This paper reviews some twelve econometric studies of agricultural producers' behavior in developing countries. In addition, it provides a tentative and more detailed bibliography including also works which though identified could not be obtained. It is part of an exploration of the possibilities of deriving agricultural supply models for developing countries.

June 19, 1968
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</table>
I. INTRODUCTION

1. The major problems of agricultural development are centered around supply response, i.e., the relationships between output quantities and resource use and prices. Agricultural supply models may help in understanding these problems in that, through appropriate quantitative relationships, they may provide estimates of changes in output, acreage, and yield per acre associated with changes in output use and in prices, which may be useful for forecasting.

2. Over the past decade the construction of agricultural supply models has become almost a classical exercise in econometrics. It has attracted a great deal of attention in the more advanced countries, notably in the United States where these techniques have been widely applied. At the same time a number of studies have been made regarding the supply relationships for some of the major commodities grown in developing countries, such as coffee, cocoa, tobacco, cotton, rice, and jute.

3. This paper reviews some twelve econometric studies of agricultural producers' behavior in developing countries. The selection of the studies reviewed was made on the basis of their being readily available and with a view to covering as many different regions and commodities as possible. Studies which were identified but could not be obtained are included in the Appendix in a tentative and more general bibliography starting back in 1960. The review focuses primarily on the actual results of these efforts in terms of the practical usefulness of the empirical equations offered.
b. For the sake of organization, we have elected to present this review on a geographical basis, grouping the various works under the heading of the geographical area to which the studies refer, namely Asia, Africa, and Latin America. Asia leads the way as it was probably in India that the first known empirical studies of agricultural supply response in developing countries were made with the publication in 1934 by A. R. Sinha, H. C. Sinha, and J. R. G. Thukurta of the Statistical Laboratory of Calcutta, of a paper entitled "Indian Cultivators' Response to Prices".  

5. The work undertaken by the U. S. Department of Agriculture, evaluating over the long term and on a worldwide scale, the supply of and demand for agricultural and livestock products has not been included, as it is concerned only with simple linear trend projections regarding supply. More than a dozen studies have now been published which may nevertheless be useful. They also are included in the tentative bibliography given in the Appendix.

\[1/\]

II. ASIA

5. Krishna (1961) studied farm supply response in the Punjab prior to Partition, analyzing the case of cotton and wheat. He found that peasants' response to relative price variations was always positive in sign. Joshi and Dhekney (1954) pointed out, however, that agricultural production in India is largely inelastic with respect to price and that it would not be safe to rely on the controlled working of the price mechanism alone.

6. In the Krishna cotton model, the supply response is analyzed in terms of acreage response only. The dependent variable is "standard irrigated acreage planted" and yield is assumed to be invariant with respect to price. Accordingly, the elasticity of planned output is regarded as equal to the elasticity of acreage only with respect to price. The unirrigated acreage (less than 1 percent of total cotton acreage) has been multiplied by a conversion factor of 0.70 and added to irrigated acres to arrive at "standard irrigated acreage". The conversion factor used is the ratio of the five year average yield of cotton in experiments on irrigated land in all districts of the undivided Punjab (1930/31-1934/35). Four alternative models were tried by Krishna based on different assumptions about price and yield expectations and acreage adjustment lags.

7. The alternative equations obtained are shown in Table 1 for

---

American cotton, Table 2 for Desi cotton, and Table 3 for wheat, the variables considered being as follows:

\[ X_t \] is standard irrigated acreage planted,
\[ P_{t-1} \] is the post harvest price of the commodity, previous year,
\[ Y_t \] is yield expected for the crop in current year,
\[ Y_{t-1} \] is yield expected for the crop, previous year,
\[ Y_t \] is actual yield of the crop, previous year,
\[ X_{t-1} \] is acreage planted previous year,
\[ X_{t-2} \] is acreage planted two years before,
\[ W_t \] is weather as measured by inches of rainfall in the current year, and
\[ t \] is the time trend.

Prices are deflated by an index of the prices of 10 alternative crops (including summer crops and winter crops).

Krishna also tested variable \( Z_{t-1} \), the lagged irrigated summer acreage of all crops with the following results, for American cotton:

\[
X_t = a_0 + 4.72 P_{t-1} + 0.62 Y_{t-1} + 0.20 Z_{t-1} + 0.60 X_{t-1} \\
(1.46) \quad (0.42) \quad (0.13) \quad (0.13)
\]

\[ R^2 = 0.93 \]

where \( Z_{t-1} \) does not add anything to the determination when we compare this equation with equation (CA.3) in Table 1.

An alternative equation offered is:

\[
X_t = a_0 + 6.23 P_{t-1} + 0.34 Z_{t-1} + 0.56 X_{t-1} \\
(1.08) \quad (0.09) \quad (0.15)
\]

\[ R^2 = 0.92 \]

where \( Z_{t-1} \) performs as well as \( Y_{t-1} \), supporting the view that the extension of irrigation is the major determinant of average yield increase.
Table 1: Acreage Response Functions for American Cotton
  in Undivided Punjab (1922-1944) 1/

<table>
<thead>
<tr>
<th>Equations</th>
<th>$P_{t-1}$</th>
<th>$Y^*_t$</th>
<th>$Y^*_{t-1}$</th>
<th>$Y_{t-1}$</th>
<th>$X_{t-1}$</th>
<th>$X_{t-2}$</th>
<th>$R^2$</th>
<th>$d$</th>
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<tr>
<td>Simple</td>
<td>3.52</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>.06</td>
<td>--</td>
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<tr>
<td>$X_t = f(P_{t-1})$</td>
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<tr>
<td>Simple</td>
<td>--</td>
<td>3.50</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>.84</td>
<td>--</td>
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<tr>
<td>$X_t = f(Y^*_t)$</td>
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<tr>
<td>CA.0</td>
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<tr>
<td></td>
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<tr>
<td>CA.1</td>
<td>3.31</td>
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<td>--</td>
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<td>--</td>
<td>.89</td>
<td>1.96</td>
</tr>
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<td></td>
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<tr>
<td>CA.2</td>
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<td>2.52</td>
<td>-1.04</td>
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<td>.72</td>
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<td>.89</td>
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<td></td>
<td>(2.36)</td>
<td>(.79)</td>
<td>(1.07)</td>
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<td>(.28)</td>
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<td>CA.3</td>
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<td>CA.4</td>
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<td>.23</td>
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<td>(.17)</td>
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</tr>
</tbody>
</table>

1/ The figures in parentheses are the standard errors of the coefficients. The levels of significance are not explicitly given by the author.
2/ Durbin-Watson statistic.

