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LAND DEVELOPMENT UNDER REGULATION: COMPARISON BETWEEN THE EAST AND WEST SIDES OF THE CASCADE RANGE IN OREGON, WASHINGTON, AND CALIFORNIA

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We compare how socioeconomic factors,physical landscape, profit uncertainty, and local land use policies have affected land development on the east and west sides of the Cascade Range in Oregon, Washington, and California. It is found that the west side has more actively planned and regulated land use than the east side. Consequently, the more intense land use regulations on the west side have reduced more land development than on the east side. Risks associated with alternative land uses as well as profits were important in land development decisions of both sides.

1. Introduction

In recent years, rapid land development and inefficient land use patterns have received much attention in the USA. Reported statistics such as: "Pace of farmland loss increased from 1.4 million acres a year between 1982 and 1992 to 2.2 million acres a year between 1992 and 1997" (US Department of Agriculture, 1999) or "One-third more land per person was consumed by urban uses in 1990 than 1970" (Daniels and Bowers, 1997) have changed Americans' perceptions about land development. Now, many people believe that American cities are no longer able to afford development frenzies without land use planning.

Although land use regulations are largely a local and regional issue (Daniels, 1999), few studies have focused on local land use regulations and policies. Those that do focus on land use policies tend to be case studies of specific programs in specific areas. For example, Bills and Boisvert (1987) analyzed the effectiveness of agricultural districts and use-value assessment in

New York. Henderson (1991) and McMillen and McDonald (1993) studied the effectiveness of zoning ordinances. Pfeffer and Lapping (1994) and Daniels (1998) studied the exchange of development rights in the northeastern USA. Lang and Hornburg (1997) studied urban growth management in Portland, Oregon. Kline and Alig (1999) reviewed the effectiveness of Oregon's land use planning program with regard to its protection of forests and farmland from development. These studies focused on individual land use regulations and policies. Relatively few studies have analyzed the combined effects of different land use regulations over a broad area. In this study, various land use regulations at county and state levels are examined for a large region using first-hand data from a comprehensive survey of land use regulations.[1]

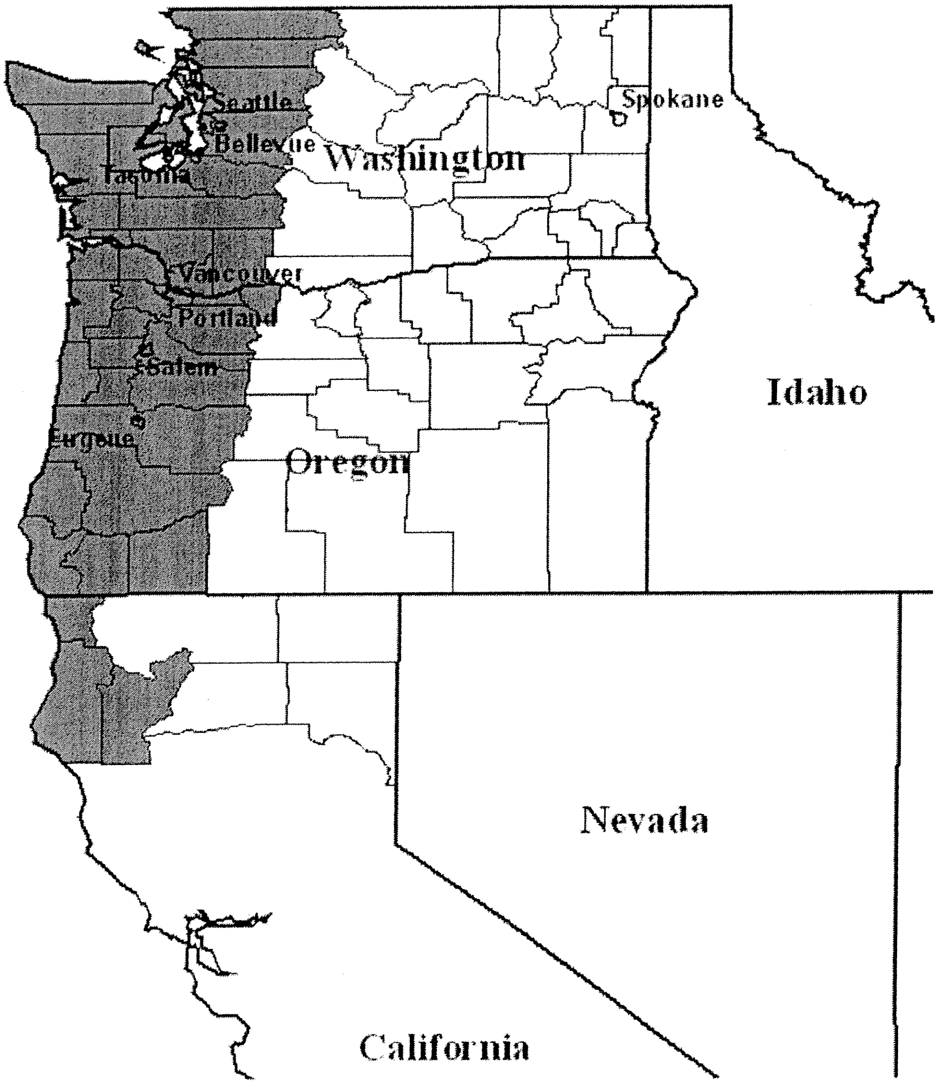
In this study, we compare land development and regulation between the west and east side of the Cascade Range in Oregon, Washington, and California. We estimate three sets of empirical models (one for the east side, one for the west side, and one for the entire region as a whole) to address the following questions: (i) given the dramatically different socioeconomic factors and physical landscapes, do land use changes differ between the two regions; (ii) to what extent do risks associated with alternative land uses affect land development; and (iii) do local land use policies and their influences differ between the west and east sides of the Cascade Range? The answers to these questions may help policymakers and local land use planners develop more effective policies for growth management.

