Modeling Salinity Costs to Agricultural Production

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Enforcenomics Workshop,
Claremont Hotel, Berkeley
January 10, 2008
What can we do with SWAP?

• Evaluate changes at the extensive and intensive margins:
  – EXTENSIVE
    • Changes in the total area of irrigated crops
    • Adjustments in the regional cropping mix.
  – INTENSIVE
    • A change in crop input use per acre
    • Changes in water application efficiency due to technology and management.
Yield Reduction by Salinity

\[ Y_r = \frac{1}{1 + \left(\frac{C}{C_{50}}\right)^P} \]

- **Crop** | **C_{50} (mS/cm)**
- Alfalfa | 6.85
- Field corn | 6.85
- Grain | 13.04
- Orchard | 4.13
- Pasture | 8.85
- Rice | 18.00
- Sugar beet | 13.04
- Tomato | 6.85
- Truck crop | 6.50
- Wine grape | 8.85

Here we used \( P=2.5 \) based on the crop mix empirical average.
Central Valley Salinity Study

- Estimate the effects of no action
- SWAP is used as an input for another model called REMI, to estimate regional effects
- Two Approachs
  - Analytical optimization model
  - Inductive econometric model
  - Salt accumulation estimations year 2030
Disaggregated Farm Level Data

Detail of Agricultural Land Use at CVPM 19

Legend
Land Use
Source DWR 1998 Survey Kern County
- Alfalfa
- Citrus
- Cotton
- Field Crops
- Grains
- Orchards
- Pasture
- Sugar Beets
- Grapes
- Truck Crops
- Other Crops
Kings County Salinity-Land Use

Legend

Salinity2001
EC_U_CM
- 0 to 2000
- 10000 to 20000
- 2000 to 4000
- 4000 to 10000
- greater than 20000

2003King
Land Use
- Citrus
- Deciduous
- Fallow Land
- Grain
- Idle
- Pasture
- Truck
- Vineyard
- Riparian Vegetation
- Native Vegetation
- Surface Water
- Semi Agriculture
- Urban General
- Urban Commercial
- Urban Industrial
- Urban Landscape
- Urban Residential
- Urban Vacant
- Outside
Deductive versus Inductive Approach

• Validate/compare effects of salinity on the economics of agricultural production in California’s Central Valley
• Same initial conditions.
• Inductive approach, Multinominal logit.
  – Dependent variable, probability of observing a crop
  – Explanatory variables, soil type, salinity, field size.
Multinomial Logit model specification

\[
Pr(Crop = k) = \frac{e^{x_i \beta_k}}{\sum_{l=1}^{12} e^{x_i \beta_l}}
\]

- Citrus and Pasture were both dropped from the Multinomial logit model as they are less than 1\% of acres in all but one CVPM
- Zone – Integer 0-4 with increasing salinity
- Soil – Integer 0-5 with decreasing soil quality
- Acres – Continuous measure of parcel area
## Marginal Effects of Salinity

Evaluated Separately at Average and by Respective Salinity Zone

<table>
<thead>
<tr>
<th>Crop</th>
<th>Salt Tolerance dS/m*</th>
<th>CVPM 10</th>
<th>CVPM 14</th>
<th>CVPM 15</th>
<th>CVPM 19</th>
<th>CVPM 21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table Grapes</td>
<td>1</td>
<td>-0.20%**</td>
<td>-1.06%**</td>
<td>-8.67%**</td>
<td>-0.94%</td>
<td>-13.02%</td>
</tr>
<tr>
<td>Orchard</td>
<td>1.4</td>
<td>-12.29%**</td>
<td>-4.69%**</td>
<td>-17.40%**</td>
<td>-5.68%**</td>
<td>-6.22%</td>
</tr>
<tr>
<td>Truck</td>
<td>1.5</td>
<td>-2.95%*</td>
<td>-1.56%*</td>
<td>0.22%*</td>
<td>-0.76%*</td>
<td>-11.78%</td>
</tr>
<tr>
<td>Tomato</td>
<td>1.7</td>
<td>.</td>
<td>-2.07%*</td>
<td>0.75%*</td>
<td>-0.07%**</td>
<td>.</td>
</tr>
<tr>
<td>Grain</td>
<td>4.5</td>
<td>0.60%</td>
<td>1.55%*</td>
<td>3.83%*</td>
<td>2.82%**</td>
<td>6.74%</td>
</tr>
<tr>
<td>Field</td>
<td>5</td>
<td>2.21%**</td>
<td>-0.45%**</td>
<td>0.69%</td>
<td>-0.96%*</td>
<td>6.40%</td>
</tr>
<tr>
<td>Cotton</td>
<td>5.1</td>
<td>6.30%*</td>
<td>4.57%*</td>
<td>9.30%*</td>
<td>5.80%**</td>
<td>7.80%</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>8</td>
<td>5.79%*</td>
<td>2.71%*</td>
<td>4.52%*</td>
<td>-0.40%**</td>
<td>6.87%</td>
</tr>
</tbody>
</table>