Source: Krishna, op. cit.
Table 2: Acreage Response Functions for Desi Cotton in Undivided Punjab (1922-1943) 1/

<table>
<thead>
<tr>
<th>Equations</th>
<th>$P_{t-1}$</th>
<th>$Y_{t-1}$</th>
<th>$Y_t^*$</th>
<th>$X_{t-1}$</th>
<th>$X_{t-2}$</th>
<th>$R^2$</th>
<th>$d$ 2/</th>
</tr>
</thead>
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<tr>
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<td>.12</td>
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<td>--</td>
<td>.537</td>
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<tr>
<td></td>
<td>(2.03)</td>
<td>(2.03)</td>
<td>(2.03)</td>
<td>(2.03)</td>
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<tr>
<td>CD.3</td>
<td>6.32</td>
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<td>.51</td>
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<td>.671</td>
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<td>(1.46)</td>
<td>(1.46)</td>
<td>(1.46)</td>
<td>(1.46)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CD.4</td>
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<td>.43</td>
<td>.757</td>
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<td>(1.55)</td>
<td>(1.55)</td>
<td>(1.55)</td>
<td>(1.55)</td>
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</tr>
<tr>
<td>$CDRT.3$</td>
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<td>.45</td>
<td>--</td>
<td>.725</td>
<td>2.34</td>
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<td>(1.36)</td>
<td>(1.36)</td>
<td>(1.36)</td>
<td>(1.36)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$CDRT.4$</td>
<td>8.66</td>
<td>3.07</td>
<td>--</td>
<td>.35</td>
<td>.38</td>
<td>.766</td>
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<td></td>
<td>(1.48)</td>
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<td>(1.48)</td>
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<td></td>
</tr>
</tbody>
</table>

1/ The figures in parenthesis are the standard errors of the coefficients. The levels of significance are not explicitly given by the author.

2/ Durbin-Watson statistic.

3/ In equation $CDRT.3$ and $CDRT.4$, an Index of Relative Yield rather than the absolute yield of cotton was used as the yield variable. Relative yield was defined as the yield of Desi cotton deflated by an index of the yield of six alternative summer crops.

Source: Krishna, op. cit.
Table 2: (cont'd.) Additional Acreage Response Functions for Desi Cotton in Undivided Punjab (1922-1947)

<table>
<thead>
<tr>
<th>Equation No.</th>
<th>( P_{t-1} )</th>
<th>( Y_{t-1} )</th>
<th>( X_{t-1} )</th>
<th>( X_{t-2} )</th>
<th>( R^2 )</th>
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<td>(.39)</td>
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<td>(.15)</td>
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</tr>
<tr>
<td>CD.6</td>
<td>8.17*</td>
<td>2.52*</td>
<td>.38*</td>
<td>.45*</td>
<td>.77</td>
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<td>(.41)</td>
<td>(.99)</td>
<td>(.15)</td>
<td>(.18)</td>
<td></td>
</tr>
<tr>
<td>CD.7</td>
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<td>.03</td>
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<tr>
<td></td>
<td>(.02)</td>
<td>(.017)</td>
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<td>CD.8</td>
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<td>.03</td>
<td>.46*</td>
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<td>.81</td>
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<td>(.016)</td>
<td>(.18)</td>
<td>(.20)</td>
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<tr>
<td>CD.9</td>
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<td>.008</td>
<td>.55*</td>
<td>--</td>
<td>.64</td>
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<td>(.009)</td>
<td>(.008)</td>
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</tbody>
</table>

The figures in parentheses are the standard errors of the coefficients. No Durbin-Watson statistics are given for these equations.

A * indicates coefficient estimates which are significant at least at the 5 percent level.

Source: Krishna, op. cit.
Table 3: Acreage Response Functions for Wheat

In Undivided Punjab (1915-1944)

<table>
<thead>
<tr>
<th>Equation</th>
<th>P_{t-1}</th>
<th>Y_{t-1}</th>
<th>X_{t-1}</th>
<th>t</th>
<th>W_{t}</th>
<th>R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>W.1</td>
<td>0.0339</td>
<td>-0.080</td>
<td>0.2251</td>
<td>0.0014</td>
<td>0.1139</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>(0.0496)</td>
<td>(0.0755)</td>
<td>(0.1622)</td>
<td>(0.0005)</td>
<td>(0.0346)</td>
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</tr>
<tr>
<td>W.2</td>
<td>0.0713*</td>
<td>0.0146</td>
<td>0.5858</td>
<td>0.0013</td>
<td>--</td>
<td>0.83</td>
</tr>
<tr>
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<td>(0.0392)</td>
<td>(0.0594)</td>
<td>(0.1759)</td>
<td>(0.0006)</td>
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<td>W.3</td>
<td>-0.2599</td>
<td>-9.279</td>
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<tr>
<td></td>
<td>(5.5666)</td>
<td>(6.865)</td>
<td>(1.1436)</td>
<td></td>
<td>(13.88)</td>
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</tr>
<tr>
<td>W.4</td>
<td>0.0385*</td>
<td>0.0296</td>
<td>0.0888</td>
<td>-0.0597</td>
<td>-0.1283</td>
<td>0.40</td>
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<td></td>
<td>(0.0190)</td>
<td>(0.0238)</td>
<td>(0.1776)</td>
<td>(0.0316)</td>
<td>(0.0458)</td>
<td></td>
</tr>
<tr>
<td>W.5</td>
<td>0.0221*</td>
<td>0.0144</td>
<td>0.3272*</td>
<td>-0.1477</td>
<td>--</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>(0.0111)</td>
<td>(0.0150)</td>
<td>(0.1807)</td>
<td>(0.0438)</td>
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</tr>
</tbody>
</table>

1/ The figures in parentheses are the standard errors of the coefficients. No Durbin-Watson statistics are given for these equations.

* indicates coefficient estimates significant at least at the 5 percent level.

Source: Krishna, op. cit.
in the area under study. Interestingly, weather (rainfall in the current year) is not included in any of the alternative cotton acreage equation proposed by Krishna, while it appears to be an important factor in his wheat acreage equations.

8. As in the case of cotton, Krishna tried several models for gauging the supply response of wheat (Table 3). In the first equation where all the variables are in logarithms except t, the dependent variable is standard irrigated acreage. In the second equation (also in logarithms except t) it is irrigated acreage only and the weather variable is omitted. In the third equation (linear), the dependent variable is unirrigated acreage only. In the fourth equation (linear) the dependent variable is the ratio of total acreage in wheat to total acreage in all crops. In the fifth equation (linear), the dependent variable is the ratio of irrigated acreage in wheat to the irrigated acreage in all crops. In all equations, the performance of the price variable is poor. The yield variable was not found to produce parameter estimates significantly different from zero. An important part of the variation in wheat acreage is explained by the time trend and/or rainfall. The time trend is interpreted to reflect population growth.

9. Stern (1962) attempted to measure the supply elasticity of jute in terms of acreage adjustments made by producers in response to changes in the relative price of jute in East Pakistan following

\[ \text{The standard wheat irrigated area is equal to the irrigated area plus 0.6 times the unirrigated area.} \]

Partition from 1949/50 to 1959/60, which does not cover a sufficient number of years to permit any generalization about the magnitude of the response of jute producers to changes in the relative price of jute.

For the undivided Indian Provinces of Bengal, Bihar, and Orissa for the longer period from 1893/94 or 1911/12, depending on the data, to 1938/39, the relationship considered by Stern is of the form:

\[ y_t = a + bx_{t-1} \]

where \( y_t \) is the ratio acreage under jute to that of rice and other competing crops

\( x_{t-1} \) is the lagged average annual price index of jute relative to rice and other crops.

