AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

ESTIMATING THE PRODUCT REVENUE BIAS OF TECHNOLOGICAL CHANGE

UNIVERSITY OF ...
Agricultural Economics Library

by

Adesoji Adelaja and Anwarul Hoque*

Paper prepared for presentation at the 76th annual meeting of the American Agricultural Economics Association, July 1985

*The authors are, respectively, Lecturer, Department of Economics; and Associate Professor, Department of Agricultural Economics; West Virginia University. This research was supported by funds appropriated under the Hatch Act.

ESTIMATING THE PRODUCT REVENUE BIAS OF TECHNOLOGICAL CHANGE

The effect of technological change on production input mix received significant attention by economists during the last few decades. Most studies on the subject estimated the input biases of technological change which indicate the effect of new technology on input mix by utilizing the two-factor single product models (David and van de Klundert, 1965; Beckman and Sato, 1969; Nadiri, 1970). These models, however, were quite restrictive and could not be used to estimate input biases when more than two inputs are used in production.

Binswanger (1974) used the duality theory approach to demonstrate that Hicks type biases can be estimated for production processes involving multiple inputs but a single product. More recently, however, several studies have suggested that even the multiple-input/single-product models are restrictive in modeling the production technologies employed in multi-product industries such as agriculture. Ray (1982); Shumway, Pope and Nash (1983); and several others therefore proposed the multiproduct models for estimating farm production technology.

One important but often ignored aspect of technological change is its possible effect on the product side. Although, with the advent of the multi-product models, the possibility of estimating the effects of technological change on the product mix and the relative shares of farm revenues from various farm product categories seems stronger, very little empirical effort has been aimed at such estimation. Knowledge gained from such a study can be useful to farmers and policy makers in understanding the potential impact of new technology on farm revenues and the relative incomes and profitability of various types of farm enterprises.

In this paper, a multi-product model capable of providing estimates of input biases and the product revenue biases of technological change is

ABSTRACT

A joint multi-product model was used to derive measures of marginal rates of product tranformation and the input biases, product biases and rates of technological change in the West Virginia farm sector. These were used to analyze the effect of technological change on the revenue shares of the economy's sub-sectors

presented and applied to data from West Virginia's agricultural sector in order to determine the extent to which technological change has encouraged or discouraged the production of various farm commodity categories.

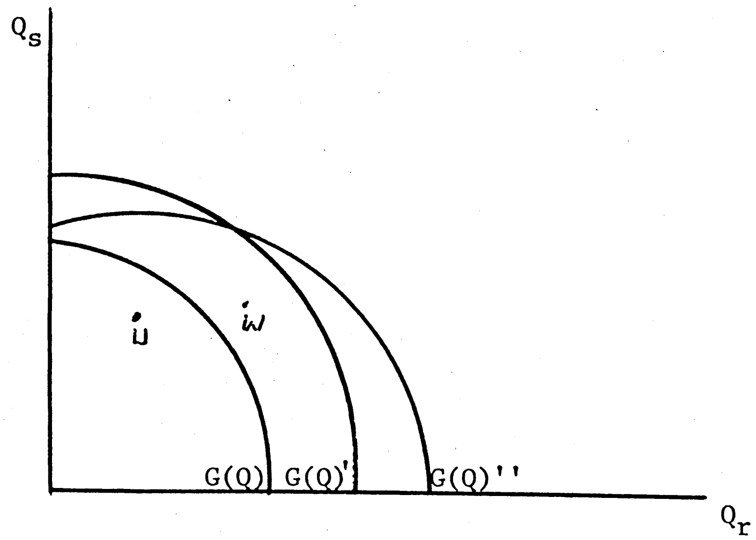
THEORETICAL BACKGROUND

Assuming full employment of production resources, fixed technology, optimal efficiency and technological jointness in the production of a vector of products (Q), a production possibilities frontier, G(Q), exists for the industry which is non-linear and concave. Concavity of G(Q) implies that the marginal rate of product transformation ($MRTS_{rs}$) of the r^{th} product (Q_r) for the s^{th} product (Q_s) along G(Q) increases as the output of product Q_s increases. By further assuming that only two products (Q_r and Q_s) are produced, a two-dimentional production possibilities curve, such as shown in Figure 1, can be used to illustrate the output alternatives available in the production process.

In Figure 1, it is important to note that all points within G(Q), such as U, represent inefficient use of resources while all points beyond G(Q), such as W, are unattainable unless technological change facilitates a shift in the G(Q) function. This occurs when newer technologies allow greater output from a given level of resources or when the same level of output can be produced at a lower cost. Furthermore, MRPT of Q_r for Q_s is the slope of the G(Q) function.

