REGIONAL AGRICULTURAL SUPPLIES AND INPUT DEMANDS

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Abstract

Econometric estimates of supply for five output groups and demand for four input groups in each of ten regions of the United States are obtained and evaluated. They provide emphatic evidence of the unequal effects of changes in economic conditions and government agricultural policies on major production regions.

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Governmental agencies at many levels (federal, state, and local) in the United States are heavily involved in intervention in agricultural input and output markets to effect desired social goals. The most pervasive of the intervention activities are undertaken at the federal level and are uniformly available to most producers of specified commodities throughout the nation. However, because production characteristics and local market conditions are not homogeneous geographically, such policies have the inherent potential to affect producers in different locations unequally (Schertz, et al.).

Production relationships have been estimated previously at the regional or state level for selected commodities and/or regions by several researchers (e.g. Weaver; Shumway; Dixon, et al.; Stranahan and Shonkwiler; Taylor and Monson; Grisley and Gitu; Bailey and Womack). Included commodities and inputs, geographic delineation, and model specification have varied between these studies. No set of econometric estimates is currently available that was developed in a consistent manner for all U.S. production areas and for a comprehensive array of agricultural outputs and inputs. Our ability to evaluate differences in regional impacts of general changes in economic conditions or of specific governmental interventions is consequently extremely limited.

The objective of this paper is to assess the extent to which major agricultural production regions of the U.S. differ in their response to market stimuli and associated governmental interventions. Parametric relationships and recent elasticities of supply for five output groups and demand for four input groups are estimated for each of the ten USDA farm production regions comprising the contiguous 48 states (USDA, 1986).
The econometric estimation of complete systems of product supply and input demand equations is carried out subject to the competitive theory and assuming regional independence.

Method of Analysis

Assuming competitive behavior, exogenous prices of outputs and variable inputs, and a twice-continuously differentiable and strictly concave industry production function, the indirect restricted profit function was modeled using the normalized quadratic form (Lau, 1978a; Lerttamrab; Shumway):

\[ \tilde{\mathcal{T}}^* = b_0 + \tilde{C}^* + 0.5\tilde{P}'\tilde{D}\tilde{P}, \]

where \( \tilde{\mathcal{T}}^* \) is profit divided by price of netput 1; \( \tilde{P} = [\tilde{p}_2, \ldots, \tilde{p}_m, \tilde{x}_{m+1}, \ldots, \tilde{x}_n] \) is the vector of normalized prices (\( \tilde{p}_i = p_i/p_1 \)) and quantities of quasi-fixed inputs and related exogenous variables (\( \tilde{x}_{m+1}, \ldots, \tilde{x}_n \)); \( p_i \) is the price of netput \( i \); \( b_0, C \) and \( D \) are parameters. Following the "netput" convention, output quantities are positive and variable input quantities are negative.

By the envelope theorem, the first derivatives of normalized profit with respect to normalized prices of variable inputs and outputs are the input demand and output supply equations:

\[ \tilde{x}_{it} = c_i + \sum_{j=2}^{m} \tilde{d}_{ij}\tilde{p}_{jt} + \sum_{j=m+1}^{n} \tilde{d}_{ij}\tilde{x}_{jt}, \quad i=2, \ldots, m, \quad t=1, \ldots, T, \]

where \( t \) is time.

The numeraire (netput 1) demand equation can be derived also via the envelope theorem as the first derivative of the (unnormalized) profit function with respect to the numeraire price. It is quadratic in prices and other exogenous variables:
Parameters were estimated for the complete system of nine stacked supply and demand equations, (2) and (3), in each region subject to homogeneity (maintained by the functional form), symmetry, and convexity of the profit function in prices. Monotonicity was not maintained in estimation but was checked at each observation. Errors were assumed to be additive, independently and identically distributed within each region with mean zero and constant contemporaneous covariance matrix. Estimation was carried out by constrained nonlinear least squares using the Cholesky factorization to maintain convexity (Lau, 1978b). A reduced-gradient nonlinear programming procedure (Talpaz, Alexander, and Shumway), employing algorithm code MINOS version 5.0 (Murtagh and Saunders), was used to obtain these parameter estimates consistent with the theory of the competitive industry.