The study region is shown in Figure 1. The west side of the Cascade Range includes 41 million acres (166,000 km^2) in 41 counties located west of the crest of the Cascade Range. The east side includes 82 million acres (332,000 km^2) in 41 counties located east of the crest of the Cascade Range. The area was selected because it reflects vastly different land development patterns and may serve as a microcosm for many land development patterns observed in other regions of North America. The analysis gives us unique insights into the differences and similarities of land development on each side.

The Cascade Range is a chain of mountains and volcanoes stretching from northern California, through Oregon and Washington State, and for a short distance into British Columbia. It is approximately 700 miles (1,100 km) in length, varying in width from 50 miles (80 km) in the southern and central parts to 120 miles (190 km) in the north. Its average height above sea level is approximately 5,000 feet (1,500 m). The Cascade Range, with its towering volcanoes and mountains, creates a substantial barrier between east and west. Rainfall levels are high west of the Cascades and in the mountains themselves. To the east of the Cascades rainfall is considerably less, and the southeastern part of Oregon is considered part of the Great Basin Desert. A large area east of the Cascades in Washington is used for agricultural purposes; it is known as the Inland Empire. The climate in the east has more extreme temperatures. Meanwhile, the west side experiences a milder climate. The Cascade Range has been a difficult barrier for people to cross. The only sea level passage is the Columbia River Gorge. The drastic climatic differences and the difficulties of crossing the mountains have caused human settlements to expand under the distinctive physical structures of the landscape and the socioeconomic conditions of each side. Consequently, land development patterns of the west and the east sides of the Cascade Range have been different. Between 1982 and 1992, the number of population for the west of the Cascades went from 5.7 million to 6.8 million, an increase of 19%. This increase is far greater

[1] Turner *et al.* (1996) estimated models of land cover changes for the Southern Appalachian Highlands and the Olympic Peninsula region of the USA. However, they did not address the issue of the institutional influences of land use policies.

Figure 1. West and east sides of the Cascase Range in Oregon, Washington, and California. Note: darker shaded areas represent counties in the west side and lighter shaded areas represent counties in the east side. All cities shown on the map have a population >100 000.



than increase for the east of the Cascades from 1.6 million to 1.7 million, an increase of 6% during the same period of time. Although each region shares some common factors influencing land development, they also have clear differences.

The remainder of this paper is organized as follows. In the next section, we present a model of land use conversion decisions. The subsequent section presents empirical specification of the model. Our descriptions of data and estimation results follow, and we close with a discussion of the results and their possible interpretation.

2. Model of land use conversion decisions

In this section we present a simple model to motivate our empirical analysis. Suppose a landowner is considering development of their farmland. We model his decision in a two-period framework: a first period followed by future time horizon compressed into a single second period. The landowner knows the profit from both farming and development in the first period, but is uncertain about the profit from farming and development in the second period.

Let π_i^f be the profit from farming in period i, and let π_i^d be the profit from development in period i. For the time being, we assume that the difference between profits from farming and development in the second period, $(\pi_2^d - \pi_2^f)$, can take two possible values: It takes a positive value (net gain), $\Delta\pi_2^g$, with probability of P and a negative value (net loss), $\Delta\pi_2^l$, with probability of $(1 - P)$. Land will be developed in the second period only if $(\pi_2^d - \pi_2^f)$ turns out to be $\Delta\pi_2^g$. Later on, we will relax this binary assumption to examine the degree of uncertainty on development decisions. All values from the second period are discounted.

Under the traditional net present value approach, the land should be developed if the net present value is positive:

$$NPV = (\pi_1^d - \pi_1^f) + [P\Delta\pi_2^g + (1 - P)\Delta\pi_2^l] > 0 \tag{1}$$

where $(\pi_1^d - \pi_1^f)$ is the net gain from development in the first period and $[P\Delta\pi_2^g + (1 - P)\Delta\pi_2^l]$ is the expected net gain from development in the second period. Alternatively, this decision rule can be written as:

$$\pi_1^d > \pi_1^f - [P\Delta\pi_2^g + (1 - P)\Delta\pi_2^l] \tag{2}$$

This decision rule works well when both profits from farming and development are relatively certain and there is no time available to defer development. However, when development can be revised at the start of second period, based upon information that has accumulated concerning profits in the first period under uncertainty in the second period, this decision rule would lead to over-development because it ignores the option value from the flexibility of not developing the property if the decision is postponed and if the net benefit from development turns out to be negative. To derive this result, suppose the landowner waits a period before making the development decision. In this case, the expected net gain would be