Both variables are expressed in logarithms. Hence the parameter estimate of \( b \) is equal to the elasticity of the area ratio with respect to the relative price of jute. Stern concludes that primary producers appear rather responsive to prices. The elasticities obtained by him range from 0.57 to 0.76 and his simple correlation coefficients ranging from 0.51 to 0.56. He also performs a multiple regression involving the dependent variable lagged one year as an independent variable which yields higher elasticities.

10. Hopper (1965) by examining the prices implicit in the allocation of resources in Indian agriculture, tested the hypothesis that Indian cultivators who use traditional technology make rational profit maximizing allocations of factors in Indian agriculture. "It seems likely

\[ \frac{1}{1} \]

that in a technologically stagnant agriculture farmers are intuitively aware of the resource substitution possibilities and the production responses of their agricultural enterprises." It is, therefore, not surprising, says Hopper, to find relatively few allocation errors and a high level of production efficiency within the framework of the traditional state-of-the-arts.

11. Sturt (1965) studied producer response to technological change. Conducting a personal interview survey including 200 cultivators from four villages in Pakistan, he tried to analyze the extent to which a broad array of changes in agricultural practices were carried out and the economic linkage between decisions to change and the "acquisitive" desires of cultivators. Information studied in the paper included: the types of technological change feasible and known to cultivators, the extent to which these changes were adopted in 1962, and the role of the individual cultivator in decision making leading to change, the motivation for adopting new practices and the barriers to the adoption of new practices. Sturt observed that cultivators making changes took advantage of possibilities for greater efficiency.

12. Other works include a comprehensive study by Rao (1965) of the efficiency of resource use among farms in selected regions of India, sponsored by the Indian Institute of Economic Growth. The study covers three different aspects of the problem: (1) an analysis of resource

Table 4: Summary Regressions of Jute Area Ratio and Relative Price in the Undivided Indian Provinces of Bengal, Bihar, and Orissa 1/

<table>
<thead>
<tr>
<th>Equation</th>
<th>Provinces Included</th>
<th>Jute in Relation to</th>
<th>Years 2/</th>
<th>Regression</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Ia)</td>
<td>Combined Provinces</td>
<td>Rice</td>
<td>1893/94-1938/39</td>
<td>$Y_t = -1.11 + .57 X_{t-1}$ (( .15 ))</td>
<td>.51</td>
</tr>
<tr>
<td>(Ib)</td>
<td>Combined Provinces</td>
<td>Rice and other crops</td>
<td>1911/12-1938/39</td>
<td>$Y_t = -1.20 + .65 X_{t-1}$ (( .25 ))</td>
<td>.50</td>
</tr>
<tr>
<td>(Ic)</td>
<td>Bengal only</td>
<td>Rice</td>
<td>1911/12-1938/39</td>
<td>$Y_t = - .93 + .76 X_{t-1}$ (( .24 ))</td>
<td>.56</td>
</tr>
<tr>
<td>(Id)</td>
<td>Bengal only</td>
<td>Rice and other crops</td>
<td>1911/12-1938/39</td>
<td>$Y_t = - .36 + .75 X_{t-1}$ (( .25 ))</td>
<td>.55</td>
</tr>
</tbody>
</table>

1/The figures in parenthesis are the standard errors of the coefficients. The levels of significance are not explicitly given by the author.

2/The years, 1913/14-1919/20 are excluded; their inclusion yields the following simple regression and correlation coefficients: (Ia), $b = .55$ and $r = .63$; (Ib) $b = .63$ and $r = .38$; (Ic), $b = .50$ and $r = .42$; (Id), $b = .50$ and $r = .43$.

Source: Stern, op. cit.
productivities and returns to scale among farms in the former Hyderabad State, (2) an analysis of the efficiency of farms according to size, (3) an analysis of the efficiency of land allocation between different crops. Rao's findings suggest that the main obstacle to agricultural development is not so much the "smallness" of the farm, or the lack of "profit-mindedness" on the part of the farmers, as the insufficient availability of certain inputs and the presence of other typical and natural constraints.
Stern (1964) also discussed the determinants of cocoa supply in West Africa for the period prior to 1945 and found evidence for Nigeria that the price of cocoa influenced the planting decision. The statistical tests for Ghana indicated some evidence of the importance of prices in the harvesting decision for the pre-1938 period, but the long run influence of prices was questionable. Statistical relationships for other West African countries for either the pre- or postwar periods and those for Ghana and Nigeria in the post-1946 era were not found significant. The Stern model includes an equation for acreage planted in cocoa for Nigeria (1919/20-1944/45):

\[ \bar{A}_t = -5.14 + 1.11 \bar{P}_t \]

where

- \( \bar{A}_t \) is a five-year centered average of acreage planted to cocoa,
- \( \bar{P}_t \) is a five-year centered average of the real price of cocoa.

The relationship implies a price elasticity (at the mean) of 1.29 for acreage planted. It includes also an estimation of current annual cocoa production for Ghana (1923/24-1937/38).

\[ Y_t = -203.16 + 1.05 \bar{A}_t + 0.54 \bar{P}_t \]

\[ (190.64) (0.47) (0.25) \]

\[ R^2 = 0.40 \quad F = 4.05 \]
\[
Y_t = 392.37 - 0.61 \, AH_t + 0.32 \, P_t + 6.52 \, t \\
(271.16) \quad (0.70) \quad (0.21) \quad (2.34)
\]
\[ R^2 = 0.65 \quad F = 6.82 \]

where

- \( Y_t \) is the current annual cocoa production,
- \( AH_t \) is the number of harvested (bearing) acres,
- \( P_t \) is the current real price of cocoa, and
- \( t \) is the time trend.

The introduction of the time trend into the equation changed the sign of the harvested acreage from positive to negative.

In 1965, Bateman offered a new case study of cocoa in Ghana covering the period 1946-1962. It is based on the assumption that given the perennial nature of the crop, the objective of the cocoa producer is to maximize the net present value of his investment in cocoa. Coffee is considered the only significant alternative to cocoa production in some regions of Ghana and the expectation models used are of the Nerlovian type. The study suggests that annual changes in cocoa production (harvested) can be explained by producer prices, rainfall, and humidity.

The relevant estimated relationship being in the following form:

\[
\Delta Q_t = c_0 + c_1 \, P_{t-k} + c_2 \, P_{t-s} + c_3 \, C_{t-k} + c_4 \, C_{t-s} \\
+ c_5 \, \Delta R_{t-1} + c_6 \, \Delta H_{t-1} + u_t
\]


where $\Delta Q_t$ is the year to year change in the amount of cocoa harvested

- $P_{t-1}$ is the real producer price of cocoa lagged 8 years,
- $P_{t-12}$ is the real producer price of cocoa lagged 12 years,
- $C_{t-8}$ is the real producer price of coffee lagged 8 years,
- $C_{t-12}$ is the real producer price of coffee lagged 12 years,
- $\Delta R_{t-1}$ is the difference in rainfall from one year to the other, lagged one year,
- $\Delta H_{t-1}$ is the difference in humidity from one year to the other, lagged one year, and
- $u_t$ is the error term.