Variable Selection and Data

Annual data for the period 1951-82 were used in the estimation. Exogenous variables included expected prices of outputs, current observed prices of variable inputs and quantities of quasi-fixed inputs, government policies, weather and time.

The higher of lagged market price or current effective support rate (Houck and Ryan) was used to represent expected commodity price. Government supply control programs for relevant commodities were represented by the effective current diversion payment (Houck, et al.). Only direct effects of these programs were measured in the supply equations. Cross-commodity effects were not examined. Temperature and rainfall for critical planting and growing months were included in each
(in the feed grains and livestock equations) accounted for half the total number.

Of the significant input-input parameter estimates with sign consistency across regions, the following relationships were exhibited. Hired labor and machinery demands increased with increases in quantity of family labor when prices of all outputs and all other variable inputs and magnitudes of other exogenous variables remained constant. Noting that all variable input demands responded negatively to changes in own price, it is apparent that the demand for hired labor increased with the quantity of real estate and decreased with quantities of either machinery or energy, ceteris paribus. Thus, when both substitution and expansion effects were accounted for, hired labor was complementary with family labor and real estate and competitive with machinery and energy; machinery was complementary with family labor. These input relationships are generally consistent with Antle’s findings for the U.S. (1947-78 data), Lopez’s for Canada (1971 cross-sectional data), and Shumway, Alexander, and Talpaz’s for Texas (1957-79 data). They are strikingly different, however, from Weaver’s findings of complementarity among all pairs of five variable inputs in North Dakota and among all but one pair in South Dakota (1950-70 data).

Of output-output relationships with sign consistency across regions, feed grains were competitive with livestock; food grains were competitive with oil crops, other crops, and livestock; oil crops and other crops were competitive with livestock. There were no consistently significant complementary relationships between output categories. This suggests a jointness in production that may have been due more to the presence of constraining allocatable inputs (such as land) than to technically
Nevertheless, a substantial share (27-48%) of the large number of exogenous variables had parameter estimates that were significant at the 5% level in each region (Table 1).

Slightly over a third of all estimated parameters were significant in at least half the regions. All temporal parameters were significant in at least seven of the ten regions. Two own-price parameters (for energy demand and livestock supply) were significant in seven or more regions. Six of the eight own-price parameters were significant in at least half the regions. The remainder, machinery demand and food grains supply, were significant in four regions. Only two cross-price parameters, between feed grains and energy and between oil crops and livestock were significant in at least half the regions. Five of nine parameters on real estate and two of nine parameters on family labor were similarly significant. Only one of ten parameters on weather variables, precipitation in the feed grain equation, and none of the three government commodity policy variable parameters were so generally significant.

Of the significant parameter estimates, six of the nine sets of temporal parameters had the same sign in all regions. They provided strong evidence of increasing output and input levels over time (even including hired labor), *ceteris paribus*. All own-price parameters were consistent in sign in all regions, which of course was a maintained hypothesis (implied by the curvature properties) in the econometric estimation. Seventeen of 29 parameters (59%) significant in at least half the regions had totally consistent significant signs. Only three of 29 parameters (10%) significant in at least half the regions had fewer than 70% of significant parameters of the same sign. Among those with substantial sign inconsistency, parameters on real estate quantity (in the machinery, energy, and other crops equations) and on family labor quantity
Empirical Results

The output supply and input demand equations were estimated by nonlinear least squares while maintaining linear homogeneity, symmetry, and convexity of the profit function in prices. Because of the space required to report all parameters estimated, they are not included in this paper but are available from the authors. Monotonicity of the profit function was not maintained in the estimation but was checked at each observation. Monotonicity was violated at only two observations in one region (Region 6 - Southeast). However, the violations were not statistically significant; the Chi-square statistic was 0.3 with a critical value at the 5% level of 6.0. The empirical estimates were consistent with the theory of the competitive industry having an aggregate multiple-product production function and facing exogenous prices in output and variable input markets. In addition, statistical tests of the maintained curvature properties failed to reject convexity of the profit function in any region; F statistics ranged from .18 to 1.23 with a critical value at the 5% level of 1.52 (see Table 1).