Product neutral technological change which maintains the product mix structure involves a parallel shift in the production possibilities curve from G(Q) to G(Q)' (Miller, 1982). An example of such shifts is improved management ability due to advances in the use of computers in farm management which is likely to keep the product proportions unchanged. On the other hand, non-neutral (biased or non-parallel) shifts in the production possibilities curve which occur when new technology favors the production of one product relative to the other is shown in Figure 1 as a shift from G(Q) to G(Q)''. For example, advancements in dairy technology are more likely to benefit dairy production than crop production. Hence, the increase in dairy output can be expected to be higher than in crop, given the same level of resources.

Figure 1. Two-product Production Possibilities Frontiers.



MODELING AGRICULTURAL SECTOR PRODUCTION TECHNOLOGY

Determining the product bias of technological change requires the specification of a multi-product model for the sector in question. Furthermore, for the agricultural sector, the model must reflect the technological jointness of farm technology which is due to the use of allocatable fixed inputs (Shumway, 1983).[1] The specification of separate production functions for each commodity produced is inappropriate because it does not account for technological jointness (Shumway, 1984). The multi-product cost function, however, seems appropriate as it takes into account technological jointness. Besides, it is useful because it can be used to estimate the marginal rate of product transformation and the revenue bias of technological change, both of which are useful in evaluating changes in the product mix.

The Model

The dual cost function for a multi-product farm sector can be implicitly expressed as follows (Ray, 1982):

(1) $C = C(Q, P, t)$

where C is total farm sector cost of production; Q is a vector of outputs (Q_r), r = 1, 2, ..., m; P is a vector of input prices (P_i), i = 1, 2, ..., n; and t is the trend variable, reflecting technological change. The cost function in (1) assumes that the production technology for the sector is joint. Furthermore, it is linearly homogeneous, continuous, concave and increasing in the input prices, non-negative and non-decreasing at all input price and output levels, and is twice differentiable with respect to the input prices and the products.

A second-order Taylor-series expansion of (1) yields the following explicit translog cost function:

$$(2) \quad \ln C = a_0 + \sum_r^m b_r \ln Q_r + \tfrac{1}{2}\sum_r^m \sum_s^m d_{rs} \ln Q_r + \sum_i^n e_i \ln P_i + \tfrac{1}{2}\sum_i^n \sum_j^n h_{ij} \ln P_i \ln P_j + z_T t$$
$$+ \tfrac{1}{2} z_{TT} t^2 + \sum_r^m \sum_i^n k_{ri} \ln Q_r \ln P_i + \sum_r^m g_{Tr} t \ln Q_r + \sum_i^n z_{Ti} t \ln P_i$$

Furthermore, the following linear homogeneity and symmetry constraint must be imposed on (2):

$$(3) \quad \sum_i^n e_i = 1; \ \sum_i^n h_{ij} = 0, \ (j=1, 2, ..., n); \ \sum_r^m k_{ri} = 0, \ (i=1, 2, ..., n);$$
$$\sum_i^n z_{Ti} = 0; \ h_{ij} = h_{ji}, \ (\text{for all } i \text{ and } j); \ d_{rs} = d_{sr}, \ (\text{for all } r \text{ and } s).$$

The input shares (S_i) can be derived by using Shephard's lemma:

$$(4) \quad S_i = X_i P_i / C = e_i + \sum_j^n h_{ij} \ln P_j + \sum_r^m k_{ri} \ln Q_r + z_{Ti} t.$$

By assuming that all product and factor markets are competitive, which implies that the r^{th} product's price (P_r) is equal to the marginal cost of producing it (MC_r), the revenue shares of each product (S_r) can also be expressed as (Ray):[2]

$$(5)\quad S_r = P_r\ Q_r/C = \partial C\ Q_r/\partial Q_r\ C = \partial \ln C/\partial \ln Q_r$$
$$= b_r + \sum_s^m d_{rs} \ln Q_s + \sum_i^n k_{ri} \ln P_i + g_{Tr} t.$$

Inherent in the joint multi-product model is the notion that product-product relationships exist in the production process. The cost function in (2) is therefore specified to allow the estimation of such relationships through the marginal rate of product transformation which is the ratio of the marginal costs of any two products. The marginal cost (MC_r) is derived as follows (Ray; Brown, Caves and Christensen):

$$6)\quad MC_r = P_r = S_r\ C/Q_r.$$

The marginal rate of product transformation ($MRPT_{rs}$) is therefore derived as (Denny and Pinto):

$$(7)\quad MRPT_{rs} = (\partial C/\partial Q_r)(\partial C/\partial Q_s) = MC_r/MC_s = ((\partial \ln C/\partial \ln Q_r)/(\partial \ln C/\partial \ln Q_s))(Q_r/Q_s)$$
$$= (S_r\ Q_s)/(S_s\ Q_r).$$

