our model to allow for reliable relative comparisons.

12. APPENDIX

Summary Statistics:

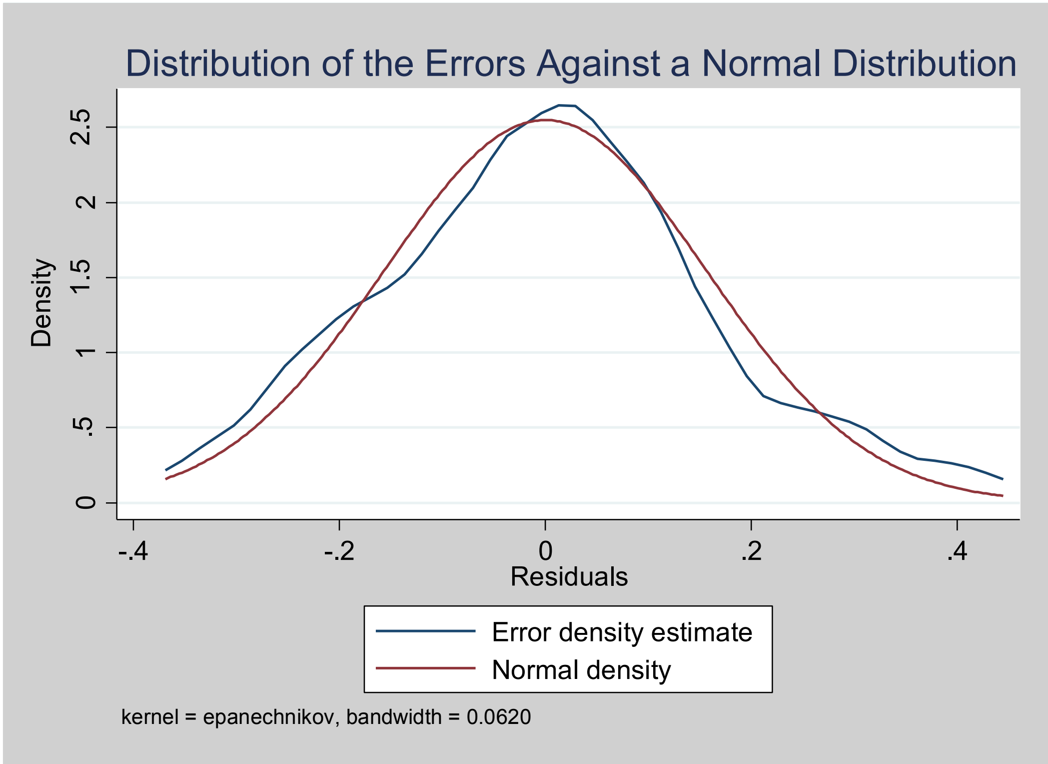
VARIABLES	N	Mean	sd	min	max
Agriculture, forestry, etc.	64	3.816	2.857	0	14.80
Construction	64	7.367	2.916	1.300	16.80
Manufacturing	64	14.21	6.441	3.100	27.50
Wholesale	64	2.861	1.544	0.600	8.600
Retail	64	13.24	2.703	7.500	20.20
Transportation and Warehousing	64	3.920	1.933	0.400	10.10
Information	64	1.677	0.963	0	4.600
Finance etc.	64	5.104	1.861	2	11.10
Professional, Scientific, etc.	64	6.893	2.663	2.100	14.60
Educational, Health and Social Services	64	20.50	5.526	5.400	37.10
Arts, Entertainment, etc.	64	9.958	4.298	2.600	25.60
Other Services	64	4.554	1.735	0.400	8.100
Public Administration	64	5.893	3.058	1.600	13.80
Log Pop	64	8.944	1.128	6.957	11.96
Res Units/ Res Acre	57	1.016	0.656	-1.041	2.555
Log of Vacant Res	62	6.069	1.298	2.493	9.360
Log of Distance to I5	64	2.959	1.815	-1.204	5.926
Log of UGB Acres	64	8.044	1.101	5.472	10.67