$$NPV = (\pi_1^f - \pi_1^d) + P\Delta\pi_2^g \tag{3}$$

where $(\pi_1^f - \pi_1^d)$ is the net gain from farming in the first period. However, if the landowner makes the development decisions in the first period, the expected net gain would be given by (1). Thus, the landowner should develop their land in the first period if and only if (1) is greater than (3). Setting (1) to be greater than (3) and rearranging terms, we obtain the following optimal decision rule for land development:[2]

$$\pi_1^d > \pi_1^f - \frac{(1-P)\Delta\pi_2^l}{2}. \tag{4}$$

The right-hand side of (4) is greater than the right-hand side of (2) because $P\Delta\pi_2^g > 0$. This suggests that too much land would be developed if the option value from the flexibility to defer the development is ignored in making development decisions. The difference between the right-hand side of (2) and the right-hand side of (4) is called the value of "flexibility option", which is what the landowner should be willing to pay for the development opportunity in the second period (Dixit and Pindyck, 1994).

To examine the effect of the degree of uncertainty on development decisions, we assume that the net gain from development in the second period, $(\pi_2^d - \pi_2^f)$, takes a normal distribution, $N(\Delta\pi_2^e, \sigma^2)$ instead of only two possible values, and that the landowner will develop the land in the second period only if $\pi_2^d > \pi_2^f$. The following truncated mean values are obtained based on the theorem of moments of the truncated normal distribution (Greene 1997, pp. 718).

$$E\left[\pi_2^d - \pi_2^f \middle| \pi_2^d > \pi_2^f\right] = \Delta\pi_2^e + \frac{\sigma\phi(\alpha)}{1-\Phi(\alpha)}, \tag{5}$$

$$E\left[\pi_2^d - \pi_2^f \middle| \pi_2^d < \pi_2^f\right] = \Delta\pi_2^e - \frac{\sigma\phi(\alpha)}{\Phi(\alpha)}, \tag{6}$$

where $\alpha = -\Delta\pi^e{}_2/\sigma$, and $\phi(\cdot)$ and $\Phi(\cdot)$ is the probability and cumulative distribution functions of the standard normal distribution, respectively. If the landowner develops the land in the first period, the expected net present value is

$$\begin{aligned} NPV &= \left(\pi_1^d - \pi_1^f\right) + P\left[\pi_2^d > \pi_2^f\right] \cdot E\left[\pi_2^d - \pi_2^f \middle| \pi_2^d > \pi_2^f\right] + P\left[\pi_2^d < \pi_2^f\right] \\ &\quad \cdot E\left[\pi_2^d - \pi_2^f \middle| \pi_2^d < \pi_2^f\right] = \left(\pi_1^d - \pi_1^f\right) + (1-\Phi(\alpha))\left[\Delta\pi_2^e + \frac{\sigma\phi(\alpha)}{1-\Phi(\alpha)}\right] \\ &\quad + \Phi(\alpha)\left[\Delta\pi_2^e - \frac{\sigma\phi(\alpha)}{\Phi(\alpha)}\right] = \left(\pi_1^d - \pi_1^f\right) + \Delta\pi_2^e \end{aligned} \tag{7}$$

However, if the landowner makes the development decision in the second period, the expected net present value is

$$\begin{aligned} NPV &= \left(\pi_1^f - \pi_1^d\right) + P\left[\pi_2^d > \pi_2^f\right] \cdot E\left[\pi_2^d - \pi_2^f \middle| \pi_2^d > \pi_2^f\right] + P\left[\pi_2^d < \pi_2^f y\right] \cdot 0 \\ &= \left(\pi_1^f - \pi_1^d\right) + (1-\Phi(\alpha))\left[\Delta\pi_2^e + \frac{\sigma\phi(\alpha)}{1-\Phi(\alpha)}\right] \end{aligned} \tag{8}$$

[2] When the underlying development decision is irreversible, as are most development decisions involving the conversion of land from agricultural to urban use, the use of a certainty framework will bias results about when land should be developed. Indeed, as we learn from this optimal decision rule, uncertainty will generally impart as option value to undeveloped land, and delay the development of land from, say, agricultural to urban use. Consequently, if we are to understand when land should be developed in the presence of irreversibilities, it is imperative that we explicitly account for uncertainty.

Note that the landowner will develop the land in the second period only if the net gain from development, $(\pi_2^d - \pi_2^f)$, turns out to be positive. The optimal decision rule for development in the first period is obtained when (7) is set to be greater than (8):

$$2(\pi_1^d - \pi_1^f) - \sigma\phi(\alpha) + \Phi(\alpha)\Delta\pi_2^e > 0. \tag{9}$$

Note that the left-hand side of (9) is a decreasing funtion of σ because its derivative with respect to σ, $-\phi(\alpha)[1 + (\pi_2^e/\sigma)^2]$, is negative. This suggests that the greater the uncertainty about profit from development in the future, the less likely that land is developed in the current period. This decision rule indicates that current development decision is a function of expected profits from both farming and development as well as the variance of profits in the future.

