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Evaluating land-use and private forest management responses to a potential forest carbon offset sales program in western Oregon (USA)

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ABSTRACT

We describe the use of linked land-use and forest sector models to simulate the effects of carbon offset sales on private forest owners' land-use and forest management decisions in western Oregon (USA). Our work focuses on forest management decisions rather than afforestation, allows full forest sector price adjustment to land-use changes, and incorporates time-dependent costs and restrictions of offset programs. The land-use model utilizes structure count data on some 21,000 plots spanning 30 years. The intertemporal optimizing forest sector model employs mill-level demand and FIA plot-level inventory. Our linked simulation modeling projects that an offset sales program could reduce forest land loss to development in western Oregon by about 4700 acres over the 2010–2060 simulation period for each $1 increase in the carbon price. At $10 per tonne CO_2, regional private carbon stocks would be roughly stabilized at current levels over the period to 2060. Rotations would lengthen on enrolled lands, as expected, but use of planting, thinning and uneven-aged management would decline.

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1. Introduction

Policymakers and the concerned public have emphasized the need for carbon emission mitigation programs to address climate change resulting from global use of fossil fuels (Metz et al., 2007). Among proposed approaches, carbon markets and carbon offsets have received significant attention. Carbon markets would establish and sell a supply of tradable emission permits, allowing industrial users of fossil fuels to emit a set amount of CO_2 as defined by the permits held. A forest carbon offset program would allow forest landowners to sell carbon emission permits in return for altering their forest area and/or its management in ways to sequester and store additional carbon. Carbon offset sales are of particular interest among forest policymakers because they would, in theory, provide financial incentives to owners to retain land in forest cover rather than convert it to non-forest and developed uses with attendant losses of an array of ecosystem services (Collins and Larry, 2007). The extent to which forest carbon offset sales programs would actually slow land shifts from forest to non-forest uses depends on the array of development opportunities available and the degree to which private landowners would respond to an offset sales program in their land-use and forest management decisions (Kline et al., 2009).

This research links land-use and forest sector models to simulate the effects of forest carbon offset sales on private forest owners' land-use and forest management decisions in western Oregon (USA). In this region, land shifts between agriculture and forestry have been minimal for the past several decades. As a result adaptation to an offset sales program will likely involve adjustments in rates of forest land shifted to development and changes in forest management practices. We simulate a hypothetical offset sales program that is similar in broad form to the Climate Action Reserve protocol (Climate Action Reserve, 2012). The analysis provides estimates of potential land-use trends (shifts of forest to developed uses), silvicultural decisions (including harvest age), timber stocks and harvest, and carbon offset supply outcomes in response to alternative carbon prices in the sales program.

2. Departures from previous studies

Richards and Stokes (2004), van Kooten et al. (2004) and Stavins and Richards (2005) provide excellent reviews of past studies of the costs and impacts of forest carbon offset sales (or carbon tax/subsidy) programs. Following Richards and Stokes (2004), these studies can be divided into engineering approaches, econometric land-use models, and forest-agriculture sector simulators. Engineering studies (e.g., Moulton and Richards, 1990; Parks and Hardie, 1995) develop, in effect, comparative cost evaluations of alternative carbon sequestration projects in forestry and/or agriculture. While they have been used to examine afforestation options on agricultural land, they do not provide a way for considering land use competition with development.

Applied econometric land-use models employ historical land-use data in empirical specifications derived from rent maximizing behavior

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to explain shifts in land among classes of use (e.g., Plantinga et al., 1999; Lubowski et al., 2006). Assuming that land-use responses to carbon offset revenues will be the same as historical responses to land rent changes (without carbon markets), land rents are adjusted by offset sales revenues and new land-use patterns (with associated carbon flux changes) are projected. Land use change is voluntary from a landowner's perspective in this context, and the models distill landowners' "revealed preferences" (e.g., Newell and Stavins, 2000). These studies model only afforestation and deforestation options and most have used highly simplified biological representations of the forest resource. Some have considered product price feedback to land rents in an approximate form (Lubowski et al., 2006, appendix A). Offset sales programs have generally been simulated as tax or subsidy payments and without formal treatment of the distinct contract costs and restrictions of such programs.

Forestry-agriculture sector models (e.g., Adams et al., 1999; Sohngen and Mendelsohn, 2003) employ the strong assumption of market surplus maximization to project land-use and production decisions in the two sectors where some portion of the joint land base can be employed in both forestry and agriculture. Land-use decisions are made to maximize land rents, given prices, costs and discount rate. With the exception of Latta et al. (2011), past approaches have treated enrollment as mandatory and not as a function of relative rent impacts. Land loss to urban and developed uses is generally treated as exogenous and invariant with rents in the endogenous sectors. Most models have employed some detail in the projection of forest growth and have addressed program responses in the management of existing stands and through afforestation and deforestation. Sector product price and output feedbacks on land rents are endogenous in these models. Offset sales programs have generally been highly simplified.