Regression Output:

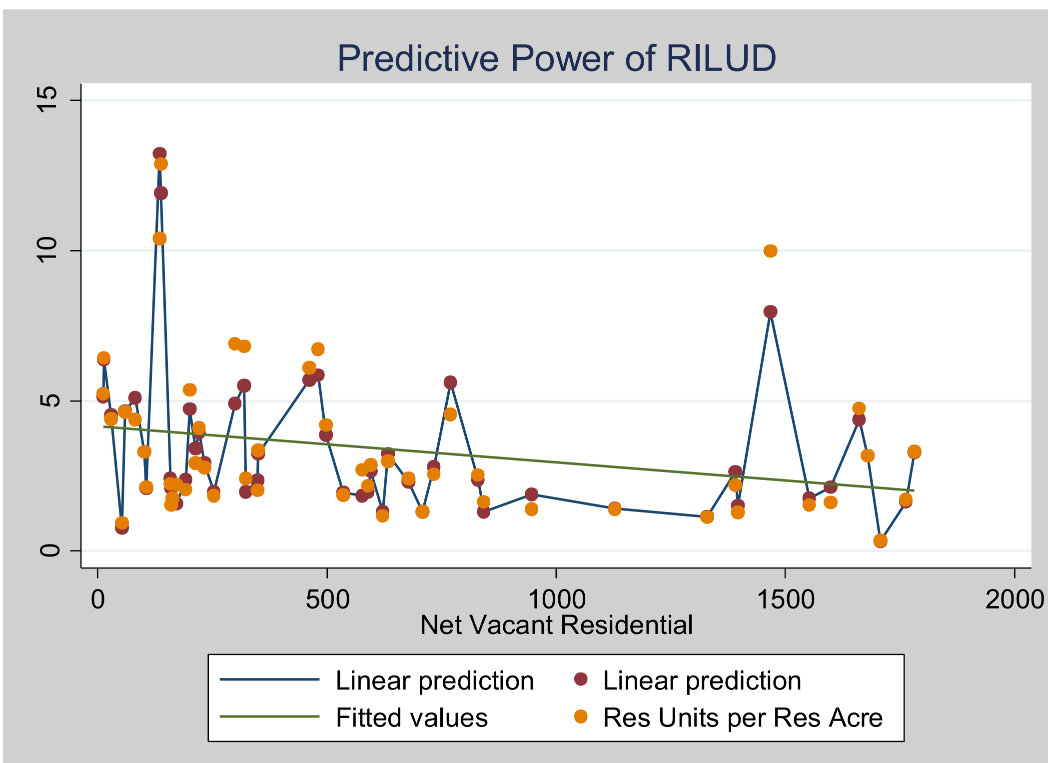
VARIABLES	(1) Res Units/Res Acre
Log Pop	3.589**
	(1.367)
Squared Log of Pop	-0.155*
	(0.0737)
Squared Log of Vacant Res	0.146***
	(0.0490)
Log of UGB Acres	-0.610**
	(0.219)
Log of Distance to I5	-0.248***
	(0.0725)
Log of Vacant Res	19.04***
	(5.297)
2.mkn#c.lnpop	0.0938
	(0.0595)
3.mkn#c.lnpop	-0.0405
	(0.0509)
4.mkn#c.lnpop	0.0761
	(0.0784)
5.mkn#c.lnpop	0.184
	(0.137)
6.mkn#c.lnpop	0.245*
	(0.125)
INT: ODA1 & Log Vacant Res	0.121
	(0.175)
INT: ODA2 & Log Vacant Res	0.127
	(0.214)
INT: ODA3 & Log Vacant Res	-0.0757
	(0.0982)
INT: ODA4 & Log Vacant Res	-0.0874*
	(0.0479)
INT: ODA5 & Log Vacant Res	-0.274***
	(0.0696)
INT: AGG & Log Vacant Res	-0.140**
	(0.0559)
INT: Construction & Log Vacant Res	-0.232***
	(0.0601)
INT: Manufacturing & Log Vacant Res	-0.269***
	(0.0640)
INT: Retail & Log Vacant Res	-0.136*
	(0.0682)
INT: Wholesale & Log Vacant Res	-0.126*
	(0.0598)