3. Empirical specification

To derive an empirically applicable mode of land use conversions, we rewrite the optimal decision rule (9) as:

$$2(\pi_1^d - \pi_1^f) - \sigma\phi(\alpha) + \Phi(\alpha)\Delta\pi_2^e = f(x) + \varepsilon > 0, \tag{10}$$

where an error term, ε, is added to capture the unobserved variations in landowner tastes and other random variables; $f(x)$ is a vector of variables affecting the landowner's development decisions, including those affecting π_1^d, π_1^f, σ^2, and $\Delta\pi_2^e$. Our analysis is based on the land use share model that has been used in various land economic literature. The model estimates land use shares as functions of variables affecting land use allocations. The share equation can be assumed to take a logistic form (Tyrrell and Mount, 1982; Considine and Mount, 1984; Chavas and Segerson, 1986; Considine, 1990; Wu and Segerson, 1995; Hardie and Parks, 1997; Ahn *et al.*, 2000). This body of work corroborates and extends the VonThunen theory[3] and highlights how economic factors and physical landscape features influence land use allocations. The model is easily applied to spatially broad units such as counties and county groupings. We apply share equations to the west side and the east side of the Cascade Range. Equations are estimated for each side separately and both sides together. In discrete choice models, ε is typically assumed to follow the logistic or normal distribution. Our equations are assumed to take the logistic form

$$P = \frac{e^{f(x)}}{1 + e^{f(x)}}, \quad (1 - P) = \frac{1}{1 + e^{f(x)}} \tag{11}$$

where P is the probability that the land is converted, $(1 - P)$ is the probability that the land remains unconverted, and $e^{f(x)}$ is the exponential function of explanatory variables. By taking a log of the ratio of the two equations, we get

$$\log\left(\frac{P}{1 - P}\right) = f(x). \tag{12}$$

[3] Von Thunen's theory asserts that land values will be highest near the central market and decrease with distance away from the center. Intensity of land use will also be greatest near the center and decrease with distance away from the center.

In empirical applications, P and $(1 - P)$ are often estimated as the shares of land converted and unconverted, respectively. Thus, $P/(1 - P)$ equals the ratio of acres converted to acres unconverted in a county. The three share equations are specified for conversions of non-urban to urban land, farmland to non-farmland, and forest land to non-forest land as a function of explanatory variables. The functional form, $f(x)$, is assumed to be linear. We estimate the following three land share equations for the west side, the east side, and the entire region:

$$\log(CU_{jt}/RN_{jt}) = X_{jt}\gamma + \nu_{jt} \tag{13}$$

$$\log(NA_{jt}/RA_{jt}) = X_{jt}\beta + u_{jt}, \tag{14}$$

$$\log(NF_{jt}/RF_{jt}) = X_{jt}\eta + \varepsilon_{jt}, \tag{15}$$

where

$CU_{jt} =$ acres of non-urban land converted to urban land in county j in period t
$RN_{jt} =$ acres of non-urban land remaining in non-urban uses in county j in period t,
$NA_{jt} =$ acres of farmland converted to non-farmland in county j in period t,
$RA_{jt} =$ acres of farmland remaining in farm uses in county j in period t,
$NF_{jt} =$ acres of forest land converted to non-forest land in county j in period t,
$RF_{jt} =$ acres of forest land remaining in forest uses in county j in period t,
$\gamma, \beta, \eta =$ vectors of parameters to be estimated,
$X_{jt} =$ explanatory variables in county j in period t,
$t =$ periods of 1982–1987 and 1987–1992, and
$\nu_{jt}, u_{jt}, \varepsilon_{jt} =$ error terms.

Farmland includes cultivated cropland, non-cultivated cropland, pastureland, and rangeland. Urban land includes urban and built-up land. Land that is not classified as farmland, forest land, and urban land is categorized as other land. Non-urban land refers to the combined group of farmland, forest land, and other land. Non-farmland refers to the forest land, urban land, and other land. Non-forest land refers to farmland, urban land, and other land.

Acreage elasticities with respect to a vector of parameters can be estimated using estimates from the equations (13), (14), and (15). For example, acreage elasticities of non-urban land converted to urban use with respect to X in county j in the period t are calculated using

$$e_{jtX} = \frac{\partial CU_{jt}}{\partial X_{jt}} \cdot \frac{X_{jt}}{CU_{jt}} = -\left(\frac{RN_{jt}}{CU_{jt} + RN_{jt}}\right) \cdot \gamma_X \cdot X_{jt} \tag{16}$$

where γ_X is the coefficient of X. We estimated the elasticities evaluated at the means of the non-dummy variables. The acreage elasticity of a dummy variable, from zero to 1 when holding all other variables at their mean values, is given as the difference between the elasticity, with the dummy variable set equal to 1, minus the dummy variable at zero. Similarly, acreage elasticities with respect to a vector of parameters for the farmland conversion and the forest land conversion models are calculated in the same way.

One potential problem of the estimation is heteroscedasticity, which is likely to occur because of variations in county size, land use history, and land characteristics across counties.

The null hypothesis of no heteroscedasticity is tested using the Lagrange multiplier (LM) test (Greene, 1997, pp. 653–58). The null hypothesis is rejected at the 1% significance level for each equation. This suggests that the three land conversion equations should be estimated simultaneously. Because heteroscedasticity appear to be present, the three land conversion models were estimated using the Seemingly Unrelated Regression procedure. This procedure is appealing because it corrects for heteroscedasticity and contemporaneous correlation at the same time.