According to Bateman, $P_{t-8}$, $P_{t-12}$, $C_{t-8}$, and $C_{t-12}$ enter the equation because they indirectly determine planting in their respective years. The changes in $R_{t-1}$ and $H_{t-1}$ enter because of their direct effects on output.

15. Bateman's study is considerably weakened by the ambiguity of the empirical model which leads to dubious conclusions. One may question first why coffee should be considered as the only significant alternative to cocoa production in a country where coffee production is very small relative to cocoa. The introduction of both $P_{t-8}$ and $P_{t-12}$ may also be questioned as has the assertion that the coffee price variables should have the same lagged distribution. There is probably some intercorrelation between $P_{t-8}$ and $P_{t-12}$ as well as between $C_{t-8}$ and

1/ 2/ Apparently the lag occurs because of the use of calendar annual rainfall data, and the fact that the crop year begins in October and extends to the following September. This suggests that it might have been more preferable to use monthly weather data.
Table 5: Regression Coefficients for Regional Supply Functions for Ghanaian Cocoa, 1966-62 (4 Regions) 1/  

<table>
<thead>
<tr>
<th>Region</th>
<th>Constant</th>
<th>Cocoa price</th>
<th>Coffee price</th>
<th>Rainfall</th>
<th>Humidity</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pt-k</td>
<td>Pt-s</td>
<td>Ct-k</td>
<td>Ct-s</td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td>-10.820</td>
<td>.129&lt;sup&gt;d&lt;/sup&gt;</td>
<td>.151&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-.137&lt;sup&gt;f&lt;/sup&gt;</td>
<td>-.021</td>
<td>.828&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>( 7.04)</td>
<td>( .060)</td>
<td>( .054)</td>
<td>( .186)</td>
<td>( .202)</td>
<td>( .305)</td>
</tr>
<tr>
<td>Western</td>
<td>-14.854</td>
<td>.100&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.151&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.931&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.724&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.820&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>( 9.90)</td>
<td>( .037)</td>
<td>( .045)</td>
<td>( .250)</td>
<td>( .196)</td>
<td>( .118)</td>
</tr>
<tr>
<td>Volta</td>
<td>-14.498</td>
<td>.069&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.058&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-.200&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.133&lt;sup&gt;d&lt;/sup&gt;</td>
<td>.430&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>( 2.15)</td>
<td>( .020)</td>
<td>( .019)</td>
<td>( .066)</td>
<td>( .069)</td>
<td>( .158)</td>
</tr>
<tr>
<td></td>
<td>- 1.419</td>
<td>.058&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.069&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-.170&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.327&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.742</td>
</tr>
<tr>
<td></td>
<td>( 1.57)</td>
<td>( .019)</td>
<td>( .017)</td>
<td>( .063)</td>
<td>( .152)</td>
<td></td>
</tr>
<tr>
<td>Volta</td>
<td>-14.455</td>
<td>.093&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.081&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-.353&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.104&lt;sup&gt;f&lt;/sup&gt;</td>
<td>.604&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>( 2.27)</td>
<td>( .019)</td>
<td>( .017)</td>
<td>( .059)</td>
<td>( .067)</td>
<td>( .140)</td>
</tr>
<tr>
<td></td>
<td>1.692</td>
<td>.097&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.101&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-.377&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.576&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.920&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>( 1.38)</td>
<td>( .018)</td>
<td>( .015)</td>
<td>( .057)</td>
<td>( .125)</td>
<td>( .138)</td>
</tr>
<tr>
<td>Eastern</td>
<td>1.603</td>
<td>.022</td>
<td>.237&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-.029</td>
<td>-.485&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.889&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>( 5.97)</td>
<td>( .057)</td>
<td>( .041)</td>
<td>( .196)</td>
<td>( .160)</td>
<td>( .359)</td>
</tr>
<tr>
<td></td>
<td>1.522</td>
<td>.240&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-.501&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.523&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.990&lt;sup&gt;c&lt;/sup&gt;</td>
<td>.848</td>
</tr>
<tr>
<td></td>
<td>( 4.925)</td>
<td>( .036)</td>
<td>( .140)</td>
<td>( .254)</td>
<td>( .404)</td>
<td></td>
</tr>
</tbody>
</table>

For footnotes see end of table on page 18.
Table 5: (Cont'd.) Regression Coefficients for Regional Supply Functions for Ghanaian Cocoa, 1919-62 (3 Regions) 1/

<table>
<thead>
<tr>
<th>Region</th>
<th>Constant</th>
<th>$P_{t-k}$</th>
<th>$P_{t-s}$</th>
<th>$C_{t-k}$</th>
<th>$C_{t-s}$</th>
<th>Rainfall</th>
<th>Humidity</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old</td>
<td>14.273</td>
<td>0.157f</td>
<td>0.352$^a$</td>
<td>-1.183d</td>
<td>1.967c</td>
<td>-1.985c</td>
<td>.901h</td>
<td></td>
</tr>
<tr>
<td>Ashanti</td>
<td>(14.03)</td>
<td>(0.111)</td>
<td>(0.089)</td>
<td>(0.424)</td>
<td>(0.587)</td>
<td>(0.748)</td>
<td>(0.762)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15.688</td>
<td>0.124c</td>
<td>0.390$^a$</td>
<td>-1.321$^b$</td>
<td>1.968$^b$</td>
<td>-2.059$^b$</td>
<td>.902</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(12.855)</td>
<td>(0.056)</td>
<td>(0.084)</td>
<td>(0.410)</td>
<td>(0.584)</td>
<td>(0.694)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunyani</td>
<td>19.790</td>
<td>0.166c</td>
<td>0.178d</td>
<td>-1.355e</td>
<td>-0.855$^a$</td>
<td>1.618$^c$</td>
<td>-4.305$^c$</td>
<td>.783</td>
</tr>
<tr>
<td></td>
<td>(20.571)</td>
<td>(0.071)</td>
<td>(0.087)</td>
<td>(0.245)</td>
<td>(0.605)</td>
<td>(0.586)</td>
<td>(1.749)</td>
<td></td>
</tr>
<tr>
<td>Goaso</td>
<td>-2.969</td>
<td>-0.78c</td>
<td>0.71d</td>
<td>.518</td>
<td>.355</td>
<td>.548</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.15)</td>
<td>(0.030)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1/ The figures in parentheses are the standard errors of the coefficients. Significance levels indicated by the author are as follows: $a = .01; b = .02; c = .05; d = .10; e = .25; f = .50.$

2/ The variable $P_{t-k}$ represents the real producer price of cocoa lagged eight years in each region; the variable $P_{t-s}$ represents $P_{t-12}$ (i.e., the real producer price of cocoa lagged 12 years) for every region except Sunyani and Goaso where the value of "s" is 13 and 10, respectively.

3/ The lag structure for coffee prices is identical with the lag in cocoa prices. See 2/.