The hypothesis of no first-order serial correlation was tested and not rejected at the 5% level for any supply or demand equation. Durbin-Watson statistics ranged from .85 to 2.69 (Table 1).

Collinearity among the regressors ranged from moderate to severe. Condition indexes on scaled and centered data for the stacked system ranged from 526 to 1897 (Table 1). Indexes above 1000 on scaled and centered data indicate "fairly strong" collinearity (Hocking and Pendleton, p. 503). This magnitude was exceeded in three of the ten regions. Since the effect of collinearity is to inflate the standard error estimates, tests of parameter significance had lower power.
supply equation. Time was included to measure the effects of disembodied technological change.

The output categories were feed grains, food grains, oil crops, other crops, and livestock. The first three were similar to three of the crop groups defined by the Economic Research Service (ERS) in their Production and Efficiency Statistics series (USDA, 1986). The fourth was an aggregate of the remaining six crop groups and the fifth was an aggregate of the three livestock groups. Output price and quantity indexes were developed using data from Agricultural Statistics (USDA, 1951-83) and unpublished data used by the ERS to construct the Production and Efficiency Statistics series (USDA, 1986).

The variable input categories were materials, hired labor, machinery, and energy. Inputs regarded as quasi-fixed were family labor and real estate. The hypothesis that first-order conditions were satisfied was not maintained for the quasi-fixed inputs, so demand (or value of marginal product) equations were not included in the estimation system for them. Their quantities did appear, however, on the right hand side of the other equations.

Except for family and hired labor, the unpublished ERS data were also used to construct input quantity indexes. All categories were redefined, however, from the input groupings in the Production and Efficiency Statistics series (USDA, 1986). The reclassification followed several recommendations of the AAEA Task Force on Measuring Agricultural Productivity (AAEA) to more accurately measure service flows from capital stocks and to organize the input categories for greater relevance to current economic issues. For further details on data construction see Shumway and Alexander.
interdependent production processes (Sakai; Shumway, Pope, and Nash). Nonjoint production of all outputs was tested and rejected at the 5% level in six of the ten regions (see Table 1).

Of output-input relationships with sign consistency across regions, feed grain supply decreased with energy price; food grains decreased with real estate quantity; oil crops decreased with energy price and increased with hired labor and machinery prices and family labor and real estate quantities; other crops increased with family labor quantity; and livestock increased with energy price and real estate quantity. Because of the maintained symmetry restrictions, the variable input demands responded to output prices with opposite sign from the response of the corresponding output supplies to the input prices.

Of other significant parameters with sign consistency across regions, output of feed grains, oil crops, and other crops were positively associated with rainfall in critical growing months; livestock output was negatively associated with rainfall; other crops output was positively associated with temperature; output of food grains and other crops was negatively associated with changes in the effective diversion payment.

Output supply and input demand own-price elasticities computed for the 1982 observation year are reported in Table 2 for all regions, along with their means and standard deviations across regions. Input demand elasticities varied across regions from -.000002 to -1.42 and output elasticities from +.01 to +1.22. The variation across regions was greater than the variation across input categories or across output categories. Hired labor demand exhibited the greatest variation in own-price elasticities across regions, ranging from -.000002 to -1.42 with a mean of -.46 and a standard deviation of .48. Oil crop supply elasticities also varied greatly, from +.04 to +1.42 with a mean of +.36 and a standard
deviation of .39. Standard deviations across regions were lower than means of the own-price elasticities for all other inputs and outputs. However, for only four (livestock supply and energy, machinery, and materials demands) were the means at least double their standard deviations. A great deal of regional diversity was evident in nearly all the own-price input demand and output supply elasticities.