Because the east and the west sides of the Cascade Range are so different in terms of socioeconomic and physical characteristics, the Chow and Wald tests[4] were conducted to check whether the regression coefficients may be regarded as constant over the west and the east sides of the Cascade Range. A Chow test is a particular test for structural change; an econometric test to determine whether the coefficients in a regression model are the same in separate subsamples. In reference to a paper of Chow (1960), "the standard F test for the equality of two sets of coefficients in linear regression models" is called a Chow test. The Chow test was used to test for structural change in some or all of the parameters of the model where the disturbance term was assumed to be the same in both sides. If they are not the same, the Chow test proves the existence of structural break between the west and the east sides. The Wald test is used to assess the statistical significance of the set of parameter estimates for a given variable. Specifically, it tests the hypothesis that each of the parameter estimates in that set equals zero. For our regression models, the Wald test checks the equality of each set of regression effects across the west and the east sides.

The equations are estimated to compare and test the influential factors of the land conversions for each side of the Cascades. The explanatory variables of the equations are chosen based on the optimal decision rule of equation (10) in the previous section. The equation indicates that expected profits from both farming and development as well as the variance of profits in the future affect current development decisions. The previous studies used other independent variables that affect the expected profits from both farming and development because the expected farm profits and housing prices in the future are difficult to measure. The other variables include average income, distance to the center of the closest metropolitan center, land quality, current housing prices, and farm profits. We used the expected variance of housing prices, the expected variance of farm profits, and covariance between farm profits and new housing values to reflect the variance of profits in the future as indicated in the decisions rule. Local land use regulations are incorporated in the model to reflect institutional factors involving land development.

4. Data

4.1 Land uses

Data on land use were taken from the 1982, 1987, and 1992 National Resource Inventory (NRI). The NRI divides land use into 11 major categories, which were grouped into four

[4] Schmidt and Sickles (1977) showed that the Chow test under heteroscedasticity overestimates the significance level and the test becomes less accurate as the variances become more different. Toyoda and Ohtani (1986) and Ohtani and Toyoda (1985) showed that the Wald test for testing equality of sets of regression coefficients in two linear regression under heteroscedasticity is quite likely to overestimate the significance levels of the t-test statistics of all coefficients.

major categories in this study (farmland, forest land, urban land, and other land). The four major categories are used in the three land conversion models, as we described in the empirical specification.

Urban land accounts for 4% of the total land area on the west side of the Cascade Range, but less than 1% on the east side in 1992. The difference in urban land use between the two sides has increased throughout the years. This reflects the fast-growing population on the west side in the last few decades. There was more forest land on the west side than on the east side, but the difference narrowed between 1987 and 1992 because of the increasing conversions of farmland and other land into forest land on the east side and the development of forest land on the west side. This indicated that area of forest land on the east side has increased recently while forest land on the west side has been more vulnerable to development.

Total farmland acreage on the east side is eight times larger than that on the west side. Total farmland acreage decreased on both sides of the Cascade Range, yet it decreased at a decreasing rate on the east side. The increasing rate of farmland loss on the west side is consistent with fast-growing land development on the west side.

4.2 Land quality, location, and socioeconomic variables

Data on average wages were obtained from the Bureau of the Census. Data on average farm profits per acre were obtained from the Census Bureau's *Regional Economic Information System: 1969–1997*. Data on the average price of new housing units were obtained from *USA Counties 1996* on CD-ROM, prepared by the Bureau of the Census. Average wages, farm profits per acre, and the average prices of new housing units for 1982, 1987, and 1992 were adjusted according to the consumer price index to 1982 dollars. All socioeconomic variables on the west side are greater in value than those on the east side. The gaps have increased consistently throughout the years. The average wage has increased, at an increasing rate on both sides. Farm profits per acre on the west side almost doubled between 1982 and 1987. Throughout the years, farm profits per acre on the west side have been more than three times those on the east side. This shows that there is a large difference in farming intensity and the types of crops grown between the two sides. Farm profits per acre decreased between 1987 and 1992 on the east side. This reflects, in part, the severe drought in the area in 1992.

We estimated distance from the geographical center of each county (defined as the cross point of the median latitude and longitude) to the center of the closest metropolitan area (defined as a city with more than 100,000 people), and to the center of the closest "wildland" type national park (national parks located in a wildland area, e.g. Crater Lake National Park) defined by the National Parks classification system. Information about the latitude and longitude of the geographical center of each county, the closest metropolitan area, and the closest national park were collected from the National Association of Counties (NACo). The website, www.indo.com/distance, was used to measure the aforementioned distances, using the information of latitude and longitude from the NACo.

The average of land capability classes was calculated for each county, using the survey records of the land capability class at each NRI sample site. The Natural Resources Conservation Service (NRCS) divides land capability into eight classes, with 1 being the best-quality land and 8 being the worst-quality land. Weighted average values of land capability classes indicate that land quality is better overall on the west side than on the east side.