Equation 2 is also specified to allow the estimation of the rate of technological progress (E_t), the input bias of technological change ($Bias_i$) and the revenue bias of technological change ($Bias_r$). The rate of technological progress is expressed as (Ball and Chambers):

$$8)\quad E_t = -(\partial \ln C/\partial t) = -(z_T + z_{TT} t + \sum_r^m g_{Tr} \ln Q_r + \sum_i^n z_{Ti} \ln P_i).$$

Furthermore, the input biases are expressed as (Binswanger):

$$9)\quad Bias_i = \partial S_i/\partial t = z_{Ti}, \quad \text{for all } i.$$

Thus, technological change is assumed to be biased with respect to input i at a constant rate of z_{Ti} such that if $z_{Ti} = 0$, $z_{Ti} < 0$ or $z_{Ti} > 0$, it is, respectively input i neutral, input i saving or input i using.

The revenue bias of technological change ($Bias_r$) can also be derived as the effect of technology on revenue shares. This is expressed as follows:

10) $Bias_r = \partial S_r/\partial t = g_{Tr}$,   for all r.

In (10), it is assumed that technological change is biased with respect to the products at constant rates of g_{Tr}. If $g_{Tr} = 0$, technological change is neutral with respect to product r and the revenue share of product r remains unchanged. On the other hand, if $g_{Tr} < 0$, technological change will decrease the revenue share of product r and if $g_{Tr} > 0$, technological change will increase the revenue share of product r. In the event that technological change reduces the revenue share of two or more products, it is useful to observe the relative bias ($Bias_{rs}$).

11) $Bias_{rs} = (Bias_r/Bias_s) = g_{Tr}/g_{Ts}$.

If $Bias_{rs} > 1$, the revenue share of product r declines more than the revenue share of product s. The reverse is true when $Bias_{rs} < 1$.

TECHNOLOGICAL CHANGE IN WEST VIRGINIA AGRICULTURE

The model was used to estimate the impact of technological change on the input as well as the revenue mix of the West Virginia agricultural sector. Farm inputs in the sector were divided into six categories; labor (L), fertilizer inputs (F), energy inputs (E), machinery inputs (M), capital (C) and miscellaneous inputs (N). The farm sector output was also divided into two categories; crop products (c) which include all grain, seed, hay, forage, silage, tobacco, fruit, berry, nut, vegetable, melon and greenhouse products; and livestock products (l) which include all poultry, dairy, cattle, calves, hogs, feeder pigs, sheep and lamb products.

Data on input prices, input shares and outputs were required to fit the model. The input price data came from the Agricultural Prices, (USDA). The input shares for each of West Virginia's fifty five counties over six time periods (1959, 1964, 1969, 1974, 1978 and 1982) were obtained from the information on farm expenses published in the Census of Agriculture, West Virginia, (USDA). For each time period, output and revenue data for each county were also obtained from the same source.

The multi-product translog cost function, the revenue share equations (5), the cost share equation (4) and the cost function itself (2) were estimated simultaneously. However, the input share equation for miscellaneous inputs was dropped and the other equations were estimated using Zellner's seemingly unrelated technique (Barten, Kmenta and Gilbert, Ray, Ruble, and Griffin and Gregory).

Given the size of the multi-product cost function and the number of parameters estimated, the estimates were found to be satisfactory since all but 9 of the 55 parameter estimates were significant at the 5 percent level. However, these estimates are not provided in this paper. The R^2 values were also considered to be adequate given the nature of the multi-product cost function and it was determined that serial correlation was not a problem. Furthermore, the test for concavity and monotonicity led to the conclution that the cost function was well behaved.[3] A number of additional tests on the cost function led to the general conclusion that the technology was non-joint and non-homothetic and that technological change in the sector was non-neutral.