Extreme variability across regions was also evident from an examination of cross-price elasticities. For example, demand elasticities between hired labor and energy price varied from -.34 to +.58 with six positive and four negative. Supply elasticities between oil crops and miscellaneous crops price varied from -2.80 to +.27 with three positive; between oil crops and livestock price, they varied from -1.03 to +.19 with two positive; between oil crops and machinery price, they varied from -.12 to +3.12 with seven positive; between food grains and livestock price, they varied from -.26 to +.82 with five positive; between food grains and machinery price, they varied from -.04 to -1.09. While these particular cross-price elasticities exhibited some of the greatest variation across regions, others also varied widely.

Since expected output prices are based on the higher of lagged market price and current effective support rate, it is clear that the various regions differed markedly in their responsiveness to market stimuli and associated governmental interventions.
Conclusions

The theory of the competitive industry has been fully maintained (or not significantly violated) in this comprehensive econometric estimation of agricultural output supplies and input demands in ten farm production regions comprising the contiguous 48 states of the U.S.

Collinearity among the regressors was moderate to strong in all regions. A test of no first order serial correlation was not rejected for any equation in any region. A test of the maintained curvature properties failed to reject convexity of the profit function in any region. Signs of significant parameters exhibited considerable consistency across regions.

However, considerable diversity among regions was evident in other aspects of the empirical estimates. Nonjointness in production of all output categories was rejected in six of the ten regions. Elasticities of output supply and input demand computed for the last observation year, 1982, exhibited a great deal of regional variation. Both own-price and cross-price elasticities varied more across regions than across input categories or output categories. They clearly document the importance of considering regional differences in predicting the distributional effects of potential changes in economic conditions or government policies affecting agriculture. Because of extreme geographic variability in production patterns and relationships, changes can be expected to impact the various regions very differently.
Table 1. Summary Statistics of the Regional Normalized Profit Function Estimates

<table>
<thead>
<tr>
<th>Region</th>
<th>F Statistic, Convexity</th>
<th>Condition Index</th>
<th>Percent of Parameters Significant at 5% Level</th>
<th>Durbin-Watson, Range</th>
<th>Chi-Square Statistic, Nonjointness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Northeast</td>
<td>.78</td>
<td>802</td>
<td>29</td>
<td>1.36-2.41</td>
<td>12.3</td>
</tr>
<tr>
<td>2. Lake States</td>
<td>.34</td>
<td>753</td>
<td>34</td>
<td>0.85-2.69</td>
<td>11.3</td>
</tr>
<tr>
<td>3. Corn Belt</td>
<td>.18</td>
<td>1897</td>
<td>27</td>
<td>1.18-2.53</td>
<td>18.2</td>
</tr>
<tr>
<td>4. Northern Plains</td>
<td>.91</td>
<td>1636</td>
<td>33</td>
<td>1.27-2.30</td>
<td>24.9</td>
</tr>
<tr>
<td>5. Appalachia</td>
<td>.18</td>
<td>884</td>
<td>36</td>
<td>1.41-2.37</td>
<td>70.0</td>
</tr>
<tr>
<td>6. Southeast</td>
<td>1.02</td>
<td>639</td>
<td>34</td>
<td>1.54-2.31</td>
<td>35.0</td>
</tr>
<tr>
<td>7. Delta States</td>
<td>.28</td>
<td>733</td>
<td>33</td>
<td>1.41-2.37</td>
<td>72.7</td>
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<tr>
<td>8. Southern Plains</td>
<td>1.23</td>
<td>1610</td>
<td>48</td>
<td>1.01-2.40</td>
<td>30.9</td>
</tr>
<tr>
<td>9. Mountains</td>
<td>.92</td>
<td>608</td>
<td>38</td>
<td>1.08-2.18</td>
<td>29.2</td>
</tr>
<tr>
<td>10. Pacific</td>
<td>.61</td>
<td>526</td>
<td>42</td>
<td>0.98-2.33</td>
<td>14.5</td>
</tr>
</tbody>
</table>

\(^a\) States included in regions: 1 - CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT; 2 - MI, MN, WI; 3 - IA, IL, IN, MO, OH; 4 - KS, NE, ND, SD; 5 - KY, NC, TN, VA, WV; 6 - AL, FL, GA, SC; 7 - AR, LA, MS; 8 - OK, TX; 9 - AZ, CO, ID, MT, NM, NV, UT, WY; 10 - CA, OR, WA.