4.3 Local land use regulations

A survey of land use policies was conducted to obtain information about county land use regulations in five western States (California, Idaho, Nevada, Oregon, and Washington). The survey, conducted between August and October 1999, was sent to all county land use planners or equivalent positions in the five western States. The survey asked whether each land use regulation had been enacted by 1982, 1987, and 1992, to match available NRI data.

The overall response rate for the survey was 69%. The counties of Washington had the highest response rate (87%), followed by Oregon (78%). Thirty-one of 41 counties on the west side and 34 of 41 counties on the east side responded to the survey. Among land use policies, the number of counties with county comprehensive plans and urban growth boundaries increased by 30% on both sides between 1982 and 1992. The number of counties with agricultural zoning, forestry zoning, rural residential zoning, open space zoning, and on-site septic ordinances increased by 20% on both sides between 1982 and 1992. A brief description of these local land use regulations is provided in Table 1.

The number of counties with conservation zoning on the west side has doubled and remained at twice as many as those on the east side, throughout the survey years. Minimum parcel size has been the most popular local means of land zoning and ordinances on the east side. Developer exaction and dedication has been the most popular method of land acquisition; it increased by 20% on both sides. The number of counties with fee-simple purchase increased by more than 30% on the west side, while just one more county adopted it on the east side between 1982 and 1992. Preferential property taxation has been the most popular incentive-based management method; it increased by 20% on both sides between 1982 and 1992. Environmental impact assessments have been used widely on both sides. More counties on the west side adopted special assessments and impact fees. The specific goals of those counties' land use policies are described in Table 1.

It is a challenge to incorporate all land use regulation information into the empirical analysis because there are many forms of land use regulations. Some regulations, however, have similar effects on land use. We screened regulatory variables for use in the empirical analysis by first eliminating land use regulations that were ineffective, according to the county land use planners. Second, we created dummy variables for the remaining regulations, according to the enactment year. The autocorrelations among the dummy variables were tested. If two dummy variables are highly correlated, the one that is less effective according to land use planners was eliminated. Third, the remaining variables were included in the empirical models. Those variables insignificant at the 10% level were dropped. After the three-step procedure, three regulatory variables were left. These were county comprehensive plans, agricultural zoning, and forestry zoning.

In addition to the county land use policies, the land use policy of mandatory review of a project involving farmland conversion at the state level was included in the model. Washington is the only State that has a mandatory review of projects involving farmland conversion. A summary of the variables used in this empirical analysis is given in Table 2.

5. Estimation results

The hypothesis that all regression coefficients are not different for the west and the east sides of the Cascade Range was tested with the Chow test. All F-values for land development,

Table 1. Specific goal of county land use policy

Land Use Policy	Goal
County comprehensive plan	To set a vision and to guide development based on population projections and future land-use needs.
Urban growth boundary	To set a limit on the extension of urban-type services such as public sewer and water, while identifying enough buildable land for 10–20 years.
Agricultural zoning	To separate farming activities from conflicting non-farm land uses. To protect a critical mass of farms and farmland.
Forestry zoning	To protect a critical mass of commercial timberland. To separate forestry operations from conflicting non-forestry land uses.
Rural residential zoning	To provide an area for nonfarm and non-forest housing in the countryside. Usually will have a 3- to 5- acre minimum lot size.
Conservation zoning	To protect sensitive lands. May take the form of large-lot zoning or an overlay zone. For example, floodplain overlay is a health and safety issue.
Open space zoning	To concentrate buildings on part of a property while maintaining a significant amount of open space. Sometimes used to allow developers a bonus of more buildings on a site.
On-site septic ordinances	To ensure proper installation and maintenance of on-site septic systems. To protect water quality and health.
Minimum parcel size	To set a maximum limit on the size of residential lots.
Developer exaction and dedication	To require developers to provide parks, streets, and even school space or cash in lieu of facilities return for development approval.
Fee simple purchase	To acquire property for public use, e.g. parkland.
Preferential property taxation	To encourage owners of farm and forestlands to keep their lands in those uses. To encourage the maintenance of historic properties.
Environmental impact assessment	To assess the likely effects of development on water, air, and land resources. To look at alternative sites for proposed development.
Special assessment and impact fees	To place the cost of certain public facilities, such as the extension of public sewer or water service, on the landowners in a specific area.

Source: Daniels, 1999.

2.72; farmland loss, 2.65; and forest land loss, 2.13, are greater than the critical value, 1.77. Therefore we would reject the hypothesis that all the regression coefficients are not different for the west and the east sides of the Cascade Range at the 5% level for all three models. We also tested the hypothesis using the Wald test.[5] The Wald value for land development, 31.24; farmland loss, 30.02; and forest land loss, 29.89, is greater than the critical value from the χ^2 table, 27.59. So we also reject the hypothesis based on the Wald test. Based on these two tests,

[5] If the sample is reasonably large, we can do a valid Wald test to check if the disturbance variances of the west and east sides are same. However, in a small or moderate-sized sample, the Wald test has the problem that the probability of a Type I error is persistently larger than the critical level. The number of observations of our data may or may not meet the standards of the Wald test.