<u>The Rates of Technological Progress</u>

The estimated annual rates of technical progress presented in Table 1 show that technological change was infused into the West Virginia agricultural sector at an annual rate of about 1 percent in 1964, 2 percent in 1969, 3 percent in 1974, 4 percent in 1978 and 5 percent in 1982. In 1959, however, there was technological regression in the sector. As suggested by Ball and Chambers, technological regression may be indicative of massive technological improvement but failure of the industry to grow into it due to an overestimation by farmers of the growth in demand for farm products. In the years that technological progress occured, however, the rates of technical progress in West Virginia were rather low, compared to the Northeastern U.S. dairy sector (see Hoque and Adelaja, 1984). Adelaja (1984) suggested that farms in West Virginia are reluctant to improve technology since farm technology in the U. S. tends to be too sophisticated and mechanical for West Virginia farms.

The Rates of Product Transformation

The marginal rates of product transformation (see Table 1) which represent the slope of the production possibilities curve further provide information on shifts in the product mix of the farm sector. The observed increase in absolute value of $MRPT_{lc}$ in the industry before 1974 suggests relative shifts in resources from livestock to crop products prior to 1974. However, the decrease in the absolute value of $MRPT_{lc}$ after 1974 suggests that resources were shifted back towards livestock production after 1974. Since it was observed that technological change occured during most of the period under study, changes in $MRPT_{lc}$ tend to suggest that the production frontier shifted but the product mix also changed in response to changing technology.

The Bias of Technological Change

Estimates of the input bias as well as the product bias of technological change are provided in Table 2. According to the estimates, technological change in West Virginia agriculture was labor saving, fertilizer using, energy saving, capital using, machinery using and miscellaneous inputs using. The estimated labor saving bias explained why the percentage of West Virginia labor force employed in farming has been declining over the years. The estimated capital and machinery using bias of technological change also suggests that the declining importance of labor may have been due to the increase in capital and machinery intensity of farm technology in the state. Furthermore, the estimated energy saving bias suggests that farmers are perhaps employing energy conserving technology probably due to the rapid increases in energy prices in the last few years.

The estimated product biases suggest that technological change has caused the revenue shares of both crop and livestock products to decline over the years. This finding is important because it suggests that non-marketed farm products are becoming more important to West Virginia farmers.

The non-marketed products include farm products consumed on the farm and other benefits derived from farming. These are particularly important to farmers in West Virginia where an estimated $91 million of non-money farm income (20 percent of total gross farming income) was realized in 1980 (West Virginia Department of Agriculture, Crop Reporting Service). The product biases suggest that although the farming technology does not discourage the production of livestock products or crop products, it encourages the production of farm consumed goods. This may imply that the technology employed in the state is inadequate for full scale market oriented farming.

Since the revenue bias for crops and livestock products are negative, it is helpful to observe the relative revenue bias which measures the bias for a product relative to the other. The relative bias indicates whether the reduction in the revenue share of one product, relative to the other, is greater. The relative bias ($Bias_{lc}$) for West Virginia was estimated to be 0.8125. This indicates that the technological change in the sector was livestock intensifying or, in other words, it had more impact in increasing livestock revenues than crop revenues. Thus, in general, it may be concluded that the revenues from crop and livestock have increased over time, the revenues from crops and livestock as a percentage of total farm sector benefits have declined and the decline in crop share of total revenues is higher than the decline in the livestock share of total farm sector revenues.

CONCLUDING REMARKS

The main objectives of this paper are to present and examine the efficacy of an analytical model capable of producing estimates of the revenue bias of technological change in a multiple product sector. Empirical results obtained by applying the model to West Virginia data suggest that technological change may have led to increases in livestock and crop revenues but that livestock revenues have increased faster in the sector. Also, the revenue shares of livestock and crop products have decreased over the years. This implies that there has been an increased emphasis on production of non-marketed products but a reduced emphasis on market products. The information generated is useful in analyzing trends in sources of revenues for farmers and also in the allocation of resources between multiple products.

NOTES

1. Technological jointness is often defined in terms of non-jointness. As expressed by Hall (1973), and Denny and Pinto (1978), a multi-product technology is non-joint if the output of any single process depends only on the inputs used in that process and not on the levels of inputs or outputs in any other process. On the basis of this definition, it is often assumed that agricultural production technology is joint.
2. The revenue share is the ratio of the revenue generated from a product to the total farm sector cost of production. But assuming perfect competition, the sum of market and non-market products is approximately equal to the cost of production. In other words, $S_r = P_r Q_r / C$ and $S_1 + S_2 + S_3 + \ldots\ldots\ldots\ldots + S_m = 1$.
3. For details of these tests, see Adelaja (1984).

