How well can we predict land use?

Andrew J. Plantinga
Department of Agricultural and Resource Economics
Oregon State University
Why predict land use?

• Additionality
  – Government wants only to pay for activities that are additional (i.e., would not otherwise have happened)
  – When is additionality a concern?
    • Provision of an impure public good
      – Carbon sequestration from afforestation v. CCS
    • Public funds have opportunity costs
    • Government policy is limited to payments for desired actions
    • Asymmetric information
      – The government knows which landowners want to provide the environmental service, but cannot distinguish between additional and non-additional participants.
Asymmetric information
Asymmetric Information Problem

• Government cannot distinguish between additional and non-additional participants
  – Non-additional participants have an incentive to claim their actions are additional (moral hazard)

• Is it possible to identify the unobservable counterfactual (business-as-usual)?
  – Historical behavior
  – Econometric models
  – Policy design
Use data on historical behavior

• Assume that any departure from past behavior is additional
  – For example, landowner X had their land in crops for 10 years. They switched to forest following the introduction of a tree-planting subsidy.

• Potential problem
  – If historical participation is low, then it is likely that getting a high level of participation will be costly
  – In other words, in low-cost areas where a limited budget will go further, additionality is likely to be a greater concern
An area with low historical participation

Net benefits from participation

With the payment

Without the payment
An area with high historical participation
589 counties with no forest area change, 1982-1997
589 counties with the largest absolute changes in forest area, 1982-1997
Econometric models

• Estimate the relationship between land use and economic determinants (rents associated with different uses, soil quality, etc.).
• Plug the current values of determinants into the estimated econometric model to predict the counterfactual
Predictions of forest area


• Model of forest and agricultural land shares in Alabama estimated with panel data on counties
  – Explanatory variables include county average rents and land quality
  – OLS, fixed and random effects specifications
  – Out-of-sample forecasts evaluated
State-level predictions

Table 5. The accuracy of forest area forecasts from models estimated with data from 1964 to 1982.

<table>
<thead>
<tr>
<th>Forecast year</th>
<th>Model</th>
<th>State-level forest area (1,000 ha)</th>
<th>Theil’s inequality coefficient ($U$) and decomposition into proportions of inequality ($U^m$, $U^f$, $U^e$)*</th>
<th>$U$</th>
<th>$U^m$</th>
<th>$U^f$</th>
<th>$U^e$</th>
<th>$U^m+U^f+U^e$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>Actual</td>
<td>8,381</td>
<td></td>
<td>0.072</td>
<td>0.083</td>
<td>0.093</td>
<td>0.837</td>
<td>1.00</td>
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<tr>
<td></td>
<td>OLS</td>
<td>8,611</td>
<td></td>
<td>0.026</td>
<td>0.013</td>
<td>0.016</td>
<td>0.986</td>
<td>1.00</td>
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<tr>
<td></td>
<td>Dummy variables</td>
<td>8,364</td>
<td></td>
<td>0.077</td>
<td>0.008</td>
<td>0.112</td>
<td>0.895</td>
<td>1.00</td>
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<td></td>
<td>Error components</td>
<td>8,350</td>
<td></td>
<td>0.083</td>
<td>0.000</td>
<td>0.129</td>
<td>0.886</td>
<td>1.00</td>
</tr>
<tr>
<td>1992</td>
<td>Actual</td>
<td>8,433</td>
<td></td>
<td>0.075</td>
<td>0.039</td>
<td>0.123</td>
<td>0.852</td>
<td>1.00</td>
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<td></td>
<td>OLS</td>
<td>8,594</td>
<td></td>
<td>0.051</td>
<td>0.036</td>
<td>0.023</td>
<td>0.956</td>
<td>1.00</td>
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<tr>
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<td>Dummy variables</td>
<td>8,337</td>
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<td>0.083</td>
<td>0.000</td>
<td>0.129</td>
<td>0.886</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Error components</td>
<td>8,325</td>
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<td></td>
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</tbody>
</table>

* Theil’s inequality coefficient ($U$) and the proportions of inequality ($U^m$, $U^f$, and $U^e$) are defined in Equations (16) and (17), respectively.

For 1992, OLS estimate is off by 2%; fixed effects estimate is off by 1%
County-level forecast errors

Figure 1. A comparison of 1987 and 1992 forecast errors for OLS and dummy variables models estimated with data for 1964 to 1982.
Econometric models

• Ideally, we would make predictions for individual landowners. If models are estimated with individual-level data, we should expect significant prediction error at the individual scale.
  – Data limitations
  – Unobservable landowner heterogeneity

• At best, one could characterize distributions over business-as-usual actions conditioned on observables (e.g., county, soil quality)
Hypothetical distribution over b-a-u increases in forest area

Share of land converted to forest

Landowner X

Landowner Y
Baseline forest share distributions


<table>
<thead>
<tr>
<th>State</th>
<th>LCC I&amp;II lower</th>
<th>LCC I&amp;II upper</th>
<th>LCC III&amp;IV lower</th>
<th>LCC III&amp;IV upper</th>
<th>LCC V&amp;VI lower</th>
<th>LCC V&amp;VI upper</th>
<th>LCC VII&amp;VIII lower</th>
<th>LCC VII&amp;VIII upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL</td>
<td>0.010</td>
<td>0.485</td>
<td>0.209</td>
<td>0.658</td>
<td>0.600</td>
<td>0.856</td>
<td>0.528</td>
<td>0.812</td>
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<tr>
<td>MN</td>
<td>0.011</td>
<td>0.318</td>
<td>0.170</td>
<td>0.490</td>
<td>0.543</td>
<td>0.813</td>
<td>0.573</td>
<td>0.790</td>
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<tr>
<td>W. OR &amp; WA</td>
<td>0.002</td>
<td>0.441</td>
<td>0.159</td>
<td>0.684</td>
<td>0.358</td>
<td>0.920</td>
<td>0.129</td>
<td>0.830</td>
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</tbody>
</table>
Policy Design


• We design a menu of contracts for forestation (afforestation and avoided deforestation) involving a per-acre payment combined with a clawback (a lump-sum transfer).
  – Uses subsidies: total payment to each participating landowner is positive
  – Voluntary: landowners choose the contract they want, including possibly no contract
  – Assumes the government knows the distribution over landowner responses, but landowners have private information about individual responses
Empirical Results

- With contract approach, government pays only for additional forestation and its expenditures are considerably lower with than with a uniform payment to all landowners.

<table>
<thead>
<tr>
<th>State</th>
<th>Maximum forest area</th>
<th>Increase in forest</th>
<th>Government costs</th>
<th>Private costs</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Contracts</td>
<td>Subsidy</td>
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<tr>
<td>AL</td>
<td>28338</td>
<td>181</td>
<td>12.0</td>
<td>59.5</td>
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<tr>
<td>MN</td>
<td>42640</td>
<td>1262</td>
<td>84.5</td>
<td>163.0</td>
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<tr>
<td>Western OR &amp; WA</td>
<td>18788</td>
<td>7</td>
<td>0.4</td>
<td>8.0</td>
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Questions?