Table 2. Summary of variables

Variable	Definition	Mean	
		West	East
Socioeconomic Variables			
Farm profit ($)	Farm profit per acre at the beginning of the period	14.1	2.6
New housing value ($1,000)	Value of private new housing units at the beginning of the period	109.8	61.6
Average wage ($1,000)	Salary of the five year average	20.3	17.5
Risk Variables Variance of farm profit	Variance of farm profit at the beginning of the period	12.1	10.7
Variance of new housing value	Variance of housing value at the beginning of the period	53.1	21.3
Covariance between farm profit and new housing value	Covariance between farm profit and new housing value at the beginning of the period	472.0	454.2
Land Use Policies County comprehensive plan	A dummy variable for the county comprehensive plan at the beginning of the period	0.8	0.8
Agricultural zoning	A dummy variable for the agricultural zoning at the beginning of the period	0.3	0.3
Forestry zoning	A dummy variable for the forestry zoning at the beginning of the period	0.2	0.1
State planning	A dummy variable for the state land use planning at the beginning of the period	0.9	0.7
Mandatory review	A dummy variable for mandatory review of project involving farmland conversion at the beginning of the period	0.3	0.2
Land Quality and Location Variables Land capability class	Weighted average of land capability class with 1 being the best land and 8 being the worst land	4.5	4.9
Distance to the closest metropolitan center (mile)	Distance from the geographic center of a county to the closest metropolitan center (population $\geq$ 100,000)	56.7	108.6
Distance to the closest wilderness national park (mile)	Distance from the geographic center of a county to the center of the closest wilderness national park	78.9	72.4

we conclude that we should estimate separate models for the east and west sides of the Cascade Range.

Using the estimated coefficients and the mean values of the variables, acreage elasticities with respect to socioeconomic variables, risk variables, land use policies, land quality, and location variables were calculated using equation (16) for land development, farmland loss, and forest land loss. The results are presented in Tables 3–5, respectively. The goodness of fit of the three models on the west, east, and entire area ranges between 0.65 and 0.75. The goodness of fit and overall statistical significance show that the models perform better for the west side than on the east side.

Table 3. Estimated acreage elasticities from the land development model

Variables	West Side	East Side	Pooled
Socioeconomic Variables			
Farm profit	−0.016***	−0.011***	−0.013**
New housing value	0.031***	0.024**	0.027***
Average salary	0.215**	0.097*	0.102**
Risk Variables			
Variance of farm profit	0.021*	0.014	0.016*
Variance of new housing value	−0.096***	−0.055**	−0.089**
Covariance between farm profit and new housing value	−0.036**	−0.023	−0.031*
Land Use Policies at the Beginning of the Period			
County comprehensive plan	−0.058**	−0.020*	−0.031**
Agricultural zoning	−0.275***	−0.211***	−0.246***
Forestry zoning	−0.210**	−0.115**	−0.163**
Mandatory review	−0.033***	−0.019**	−0.041**
Land Quality and Location Variables			
Land capability class	−0.041***	−0.028**	−0.035***
Distance to the closest metropolitan center	−0.274***	−0.218*	−0.252***
Distance to the closest wildland national park	0.007**	0.013***	0.012**
System weighted R^2	0.75	0.66	0.72
F statistic = 2.72			
Wald statistic = 31.24			

Note: *significant at 10%; **significant at 5%; ***significant at 1%.

The acreage elasticities with respect to farm profits and new housing values from all three models are significant at the 5% level, for both sides of the Cascade Range. A decrease in farm profits causes more farmers to give up their land for development. An increase in new housing values provides developers with greater incentive for development. The positive elasticity of farm profits on forest land loss implies that developers look for alternative land to develop when development on farmland is more costly. This shows that forest land development is a substitute for farmland development. Higher income draws more development on both sides; but the acreage elasticities with respect to income are greater and more significant on the west than on the east side. This implies that an increase in income will attract more development on the west side than on the east side.

The acreage elasticities with respect to the variance of farm profits are positive and significant at the 5% level in the farmland loss model for both sides, while they are negative and significant at the 5% level on the west side in the forest land loss model. The variance of farm profits reflects the risks associated with farming. It has a significant influence on farmland loss on both sides. It also affects forest land conversions on the west side. Increasing uncertainties about farm profits increase farmland loss, but decrease forest land loss. This provides another piece of evidence that forest land development is a substitute for farmland development. The influence of variance of new housing values is negative and significant at the 5% level in all three models. The variance of new housing values is more significant than the variance of farm profits. This suggests that developers are more concerned with risks associated with housing prices than with farm profits.

The acreage elasticities with respect to the covariance between farm profits and new housing values are negative and significant at the 5% level in the land development and farmland loss models for both sides, and the influence is greater and more significant in the farmland loss

Table 4. Estimated acreage elasticities from the farmland loss model

Variables	West Side	East Side	Pooled
Socioeconomic Variables			
Farm profit	−0.214***	−0.119**	−0.149***
New housing value	0.419***	0.340**	0.382***
Average salary	0.167**	0.031*	0.102**
Risk Variables			
Variance of farm profit	0.024**	0.015**	0.019**
Variance of new housing value	−0.027**	−0.019**	−0.025**
Covariance between farm profit and new housing value	−0.059**	−0.004*	−0.043**
Land Use Policies at the Beginning of the Period			
County comprehensive plan	−0.030**	−0.018*	−0.022*
Agricultural zoning	−0.437***	−0.364***	−0.435***
Forestry zoning	0.091**	0.046**	0.76**
Mandatory review	−0.027**	−0.021**	−0.025**
Land Quality and Location Variables			
Land capability class	−1.610***	−1.558*	−1.521**
Distance to the closest metropolitan center	−0.418**	−0.283*	−0.324**
Distance to the closest wildland national park	0.015***	0.041***	0.026***
System weighted R^2	0.74	0.66	0.71
F statistic = 2.65			
Wald statistic = 30.02			

Note: *significant at 10%; **significant at 5%; ***significant at 1%.