Table 1. Estimated Marginal Rates of Product Transformation and the Rates of Technical Progress in West Virginia Agriculture, 1959-1982

Year	Marginal Rate of Product Transformation	Rate of Technical Progress
1959	-0.597	-0.0052
1964	-0.632	0.0095
1969	-0.669	0.0187
1974	-0.540	0.0331
1978	-0.508	0.0410
1982	-0.460	0.0506

Table 2. The Estimated Bias of Technological Change

Input/Output	Estimated Bias	Standard Error	Nature of Bias
$Bias_L$	-0.0056	0.0008	Saving
$Bias_F$	0.0001*	0.0004	Using
$Bias_E$	-0.0008	0.0002	Saving
$Bias_M$	0.0025	0.0005	Using
$Bias_C$	0.0149	0.0019	Using
$Bias_N$	-0.0111	-----	Saving
$Bias_l$	-0.0052	0.0015	Livestock Revenue Reducing
$Bias_c$	-0.0064	0.0014	Crop Revenue Reducing
$Bias_{lc}$	0.8125	-----	Livestock Revenue Intensifying

References

Adelaja, A.O. "An Analysis of Production Technology and Policy in the Multi-Product Cost Function Framework: The Case of West Virginia Agriculture." Unpublished Ph.D. Dissertation, West Virginia University. 1984.

Ball, E.V. and R.O. Chambers. "An Economic Analysis of Technology in the Meat Products Industry." Amer. J. Agric. Econ., 64 (1982): 699-709.

Barten, A.P. "Maximum Likelihood Estimations of a Complete System of Demand Equations." Europ. Econ. Rev., 1(1969): 7-73.

Beckman, M. and R. Sato. "Aggregate Production Functions and Types of Technical Progress: "A Statistical Analysis." Amer. Econ. Rev. 59(1969): 88-101.

Binswanger, H.P. "The Measurement of Technical Change Biases With Many Factors of Production." Amer. Econ. Rev., 64(1974): 964-76.

Brown, R.S., Caves, D.W. and L.R. Christensen. "Modelling the Structure of Cost and Production for Multiproduct Firms." Southern Econ. J, 46(1979): 256-273.

David, P.A. and Th. van de Klundert. "Biased Efficiency Growth and Capital-Labor Substitution in the U.S., 1899-1960." Amer. Econ. Rev. 55(1965): 357-394.

Denny, M. and C. Pinto. "An Aggregate Model with Multi-Product Technologies." Production Economics: A Dual Approach To Theory and Application. Amsterdam: North Holland Publishing Co., 1978.

Griffin, J.M. and Gregory P. R. "An Inter-Country Translog Model of Energy Substitution Responses." Amer. Econ. Rev. 66(1976): 854-857.

Hoque, A. and A. Adelaja. "Factor Demand and Returns to Scale in Milk Production: Effects of Price, Substitution and Technology." Northeastern J. Agric. Resource Econ., 13(1984): 238-245.

Kmenta , J. and R. Gilbert. "Small Sample Properties of Alternative Estimates of Seemingly Unrelated Regressions." J. Amer. Stat. Assoc. 63(1968): 1180-2000.

Miller, R.L. Intermediate Microeconomics: Theories, Issues, and Applications New York: MacGraw-Hill Book Company, 1978.

Nadiri, M.I. "Some Approaches to the Theory and Measurement of Total Factor Productivity: A Survey." J. Econ. Liter., 8(1970): 1137-1178.

Ray, S.C. "A Translog Cost Function Analysis of the U.S. Agriculture, 1939-1977." Amer. J. Agric. Econ., 64(1982): 490-498.

Ruble, W.L. "Improving the Computations of Simulataneous Stochastic Linear Equation Estimates." Unpublished Ph.D. Dissertation Michigan State University, 1968.

Shumway, C. Richard. "Supply, Demand, and Technology in a Multi-Product Industry: Texas Field Crops." Amer. J. Agric. Econ., 65(1983): 748-760.

Shumway, C. Richard, Pope, R. D. and E. K. Nash. "Allocatable Fixed Inputs and Jointness in Agricultural Production: Implications for Economic Modeling." Amer. J. Agric. Econ. 66(1984): 72-78.

U.S. Department of Agriculture, Agricultural Statistics, Washington, D. C. 1982.

---------------------------------- , Crop Reporting Board. Agricultural Prices, Washington, D. C. December Issues from 1959-1983.

U.S. Department of Commerce, Bureau of Census, West Virginia Census of Agriculture. Washington, D. C. 1959, 1964, 1974, 1978 and 1982 Preliminary Report.

West Virginia Department of Agriculture, West Virginia Crop Reporting Board, West Virginia Agricultural Statistics. Charleston, WV., selected years.