4/ For an explanation of the Goaso coefficients and the problem with the station, see Bateman's text.

Source: Bateman, op. cit.
Table 6: Aggregate Supply Functions for Ghanaian Cocoa,
1946-62, 1949-62 1/ 2/

<table>
<thead>
<tr>
<th>Pooled regions</th>
<th>Constant</th>
<th>Cocoa price</th>
<th>Coffee price</th>
<th>Rainfall</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pt-k</td>
<td>Pt-s</td>
<td>Ct-k</td>
<td>Ct-s</td>
<td></td>
</tr>
<tr>
<td>Volta, Central &amp; Sunyani (1949-62)</td>
<td>4.036</td>
<td>.125d</td>
<td>.120e</td>
<td>.589c</td>
<td>.18</td>
</tr>
<tr>
<td></td>
<td>(7.72)</td>
<td>(.066)</td>
<td>(.032)</td>
<td>(.719)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>.121a</td>
<td>.133a</td>
<td>.793a</td>
<td>.77</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.017)</td>
<td>(.021)</td>
<td>(.181)</td>
<td></td>
</tr>
<tr>
<td>Volta, Western (1946-62)</td>
<td>- .219</td>
<td>.069a</td>
<td>.081a - .239a</td>
<td>.420a</td>
<td>.76</td>
</tr>
<tr>
<td></td>
<td>(1.111)</td>
<td>(.013)</td>
<td>(.012) (.042)</td>
<td>(.113)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>.069a</td>
<td>.081a - .239a</td>
<td>.420a</td>
<td>.76</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(.013)</td>
<td>(.012) (.042)</td>
<td>(.113)</td>
<td></td>
</tr>
</tbody>
</table>

1/ The figures in parentheses are the standard errors of the coefficients. Significance levels indicated by the author are as follows: a = .01; b = .02; c = .05; d = .10; e = .25; f = .50.
2/ Since not all of the regional functions contained the same variables, it was necessary to adjust the dependent variable in the regional equations which had additional parameters.
3/ The dependent variable in the Volta region was adjusted for \( C_{t-k} \) and humidity so that it could be pooled with the Central region; the dependent variable in Sunyani was adjusted for both coffee prices and humidity so that it could be pooled with the Central region.
4/ The dependent variable in the Volta region was not adjusted and the humidity variable was omitted for the regression. When humidity was included, homogeneity was rejected in each test at all levels.

Source: Bateman, op. cit.
A more complete investigation of the distributed lag pattern of the producers' price response would have been necessary for cocoa and for coffee. Furthermore the use of a humidity variable along with the rainfall variable appears questionable as both variables are obviously intercorrelated. Some composite index might be used instead, or rainfall only if the proximity of the equator line justifies discounting temperature variations. The level of significance of the various parameter estimates and the absence of the test for serial correlation among the residuals for all equations also suggests that the conclusion drawn from the model should be interpreted with reservation.

16. Dean (1965) attempted to explain peasant grown tobacco production in Malawi and make some predictions regarding various supply relationships. In the Dean model which covers 35 years from 1926 to 1960, all of the variables are transformed to a percentage change basis, a transformation identical to a transformation to first differences among logarithms. The basic equation from which Dean's model is the following:

\[ \Delta S = \alpha + \beta \Delta P_T + \gamma \Delta W + \delta \Delta P_I + \phi \Delta D \]

\[ S \] is the symbol for sales of tobacco in lbs.,

\[ P_T \] is the money price of tobacco,

\[ W \] is the wage rate obtainable abroad (South Africa and Rhodesia),

\[ P_I \] is the price index.

D_t is the weather, and

\[ \Delta' \] expressed the percentage change in the variables between year t and year t-2. \[ \Delta D_t \] expressed the absolute change in weather.

17. Dean defined the expected price of tobacco as a weighted average of all past prices, according to Koyck:

\[ P_t^* = \alpha_1 P_{t-1} + \alpha_2 P_{t-2} + \ldots + \alpha_n P_{t-n} \]

Yet, he avoids the use of a distributed lag formulation in the equations of the model proper. A weighted average rate is also calculated according to the equation:

\[ W_t^* = 0.45 W_t + 0.45 W_{t-1} + 0.10 W_{t-2} \]

The expected average wage rate \( W_t^* \) is considered to be a function of all previous average wage rates in the past years, in a manner identical to the above expected price model. Nevertheless the coefficient estimates (or weights) of expected wage equation appear to be sheer guesswork.

18. Prices involved in the construction of the price index were obtained from several sources. All commodities being imported, unit values including custom duties were used. Data were drawn from foreign trade statistics. Prices were also obtained for a few commodities produced in Malawi. It is not clear however how the weights were chosen for these. Weather is introduced in the model through a dummy variable which is given the value +1 when the weather has improved from one year to the next, the value -1 when it has deteriorated, and the value 0 when it has been even from one year to the next.

19. Several alternative dependent variables were tried. They are the percentage change in tobacco sales per capita \( \Delta'(S/Pop)_t \), the
percentage change in tobacco sales per grower $\Delta'\left(\frac{S}{G}\right)_t$, and the percentage in the number of growers relative to the whole population $\Delta'\left(\frac{G}{opp}\right)_t$. The determining variables tested included:

- $\Delta'\left(\frac{P}{P_{t-1}}\right)_t$, the percentage change in the deflated price of tobacco lagged one year,
- $\Delta'\left(\frac{W}{P_{t-1}}\right)_t$, the percentage change in the deflated weighted wage index,
- $\Delta'P_{t-1}$, the percentage change in the undeflated current price of tobacco,
- $\Delta'P_{t-1}$, the percentage change in undeflated current price of tobacco lagged one year,
- $\Delta'P_{t-2}$, the percentage change in undeflated current price of tobacco lagged two years,
- $\Delta 'P_{t-1}$, the percentage change in the price index of "cash" goods lagged one year,
- $\Delta 'W_{t-1}$, the percentage change in the weighted wage index,
- $\Delta D_t$, the change in the weather between year $t$ and year $t-1$ expressed on a first difference basis.

$D$ is a dummy variable.