• *Denotes significance at 5%
• **Denotes significance at 1%
## SWAP and Econometrics Comparison

<table>
<thead>
<tr>
<th>Crop</th>
<th>CVPM 10</th>
<th>CVPM 14</th>
<th>CVPM 15</th>
<th>CVPM 19</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ratio of Abs. Acre SWAP/MNL</td>
<td>Ratio of Abs. Acre SWAP/MNL</td>
<td>Ratio of Abs. Acre SWAP/MNL</td>
<td>Ratio of Abs. Acre SWAP/MNL</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>0.59</td>
<td>0.82</td>
<td>0.74</td>
<td>0.43</td>
</tr>
<tr>
<td>Citrus</td>
<td>0.97</td>
<td>0.88</td>
<td>0.43</td>
<td>0.17</td>
</tr>
<tr>
<td>Cotton</td>
<td>0.61</td>
<td>0.83</td>
<td>0.90</td>
<td>0.90</td>
</tr>
<tr>
<td>Field</td>
<td>0.63</td>
<td>0.96</td>
<td>0.92</td>
<td>0.80</td>
</tr>
<tr>
<td>Grains</td>
<td>0.52</td>
<td>0.87</td>
<td>0.89</td>
<td>0.73</td>
</tr>
<tr>
<td>Orchards</td>
<td>2.23</td>
<td>3.75</td>
<td>2.61</td>
<td>1.22</td>
</tr>
<tr>
<td>Pasture</td>
<td>0.82</td>
<td>1.10</td>
<td>1.00</td>
<td>0.37</td>
</tr>
<tr>
<td>S. Beet</td>
<td>0.63</td>
<td>0.62</td>
<td>0.66</td>
<td>0.60</td>
</tr>
<tr>
<td>Grapes</td>
<td>13.33</td>
<td>7.93</td>
<td>17.48</td>
<td>.</td>
</tr>
<tr>
<td>Truck</td>
<td>0.79</td>
<td>1.19</td>
<td>1.15</td>
<td>0.97</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1.97</strong></td>
<td><strong>1.38</strong></td>
<td><strong>1.08</strong></td>
<td><strong>0.80</strong></td>
</tr>
</tbody>
</table>
### Annual Crop Revenue Loss due to Salinity Change 2030 ($1000)

<table>
<thead>
<tr>
<th>Crop</th>
<th>10</th>
<th>14</th>
<th>15</th>
<th>19</th>
<th>21</th>
<th>Total Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>-979</td>
<td>-3439</td>
<td>-13109</td>
<td>-1229</td>
<td>175</td>
<td>-18582</td>
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<tr>
<td>Citrus</td>
<td>-15</td>
<td>0</td>
<td>-8</td>
<td>-8</td>
<td>-65</td>
<td>-96</td>
</tr>
<tr>
<td>Cotton</td>
<td>-25733</td>
<td>-35869</td>
<td>-35782</td>
<td>-1372</td>
<td>-3959</td>
<td>-102714</td>
</tr>
<tr>
<td>Field crops</td>
<td>17599</td>
<td>-4727</td>
<td>3671</td>
<td>-2562</td>
<td>-311</td>
<td>13670</td>
</tr>
<tr>
<td>Grain</td>
<td>-3061</td>
<td>-15918</td>
<td>4494</td>
<td>-15542</td>
<td>-6896</td>
<td>-36922</td>
</tr>
<tr>
<td>Orchard</td>
<td>-1010</td>
<td>-9717</td>
<td>-2481</td>
<td>-1027</td>
<td>-90</td>
<td>-14324</td>
</tr>
<tr>
<td>Pasture</td>
<td>-744</td>
<td>55</td>
<td>-406</td>
<td>-314</td>
<td>2</td>
<td>-1407</td>
</tr>
<tr>
<td>Sugar Beet</td>
<td>28</td>
<td>-1318</td>
<td>-180</td>
<td>-63</td>
<td>0</td>
<td>-1533</td>
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<tr>
<td>Table</td>
<td>-35</td>
<td>-2408</td>
<td>-1149</td>
<td>-343</td>
<td>-105</td>
<td>-4041</td>
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<tr>
<td>Truck</td>
<td>-618</td>
<td>-17616</td>
<td>-180</td>
<td>-215</td>
<td>-136</td>
<td>-18765</td>
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<tr>
<td>Regional revenue</td>
<td>-14569</td>
<td>-90956</td>
<td>-45128</td>
<td>-22676</td>
<td>-11385</td>
<td>-184714</td>
</tr>
</tbody>
</table>
Hydrology dynamics from 1940-1998
Hopmans, Schoups, & Maurer
Conclusions

• In the future, water quality effects may be a bigger restriction on California crop production than water quantity.

• The costs of salinity on California crops is through yield reduction.

• The effect of salinity & drainage on California crop production can be estimated using spatial econometric methods.

• Water quantity and quality policies are closely linked

• Water prices and restrictions influence drainage quantity.