Table 5. Estimated acreage elasticities from the forest land loss model

Variables	West Side	East Side	Pooled
Socioeconomic Variables			
Farm profit	0.034**	0.021**	0.016**
New housing value	0.021***	0.008**	0.015**
Average salary	0.016**	0.012*	0.014**
Risk Variables			
Variance of farm profit	−0.004**	−0.012*	−0.007*
Variance of new housing value	−0.062**	−0.024**	−0.044**
Covariance between farm profit and new housing value	−0.025*	−0.011	−0.016*
Land Use Policies at the Beginning of the Period			
County comprehensive plan	−0.023**	−0.016**	−0.019**
Agricultural zoning	0.093***	0.078***	0.084**
Forestry zoning	−0.402***	−0.212**	−0.345***
Mandatory review	−0.022***	−0.014***	−0.018***
Land Quality and Location Variables			
Land capability class	−1.438***	−1.651**	−1.599**
Distance to the closest metropolitan center	−0.419***	−0.294***	−0.336***
Distance to the closest wildland national park	0.026***	0.052***	0.033***
System weighted R^2	0.71	0.65	0.69
F statistic = 2.13			
Wald statistic = 29.89			

Note: *significant at 10%; **significant at 5%; ***significant at 1%.

model than in the land development model. These results may reflect the fact that counties with a high correlation between farm profits and new housing values are mainly agricultural counties. These agricultural counties may experience less land development and farmland loss than non-agricultural counties.

Acreage elasticities with respect to the land use policy variables indicate that implementation of county land use policies via county comprehensive plans, agricultural zoning, forestry zoning, and a state land use regulation of mandatory review negatively influence land development. These acreage elasticities are larger and more significant for the west side than for the east side. Although the two sides had approximately the same number of regulations, the regulations are more effective in controlling development on the west side than on the east side. The influence of agricultural zoning on land development and farmland loss is significant at the 1% level and is greater than the influence of any other regulation. This implies that agricultural zoning is more effective in the management of land development and farmland loss than the other regulations.

The elasticities with respect to forestry zoning in the three models show that forestry zoning reduces forest land loss, but it shifts land development to farmland. The positive and significant influences of agricultural zoning on forest land loss shows that agricultural zoning shifts development from farmland to forest land. Agricultural zoning unintentionally creates more forest land loss; likewise, forestry zoning unintentionally creates more farmland loss.

The mandatory review of projects involving land conversion for the state of Washington is shown to be effective in controlling land development, farmland loss, and forest land loss. This is an instance where land use regulation at the State level can be effective in reducing farm land loss, if it is well managed.

Acreage elasticities with respect to land quality and location variables for land development perform reasonably well. The influences of land capability class and distance to the closest metropolitan center on land development are significant at the 5% level on the west side. The influences are larger on the west side than on the east side. The influence of distance to the closest wildland national park in all three models for both sides is significant at the 5% level. The influence is larger on the east side than on the west side. The distance to the closest metropolitan center has a significant influence on all three land conversions, and the influence is larger on the west side. The larger influence on the west side is expected because there are fewer metropolitan areas on the east side of the Cascade Range. Likewise, the greater influence of the distance to wildland national parks on the east side is expected because of the greater number of wildland national parks in this region.

6. Conclusions

The west and east sides of the Cascade Range in Oregon, Washington, and California are dramatically different in terms of topographic features and socioeconomic characteristics. Thus, they offer an excellent "laboratory" to study the effects of land use regulations and other socioeconomic variables on land development.

We compared land development and regulation between the west and east sides of the Cascade Range and analyzed how differences in socioeconomic factors, physical landscape, profit uncertainty, and local land use policies had affected land development on the two sides. We found that land development was more responsive to changes in economic variables on the west than on the east side. For instance, an increase in income will attract more development on the west side than on the east side. In addition, the west side was more actively involved in land use planning and regulation than the east side. As a result, land use regulations reduced land development by a larger amount on the west side than on the east side. Development attracted to metropolitan centers and better land quality occurred more frequently on the west side than on the east side.

We also found common attributes of land development on both sides. Forest land development is a substitute for farmland development on both sides. Agricultural zoning is more effective in the management of land development and farmland loss than other regulations on both sides. Agricultural zoning effectively reduced farmland development, but inadvertently shifted development to forest land on both sides. Likewise, forestry zoning effectively reduced forest land losses, but inadvertently shifted development to farmland. The mandatory review of projects involving land conversions for the state of Washington shows that land use regulation at the state level can be effective in reducing farmland development.

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