Estimates of the alternative equations of the Dean model are shown in Table 7. It appears that Malawi tobacco growers would be responsive to price incentives and that farm labor would respond to changes in wages in a manner consistent with economic theory. Reliability of Dean's estimates appears somewhat ambiguous. The omission of technological change, price of alternative products and the handling of the weather through a dummy variable appear highly questionable.
Table 7: Empirical Findings of the Dean Tobacco Supply Model for Malawi (1926-1960)

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Dependent variables</th>
<th>( \Delta' (S/Pop)_t )</th>
<th>( \Delta' (S/Pop)_{t-1} )</th>
<th>( \Delta' (G/Pop)_t )</th>
<th>( \Delta' (S/C)_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta' (P_T/P_I)_{t-1} )</td>
<td>.529 (3.91)</td>
<td>.337 (4.01)</td>
<td>.148 (1.30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta' (W/I)_{t-1} )</td>
<td>-.674 (-1.81)</td>
<td>-.533 (-2.32)</td>
<td>-.134 (-0.06)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta' P_{Tt} )</td>
<td>-.006 (-0.06)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta' P_{Tt-1} )</td>
<td>.512 (3.41)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta' P_{Tt-2} )</td>
<td>.082 (0.56)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta' P_{It} )</td>
<td>-.025 (-0.07)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta' W_{t-1} )</td>
<td>.865 (0.64)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta D_t )</td>
<td>.307 (3.16)</td>
<td>.311 (3.46)</td>
<td>.011 (0.20)</td>
<td>.314 (4.14)</td>
<td></td>
</tr>
<tr>
<td>Constant term</td>
<td>.089 (0.96)</td>
<td>.082 (1.56)</td>
<td>.019 (0.65)</td>
<td>.061 (1.39)</td>
<td></td>
</tr>
<tr>
<td>( R )</td>
<td>.708</td>
<td>.706</td>
<td>.625</td>
<td>.658</td>
<td></td>
</tr>
<tr>
<td>( R^2 )</td>
<td>.381</td>
<td>.445</td>
<td>.326</td>
<td>.372</td>
<td></td>
</tr>
<tr>
<td>von Neumann's ratio</td>
<td>2.557</td>
<td>2.558</td>
<td>2.210</td>
<td>2.797</td>
<td></td>
</tr>
</tbody>
</table>

1/ Figures in parentheses indicate the value of corresponding t-statistic.
Significance levels are not stated explicitly by the author.

\( R \) = Uncorrected multiple correlation coefficient
\( R^2 \) = Square of the multiple correlation coefficient, corrected for degrees of freedom.

Source: Dean, op. cit.
20. Welsh (1965) studying the response to incentives by Nigerian rice farmers tested two hypotheses: (1) that peasants in a traditional agriculture respond to economic incentives by allocating very efficiently the factors of production at their disposal, and (2) that their savings and investment decisions tend to maximize returns to scarce resources. Welsh complains perhaps rightly that too many experts in agricultural development have too eagerly adopted the idea that peasant farmers are not rational economic men, as an easier explanation to the lack of development. Welsh’s conclusions appear to be in agreement with Schultz’s hypothesis as well as other findings.


IV. LATIN AMERICA

21. Several studies of partial aspects of the beef sector in Argentina have been attempted. Two of the most important ones are those carried out by Herrmann and Branson (1962); and by the Joint Committee, Agricultural Economists of U. S. and Argentine Governments (1962). The first of these studies includes a description of the problem and its historical background, some demand and supply aspects of the problem, the structure of the domestic marketing system stressing characteristics which affect exports, and a discussion of the advantages and disadvantages of stabilization programs. The second study which does not include any statistical analysis, is concerned with the prospects of foreign markets for the products of agriculture in Argentina and the effects of relative prices on production of beef and grains.

22. Otrera (1966) attempted to develop a more comprehensive model for analyzing Argentine beef export potentials, including on the supply side an inventory relationship, the beef supply at the farm level, and the beef supply at the retail level. The inventory of beef cattle, i.e., the number of animals at the beginning of year t, is estimated as

a function of the inventory at the beginning of the previous year, the price of beef lagged one year, the price of grain lagged two years, range conditions represented by rainfall conditions lagged two years, and the rate of inflation between year $t-1$ and year $t-2$. The supply of beef cattle at the farm level, or production of beef cattle, i.e., the number of cattle marketed, plus or minus the difference in inventory, are posulated as being determined by the number of animals on farms at the beginning of period $t$, the producer price of beef cattle, range conditions (represented by an index of rainfall lagged one year, and technological improvement (represented by the time trend). The production of dressed beef is explained through its components: (1) the number of cattle slaughtered, considered to be a function of total production of beef cattle at the farm level, the current producer price of beef cattle, the past prices of beef and grains, and time; and (2) the average weight of cattle slaughtered, considered to be a function of the producer price of beef cattle, time, and annual rainfall conditions. Except for the inventory relationship, the simultaneous equations in this model are over-identified and estimated through the limited information - maximum likelihood method.\(^1\) For comparative purposes, the equations were also estimated through the classical method of least squares and the two-stage least squares. The standard errors of the coefficients are indicated in the parentheses below each coefficient. The levels of significance are nevertheless not explicitly given by the author. The test for the

\(^1\) In this method, though each equation is considered to be part of a system of simultaneous equation, it is estimated separately ignoring the information obtained from the other equations of the system.
presence of serial correlation among the residuals is provided by the ratio $d^2/s^2$ of the mean square of successive differences among residuals to the variance of the residuals.

23. **Supply of Beef at the Farm Level (1945-1964)**

a) **Limited Information Estimates**

\[
Y_1 = 0.1783 + 0.0662 Y_2 - 0.0386 Z_1 - 0.0058 Z_2 + 0.2020 Z_3
\]

\[
(0.0240) (0.0237) (0.0041) (0.0479)
\]

\[
d^2/s^2 = 1.93
\]

b) **Ordinary Least Squares Estimates**

\[
Y_1 = 0.6460 + 0.0607 Y_2 - 0.0334 Z_1 - 0.0052 Z_2 + 0.1919 Z_3
\]

\[
(0.0148) (0.0157) (0.0041) (0.0332)
\]

\[
R^2 = 0.77
d^2/s^2 = 1.92
\]

c) **Two Stage Least Squares Estimates**

\[
Y_1 = 0.4087 + 0.0635 Y_2 - 0.0360 Z_1 - 0.0055 Z_2 + 0.1970 Z_3
\]

\[
(0.0239) (0.0236) (0.0041) (0.0478)
\]

\[
d^2/s^2 = 1.93
\]

where

- $Y_1$ is number (thousand head) of animals produced on farms in year $t$,
- $Y_2$ is price of beef (liveweight) at 1964 purchasing power, at farm level in year $t$,
- $Z_1$ is time trend, representing technological improvement,
- $Z_2$ is index rainfall conditions for the Pampa region derived from recorded rainfall at 38 weather stations, and
- $Z_3$ is inventory (million head) at the beginning of year $t$.

24. **Average Weight of Cattle Slaughtered (1945-1964)**

c) **Limited Information Estimates**

\[
Y_3 = 190.6229 + 0.5725 Y_2 - 0.5769 Z_1 + 0.1208 Z_2
\]

\[
(0.1307) (0.1199) (0.0434)
\]

\[
d^2/s^2 = 1.88
\]
b) Ordinary Least Squares Estimates

\[ Y_3 = 190.2038 + 0.6595 Y_2 - 0.6595 Z_1 + 0.1089 Z_2 \]
\( (0.1143) \quad (0.1112) \quad 1 \quad (0.0418) \)

\[ R^2 = 0.77 \quad d^2/s^2 = 1.80 \]

c) Two-Stage Least Squares Estimates

\[ Y_3 = 190.5285 + 0.5921 Y_2 - 0.5894 Z_1 + 0.1181 Z_2 \]
\( (0.1297) \quad (0.1190) \quad 1 \quad (0.0430) \)

\[ d^2/s^2 = 1.86 \]

where,

- \( Y_3 \) is average weight (Kg/animal) of cattle slaughtered,
- \( Y_2 \) is price of beef (liveweight) at 1964 purchasing power at farm level, in year \( t \)
- \( Z_1 \) is time trend, representing technological improvement, and
- \( Z_2 \) is index rainfall conditions for the Pampa region derived from recorded rainfall at 38 weather stations.