INT: Information & Log Vacant Res	-0.298**
	(0.130)
INT: Finance etc. & Log Vacant Res	-0.312**
	(0.114)
INT: Professional etc. & Log Vacant Res	-0.158**
	(0.0569)
INT: Social Services & Log Vacant Res	-0.182***
	(0.0592)
INT: Arts etc. & Log Vacant Res	-0.303***
	(0.0683)
INT: Other & Log Vacant Res	-0.376***
	(0.0883)
INT: Public Admin. & Log Vacant Res	-0.206***
	(0.0556)
Agriculture, forestry, etc.	1.076***
	(0.353)
Construction	1.525***
	(0.398)
Manufacturing	1.793***
	(0.411)
Wholesale	0.661*
	(0.347)
Retail	0.894*
	(0.438)
Information	1.977**
	(0.812)
Finance etc.	2.200**
	(0.764)
Professional, Scientific, etc.	0.982***
	(0.326)
Educational, Health and Social Services	1.251***
	(0.385)
Arts, Entertainment, etc.	2.086***
	(0.467)
Other Services	2.384***
	(0.540)
Public Administration	1.283***
	(0.352)
Constant	-147.5***
	(36.85)
Observations	55
Adjusted R-squared	0.787
rmse	0.307

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

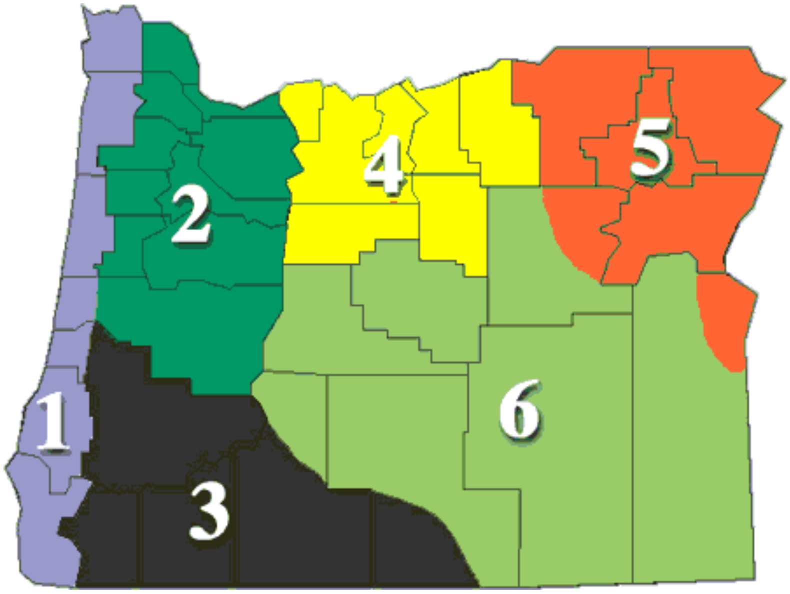


Distribution of the Errors Against a Normal Distribution
Density
0
.5
1
1.5
2
2.5
-.4
-.2
0
.2
.4
Residuals
Error density estimate
Normal density
kernel = epanechnikov, bandwidth = 0.0620



Predictive Power of RILUD
0
5
10
15
0
500
1000
1500
2000
Net Vacant Residential
Linear prediction
Linear prediction
Fitted values
Res Units per Res Acre

ODA Agricultural Regions:



PSU MKN Population Growth Regions:

MKN 1: Northwest
MKN 2: Metro
MKN 3: Valley
MKN 4: Southwest
MKN 5: Central
MKN 6: Eastern

"Oregon University System." *Future & Historical Enrollment*. N.p., n.d. Web. 08 June 2014. <http://www.ous.edu/factreport/enroll/futcur>.

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