\(^b\) Critical value for F \(0.05 \quad 85,203 = 1.52\).

\(^c\) Upper and lower limits of the Durbin-Watson inconclusive region for the alternate hypothesis of positive first-order serial correlation (5% level of significance) are: 2.411 and .703 for linear input demand equations, 2.625 and .576 for other crops and livestock supply equations, and 2.733 and .515 for the remaining supply equations.

\(^d\) Critical value for \(\chi^2_{.05,10} = 18.3\).
Table 2. Own-Price Elasticities, 1982

<table>
<thead>
<tr>
<th>Region</th>
<th>Materials</th>
<th>Hired Labor</th>
<th>Machinery</th>
<th>Energy</th>
<th>Feed Grains</th>
<th>Food Grains</th>
<th>Oil Crops</th>
<th>Other Crops</th>
<th>Livestock</th>
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<tr>
<td>1</td>
<td>-.11</td>
<td>-.00001</td>
<td>-.16</td>
<td>-.20</td>
<td>.27</td>
<td>.43</td>
<td>.63</td>
<td>.01</td>
<td>.09</td>
</tr>
<tr>
<td>2</td>
<td>-.13</td>
<td>-.21</td>
<td>-.15</td>
<td>-.26</td>
<td>.13</td>
<td>.18</td>
<td>.11</td>
<td>.09</td>
<td>.07</td>
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<tr>
<td>3</td>
<td>-.17</td>
<td>-.18</td>
<td>-.15</td>
<td>-.37</td>
<td>.11</td>
<td>.71</td>
<td>.08</td>
<td>.24</td>
<td>.14</td>
</tr>
<tr>
<td>4</td>
<td>-.12</td>
<td>-.00003</td>
<td>-.25</td>
<td>-.43</td>
<td>.16</td>
<td>.14</td>
<td>.04</td>
<td>.25</td>
<td>.22</td>
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<tr>
<td>5</td>
<td>-.08</td>
<td>-.53</td>
<td>-.28</td>
<td>-.27</td>
<td>.09</td>
<td>.33</td>
<td>.16</td>
<td>.28</td>
<td>.14</td>
</tr>
<tr>
<td>6</td>
<td>-.04</td>
<td>-.000002</td>
<td>-.27</td>
<td>-.21</td>
<td>.23</td>
<td>.15</td>
<td>.12</td>
<td>.01</td>
<td>.15</td>
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<td>7</td>
<td>-.14</td>
<td>-.142</td>
<td>-.25</td>
<td>-.21</td>
<td>.65</td>
<td>.51</td>
<td>.15</td>
<td>.60</td>
<td>.15</td>
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<tr>
<td>8</td>
<td>-.04</td>
<td>-.102</td>
<td>-.43</td>
<td>-.45</td>
<td>.06</td>
<td>.40</td>
<td>.34</td>
<td>.51</td>
<td>.11</td>
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<tr>
<td>9</td>
<td>-.14</td>
<td>-.75</td>
<td>-.55</td>
<td>-.28</td>
<td>.15</td>
<td>.29</td>
<td>1.22</td>
<td>.14</td>
<td>.21</td>
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<tr>
<td>10</td>
<td>-.01</td>
<td>-.48</td>
<td>-.48</td>
<td>-.07</td>
<td>.06</td>
<td>.31</td>
<td>.76</td>
<td>.01</td>
<td>.11</td>
</tr>
<tr>
<td>Mean</td>
<td>-.10</td>
<td>-.46</td>
<td>-.30</td>
<td>-.27</td>
<td>.19</td>
<td>.35</td>
<td>.36</td>
<td>.21</td>
<td>.14</td>
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<tr>
<td>SD(^a)</td>
<td>.05</td>
<td>.48</td>
<td>.14</td>
<td>.12</td>
<td>.18</td>
<td>.18</td>
<td>.39</td>
<td>.21</td>
<td>.05</td>
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\(^a\) Standard deviation.
REFERENCES