25. Number of Cattle Slaughtered (1945-1964)

a) Limited Information Estimates

\[ Y_4 = 8.1652 - 0.6518 Y_1 - 5.8157 Y_2 + 6.7804 Z_1 - 0.4213 Z_4 + 8.1652 Z_5 \]
\( (0.4365) \quad (2.5976) \quad (1.4554) \quad (4.6094) \quad (?) \)

\[ d^2/s^2 = 1.97 \]

b) Ordinary Least Squares Estimates

\[ Y_4 = 75.0668 + 0.0709 Y_1 - 2.0785 Y_2 + 2.747. Z_1 - 0.9792 Z_4 + 2.3357 Z_5 \]
\( (0.0663) \quad (0.1561) \quad (0.4562) \quad (0.4014) \quad (0.9726) \)

\[ R^2 = 0.80 \quad d^2/s^2 = 1.51 \]

c) Two-Stage Least Squares Estimates

\[ Y_4 = 130.4360 - 0.9660 Y_1 - 2.3405 Y_2 + 3.1396 Z_1 - 0.9677 Z_4 + 2.8155 Z_5 \]
\( (13.1170) \quad (0.7806) \quad (0.7915) \quad (0.4374) \quad (1.3853) \)

\[ d^2/s^2 = 1.68 \]
where

\[ Y_4 \] is number (thousand head) of cattle slaughtered in year t,

\[ Y_1 \] is number (thousand head) of animals produced on farms in year t,

\[ Y_2 \] is price of beef (liveweight) at 1964 purchasing power at farm level in year t,

\[ Z_1 \] is time trend, representing technological improvement,

\[ Z_2 \] is price of beef (liveweight) at 1964 purchasing power at farm level in year t-1, and

\[ Z_5 \] is the aggregative price of grain, per ton, at 1964 purchasing power in year t-1.

26. **The Inventory Relationship (1945-1964)**

Ordinary Least Squares Estimates

\[
Z_3 = 10.4623 + 0.7216 Z'_3 + 0.0607 Z_4 - 0.2981 P + 0.0031 I_f + 0.0325 R_c
\]

\[
R^2 = 0.68 \quad \text{and} \quad \frac{d^2}{s^2} = 1.71
\]

where,

\[ Z_3 \] is number (million head) of animals at beginning of year t,

\[ Z'_3 \] is number (million head) of animals at beginning of year t-1,

\[ Z_4 \] is price of beef (liveweight) at 1964 purchasing power in year t-1,

\[ P \] is price of grain (pesos per ton) at 1964 purchasing power in year t-2,

\[ I_f \] is rate of inflation between years t-2 and t-1, and

\[ R_c \] is rainfall conditions index for year t-2.

27. Otrera's effort is one of the more serious to date to develop quantitative estimates of the various relations' uses in the beef sector in Argentina. Results indicate that

1) an increase of 10 pesos in 1964 purchasing power in the price of beef at the farm level would result in approximately 66,200
head of increase in the production of beef cattle at the farm level (supply elasticity +0.16);

2) for each 10 million animals on farms at the beginning of year t there will be approximately 2 million animals produced at the farm level;

3) the number of animals slaughtered is reduced by about 580,000 head when there is an increase of 1 peso in the price at the farm level; and

4) the average weight of cattle slaughtered increases almost 600 grams with an increase of 1 peso in the price per live weight kilogram of beef cattle.

28. Nevertheless the weaknesses of the model are obvious, i.e., over identification of the relationships, multicollinearity among the variables, elements of autoregression and excessive use of the time trend variable. The influence of the weather might be more adequately estimated through an index accounting also for temperature. The use of a beef/grain price ratio rather than that of beef and grain prices deflated separately might also help improve the model. Investigation of a possible distributed lag pattern of producers' response to prices might also be necessary.

29. Miss Arak (1967)\(^1\) sets out to measure the price responsiveness of Brazilian coffee growers through the measurements of both the changes

in the yield per coffee tree and changes in the number of producing
trees. Difficulties arising regarding tree crop model building are obvious.

The basic model utilized to analyze the response of yield to price is as follows:

\[
\frac{Q_t}{T_{t-1}} = a_0 + a_1 \left( \frac{Q_{t-1}}{Q_{t-2}} - 1 \right) + a_2 r_{t-1} + \nu_t
\]

where

- \( Q_t \) is the exportable production of coffee in year \( t \) (total production minus domestic consumption),
- \( T_{t-1} \) is the number of producing coffee trees in year \( t-1 \),
- \( r_{t-1} \) is the coffee price prevailing during the previous year,
- \( \frac{Q_{t-1}}{Q_{t-2}} - 1 \) is a variable designed to take account of the biennial cycle in coffee tree yields, and
- \( \nu_t \) is the residual (including the weather).

30. Surprisingly, the question of allowing for the effect of weather variations upon the yield of coffee per tree is dismissed by the author in a manner which severly impairs the results of her study. Says Miss Arak, "The effect of weather on annual coffee yield is large but as weather is a random factor, it may be included in \( \nu_t \) which includes other random factors affecting yield. Of course, a large portion of the variance in yield is due to weather and hence our model is not expected to explain a large percent of the variance in coffee yields".
The estimated yield equations presented for the States of Sao Paulo and of Minas Geraes for the period 1926-27/1953-54 are as follows:

**Sao Paulo:**

\[ \frac{Q_t}{T_{t-1}} = 7.59 + 0.0127 r_t - 2.26 \left[ \frac{Q_{t-1}}{Q_{t-2}} - 1 \right] \quad R^2 = 0.18; \]

**Minas Geraes:**

\[ \frac{Q_t}{T_{t-1}} = 3.94 + 0.0057 r_t - 11.03 \left[ \frac{Q_{t-1}}{Q_{t-2}} - 1 \right] \quad R^2 = 0.19 \]

31. Regarding the second component, namely the number of producing units (coffee trees), the study hypothesizes first that a percentage adjustment model by itself could explain a large part of the planting of coffee trees, second that the speed of adjustment was either constant or dependent upon the stock of coffee trees. The suitability of these simple stock adjustment planting models in explaining the number of coffee trees planted depends very much upon whether or not an observation on the average amount of planting during the 1920's was added to the observation set 1930-55 (with 1937 and 1942-43 excluded). Including it, the model explained 80 percent of the variance of plantings with the following estimated equations:

\[ P_t = 2.66 + 0.201 r_t - 0.014 EP_t \quad R^2 = 0.80 \]

1/ In all equations the figures between parentheses appearing just below the coefficients are the standard errors of the coefficients. The levels of significance are not explicitly given by the author.
where

\( P_t \) is total number of coffee trees planted in year \( t \),

\( r_t \) is a measure of expected coffee price, and

\( \Lambda P_t \) is a measure of the area once suitable for coffee cultivation.

