Effects of restrictions on parameter estimates of US agricultural production

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The economic theory of producer behavior requires certain conditions to hold in order for a functional form to be representative of a production technology. Agricultural production studies are usually conducted using classical econometrics that do not allow for the imposition of curvature constraints in flexible functional forms. Therefore, some conditions required by economic theory do not hold globally in estimation. Some studies report the proportion of the sample for which curvature conditions do not hold, and the reader is aware of the unknown disturbing effects that those data points might have on their final results. Bayesian methods allow for the imposition of first- and second-order restrictions in the estimation of flexible functional forms. We estimate a flexible representation of the US agricultural production technology using Bayesian econometrics under alternative sets of restrictions, and elaborate on the effects of the restrictions on the pds of the parameter estimates.

2 - Objective
To show how the pds of the parameter estimates change when curvature restrictions are imposed to guarantee that the theoretical properties of production functions hold.

3 - Data
USDA data on agricultural production by State for 1960 through 2004 is used in estimation: 48 states, 11 regions, 1 aggregate agricultural output, 3 variable inputs (capital, labor, materials). Data details provided in Ball et al. (2004).

4 - Methodology
The proposed production function \( y = f(X,D,t) \) relating output, \( y \), with inputs, \( X = x_1, x_2, \ldots, x_m \), time, \( t \), and regional dummy, \( D = D_1, \ldots, D_n \), consists of:
\[
f(X,D,t) = \sum_{i=1}^{m} \beta_i x_i + \sum_{i=1}^{m} \sum_{j=1}^{m} \frac{1}{2} \beta_{ij} x_i x_j + \sum_{i=1}^{m} \frac{1}{3} \beta_{ii} x_i^2 + \sum_{i=1}^{m} \frac{1}{4} \beta_{i} x_i^3 \]
where \( \beta_i \)'s are Young's theorem.

• Monotonicity requires that the output elasticity with respect to each input be positive: \( \frac{\partial \ln y}{\partial \ln x_i} = \beta_i + \sum_{j=1}^{m} \beta_{ij} x_j + \beta_{ii} x_i \geq 0 \)

5 - Results

<table>
<thead>
<tr>
<th>Model</th>
<th>Mean</th>
<th>StDev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>1.238</td>
<td>0.121***</td>
</tr>
<tr>
<td>Model 2</td>
<td>0.621</td>
<td>0.089**</td>
</tr>
<tr>
<td>Model 3</td>
<td>1.187</td>
<td>0.111***</td>
</tr>
<tr>
<td>Model 4</td>
<td>1.655</td>
<td>0.122***</td>
</tr>
<tr>
<td>Model 5</td>
<td>1.309</td>
<td>0.094***</td>
</tr>
<tr>
<td>Model 6</td>
<td>1.089</td>
<td>0.071***</td>
</tr>
</tbody>
</table>

6 - Key Findings
• The technology recovered from this data set is neither monotonic nor concave in primal space. Therefore, conditions must be imposed to perform economic analysis.
• Imposing concavity (Model 2) reduces the goodness of fit of the model significantly more than imposing monotonicity at data means (Model 3).
• The output elasticities obtained after imposing monotonicity at data means and concavity (Model 4) are similar to those obtained imposing monotonicity at all data points and concavity (Model 6).
• The concavity condition calculated using mean parameter estimates obtained after imposing monotonicity at all data points (Model 5) is satisfied at the data means, but the implied output elasticities are substantially different from those obtained imposing both monotonicity and concavity (Models 4 and 6).
• US agricultural production showed increasing returns to scale over 1960-2004

7 - Next Steps
• Analyze effects of imposing restrictions on agricultural technology in dual space, and joint primal-dual models.

References:

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