To simulate the reaction of land-use decisions to an offset sales program, we integrated elements of previous work using econometric land-use and sector models. The dominant land-use shifts in western Oregon are from forestry and agriculture to development, while forestry-agriculture land exchange is very limited. Changes in forest management (including rotation age) could be an important form of adjustment to offset sales. Accordingly, we viewed silvicultural options (regeneration, harvest form and timing) as important behavioral responses to carbon offset programs. And, since the short-term derived demand for logs and stumpage is estimated to be highly inelastic in western Oregon (Adams et al., 2002), we also considered product-price feedback to land rents as potentially important. The coupled land-use and forest sector model developed for this study extends past work in three ways: (i) it develops an equilibrium linkage of land-use and forestry production decisions including product price and land rent feedback; (ii) it employs a detailed land-use data base to model land shifts to development at the sub-county level; and (iii) entry into the offset sales program is voluntary and key details of the program are explicitly recognized, including time-dependent costs of participation and use-change restrictions arising from "permanence" constraints typical in program contracts.

3. Land-use model

Following work by Kline (2003) and Kline et al. (2003), we focus on the conversion of forest and agricultural land to developed uses, which is the predominant land-use change observed in western Oregon. Although conversions of land between forest and agricultural uses are possible, they are rare. Forest to agriculture conversions between 1974 and 2009, for example, totaled just 9000 acres for the entire state relative to a non-federal land base of nearly 29 million acres, with just 3000 acres of agricultural land converting to forest (Lettman et al., 2011: 53). Stability between forest and agricultural land uses in western Oregon owes largely to the unsuitability of remaining forest land for agriculture due to soils and topography, and the high rent-earning capacity of lands currently in agricultural uses relative to forestry.

Consistent with previous studies of undeveloped to developed land conversions, we assume landowners are land rent maximizers (Bockstael, 1996; Kline, 2003; Irwin et al., 2009; Irwin and Wrenn, 2014). Forest and agricultural landowners face a range of development opportunities regarding new housing, businesses, and industry. Their decisions among these opportunities are influenced by potential future rents to be earned from development relative to rents earned from forestry and agricultural uses. Rent maximizing decisions and the extent to which new buildings are observed are potentially restricted, however, by local zoning limitations and by topographic characteristics that affect the suitability of lands for development.

We used historical data on building count changes spanning three 10-year time periods (1974 to 1984; 1984 to 1994; 1994 to 2005) compiled by the Oregon Department of Forestry and USDA Forest Service using photo-interpretation of a systematic-random grid of sample points (Lettman et al., 2011). The data consist of 21,008 geo-referenced observations of building counts per 80 acres (80-acre circular areas centered on points) observed on non-federal lands at a sampling density of one point per 462 acres. A subset of these sample points includes detailed forest vegetation survey data (the FIA Forest Survey plots), which were used to develop the biological growth representation in the forest sector model.

Recognizing the importance of these multiple factors, we posit that owners pursue building construction over time on each sample plot so as to maximize expected land rents subject to restrictions of zoning ordinances and plot physiography. We employ a count regression model (Greene, 2012) to model empirically building counts over time. The dependent variable of our land-use model is an integer count of the change in number of buildings over each time interval (1974 to 1984, 1984 to 1994, and 1994 to 2005). Explanatory variables are agricultural and forestry returns (rents), a gravity index as a proxy for urban rents, baseline (1974, 1984, and 1994) measures of building counts, plot slope and elevation, zoning variables (developed, forest, and agriculture) to control for spatial and temporal variation in land-use zoning under Oregon's statewide system of land-use planning, and fixed effects

Table 1
Descriptions and means of the explanatory variables used in the land-use model describing forest and agricultural land development.

Variable	Description	Mean
GRAVITY INDEX	Gravity index computed at the beginning of each time-period (times 1/100,000).	1.496
BUILDINGS	Number of buildings within an 80-acre circle surrounding photo point at the beginning of each time-period (times 1/100).	0.017
SLOPE	Mean slope of the 80-acre circle surrounding the photo point (times 1/100).	0.119
ELEVATION	Mean elevation (meters) of the 80-acre circle surrounding the photo point.	0.349
DEVELOP ZONE	Percent of 80-acre circle surrounding the photo point zoned for development times the proportion of time-period with zoning law in effect (times 1/100).	0.035
AGRI ZONE	Percent of 80-acre circle surrounding the photo point zoned for agricultural use times the proportion of time-period with zoning law in effect (times 1/100).	0.153
FOREST ZONE	Percent of 80-acre circle surrounding the photo point zoned for forest use times the proportion of time-period with zoning law in effect (times 1/100).	0.266
AGRI RETURN	Net present value return in agricultural use measured in $ per acre (times 1/1000).	1.147
FOREST RETURN	Net present value return in forest use measured in $ per acre (times 1/1000) (SEV value).	0.466
DUMMY 1984	Variable equals 1 if observation describes building count change from 1984 to 1994; 0 otherwise.	0.333
DUMMY 1994	Variable equals 1 if observation describes building count change from 1994 to 2005; 0 otherwise.	0.332

Note: The full sample (n = 60,745) derives from 20,317 points in western Oregon tracked over 3 time-periods. Although a majority of points (21,008) were represented in all 3 time-periods, some were not. The panel thus is unbalanced.