Excluding the observation on the average plantings during the 1920's the model appears considerably worse. Introducing \( T_{At} \), the percentage of the tree stock aged two and over in year \( t \), the estimated equations for the period (1930-1955) were found to be:

\[
P_t = -82.69 + 0.266 r_t - 0.046 \Lambda P_t + 102.10 T_{At} \quad R^2 = 0.83
\]

32. Abandonment of coffee trees in the State of Sao Paulo was estimated as a function of the number of older trees, coffee price expectations and past weather experience (frost), while, annual removals (to clear land for other crops) were estimated to be a function of expected coffee prices and weather conditions in the past years. The estimated equations for abandonments appear to be of little value in view of the rather poor explanation they provide. The corresponding equations for tree removals, on the other hand, explain about 61 percent of the variance in tree removals:

\[
E_t = 73 - 0.04 r_t + 68.6 W_{t-1} \quad R^2 = 0.61
\]

33. The proportion of trees abandoned to the total number of trees depends, among other things, upon coffee price expectations. Actually, either old or young trees or both may be abandoned or removed. The study suggests that most abandonments of old trees occurred under
expectations of raising coffee prices; on the other hand, abandonments of younger trees would occur when coffee prices were expected to decline. Removal decisions (with a view to use the land for other crops) are likewise assumed to be dependent on price expectations and weather conditions (frost). The model, however, explains only a small percentage of variations in removal decisions. This unsatisfactory result led the author to a change in the specification by using removals as a percentage of the number of trees between one-year and three-years-old, since removals are normally carried out when the trees are still very young.

34. The results indicate that expected prices play a significant role in determining new plantations. Factors such as the age distribution and the "demonstration" effect were also tried in the equations. The latter effect was allowed for by a proxy, namely the currently cultivated coffee area.

35. Separate analysis of the three components of tree crops - abandonment, removal, and plantations - is done for the States of Sao Paulo, Parana, and Minas Geraes.

36. Various price series for coffee have been constructed by Miss Arak, with expected coffee prices appearing to be moving averages over two- through seven-year periods, and used to represent alternative farmers' price expectations. The cost of living index and the price of cotton have been tried as deflators of coffee prices. Cotton is considered to be the prime alternative crop for coffee in Brazil; maize, cereals, oilseeds, sugar, and dairy products are other competing crops. The various price
estimates refer to Brazil as a whole rather than to the State of Sao Paulo. It is not clear which measures of expected prices give statistically significant results.

37. Miss Arak also examines the effect of the quota system on farmers' price expectations and thereby on plantings, as well as the role of liquidity in planting decisions. The latter is not found to be significant whereas the former turns out to reduce the average return per kilo of coffee to growers. This "finding" may appear questionable to many. The study points out that government's policy on price fixation can significantly affect new plantings, abandonment, and removal of trees through farmers' price expectations. However, in view of the weakness of the present model, it appears difficult to draw conclusions as to its ability to predict plantings reasonably well. Changes in plantings have been underway since 1958, in terms of using improved varieties, more fertilizer and better plant protection measures, and obviously these affect profit substantially.

38. Miss Arak's study was, of course, up against the difficulty of dealing with tree crops and the fact that expected prices per se are only one element in the complex interplay of all factors influencing agricultural activity. Investments in tree crops are characterized by long gestation periods which considerably dampen the response to current price variations. The yield equations and the new plantings equations would appear consistent with the real world situation as year-to-year price variations seem to be both one of the lesser determinants of yield changes and one of the major determinants of changes in the number of
producing units. The weather factor (besides frost) could have been allowed for in the model, had the weather data - which apparently are available since 1914 - in the area studied been carefully investigated.

The introduction of a "demonstration effect" variable would also seem to be questionable in an aggregate time series model where all growers' response is estimated "on the average". The proxy used introduced an element of autoregression which considerably weakens the explanatory power of the model as to the cause of changes. The case of Sao Paulo, which is the only producing state for which there are annual statistics on planting, abandonment, and removal of trees is particularly interesting. It would be more appropriate to attempt to develop a coffee growers' response model for this State alone. Such a model might well be indicative of the response pattern of Brazilian coffee growers in general.

1/ See Program Windex For The Systematic Calculation of a Weather Index To Be Used In Agricultural Production Analysis, IBRD, Economics Department Working Paper No. 3, August 14, 1967.
V. CONCLUSIONS

39. As suggested by this survey agricultural supply models thus far devised for developing countries leave much to be desired. Their main weaknesses are a serious lack of specification and a frequent use of data proxies. Comparisons among estimates are generally of dubious value as the models do not cover similar time periods and are generally based on different sets of assumptions. However great progress has been made since 1950 in assembling better statistical information in a systematic manner. Even so, the need persists for a more rigorous approach in the area of agricultural supply model building in developing countries, including the specification of a better theoretical framework and a more systematic empirical investigation, in order to make agricultural supply models comparable from country to country or area to area and from commodity to commodity.
APPENDIX

Tentative Bibliography of Existing Studies
Since 1960

(a) Unpublished Doctoral Dissertations


Chao, Ching Yuan, Dynamic and Non-Linear Programming for Optimum Farm Plans in Taiwan, Iowa State University of Science and Technology, 1963.

Coffey, Joseph Daniel, Prospects of Transforming Peru's Traditional Agriculture, North Carolina State University, 1965.


Giles, Antonio Hector, Agricultural Development at the Farm and Community Level Through Reform of Existential Structures: Two Case Studies in Peru, Iowa State University of Science and Technology, 1964.


Ho, Yi-Min, The Agricultural Development of Taiwan, 1903-60: Its Patterns and Sources of Productivity Increases, Vanderbilt University, 1965.


Khan, Riaz Ahmad, Marginal Rates of Substitution Between Fertilizer and Land in Production of Wheat and Paddy Rice, Iowa State University of Science and Technology, 1965.


Quintana, Emilio U., Resource Productivity Estimates for Five Types of Philippine Farms, Purdue University, 1960.

Randhawa, Narindar Singh, Regional Programming Models for Agricultural Development in India, Iowa State University of Science and Technology, 1963.


(b) Periodicals


(c) Books


d) Seminar Papers


(e) U. S. Department of Agriculture Studies of Major Significance on Developing Countries (available as of this date)


India: Supply of and Demand for Selected Agricultural Products in India, Projections to 1975-76, USDA, ERS, Foreign - 100 which summarizes the report of the National Council of Applied Economic Research (NCAER), New Delhi, and reviews its findings on the basis of the critical analysis undertaken by Professor John W. Mellor on USDA's behalf, and made available to them in July 1963.

Jamaica, Trinidad and Tobago, Leeward Islands, Windward Islands, Barbados, and British Guiana, Projected Levels of Demand, Supply and Imports of Agricultural Products to 1975, ERS - Foreign 91, March 1965.


Turkey: Agriculture in Turkey, Long Term Projections of Supply and Demand, School of Business Administration and Economics, Robert College, Bebek, Istanbul, 1966.


(f) Agricultural Production Statistical Data Sources
