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Estimating Production Potentials of Agricultural Areas[1]

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Variations in individual farm characteristics and behavior of farm operators are taken into account in a procedure for estimating production potentials of agricultural areas. The procedure combines sampling and programming techniques. It differs from the purely synthetic approach, or the representative firm approach, in that the programmed or budgeted results are adjusted for changes in individual farm situations on the basis of the socioeconomic characteristics of individual farmers and their resource base. Aggregate output is shown by a case study to be influenced by variables other than those normally included in budgeted linear programming models.

Key words: Production potentials; estimates; linear programming; aggregate supply; sampling.

Possible variations in individual farm characteristics and the behavior of farm operators continue to be important when analyzing aggregate output for an agricultural area. The relationship between individual behavior and aggregate output is important when considering ways of improving individual farm income, the economic development of agriculture and agribusiness in an area, and possible improvements in agricultural policies and programs. Much of the current work in supply response does not adequately consider individual farm characteristics and firm interdependencies as a part of the aggregation and estimation procedure. Instead, the emphasis has been on analysis of firms with typical or representative sets of homogeneous resources. Since individual differences in managers and resource mixes do in fact exist and are explanatory variables in firm behavior, the absence of them in our models results in biased estimates. This bias has recently been examined by Barker and Stanton (*1*),[2] Frick and Andrews (*3*), Lee (*4*), Miller (*5*), Sheehy and McAlexander (*6*), and Stovall (*7*), among others.

Many current methods of estimating production potentials also lack adequate procedures for estimating statistical error terms for aggregate figures. This deficiency occurs mainly because of the nature of the representative firm approach in which results are based on synthesized coefficients and restrictions rather than on observation of actual farms. Thus, there is no way to compute error terms by the usual statistical techniques.

The primary objective of this article is to present a method for improving the realism and accuracy of our estimates of production potentials. The procedure could also be used to develop better information for decisions on agricultural adjustment problems in local areas. Basically the methodology described is a combination of area sampling and linear programming. In addition to providing individual farm output and aggregate supply estimates, the method allows for (1) specifying individual farm resource quantities and qualities, alternative enterprises, constraints imposed by personal characteristics of farm operators such as age, health, education and preferences, and constraints due to firm interdependencies; (2) adjusting the aggregate results obtained from optimal farm solutions for past practices and production patterns due to individual behavioral patterns of farmers; and (3) estimating error terms and ranges of error for aggregate supply estimates. The procedure presented here is illustrated by an application to an agricultural county. In this particular application, estimates were made of resource requirements and use, incomes, and production for two situations: (1) The prevailing situation with current technology, and (2) the potential situation with improved technology and three assumptions about the future number of farms.

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[1] The empirical results in this article are taken from the senior author's Ph.D. dissertation submitted to North Carolina State University.

[2] Italic numbers in parentheses indicate items in the References, p. 99.

Procedure and Results

The general procedure used, with illustrative results, was as follows:

(1) An area sample was taken to provide basic data for the analysis. The sample was designed as a stratified random sample with proportional allocation to the strata. The county was divided into four strata on the basis of soil types and kinds of enterprises produced. A sample unit size of approximately 15 occupied dwelling units was selected so that the interdependency of the various farm units could be studied. For example, this sample unit size permitted the observation of labor movements among farms, the availability of rented land, etc. Out of a total of 244 sample units in the county three units were drawn from each stratum for a total of 12 units. This resulted in a sample total of 102 farm units and 269 families.

(2) County estimates of resources available, farm production, incomes, and other characteristics were made for the situation at the time of the survey. Data from the sample were supplemented with data from secondary sources when necessary.

(3) Linear programming and budgeting techniques were used to determine optimum long-run plans for each farm in the sample, assuming improved levels of technology. There were three assumptions with respect to future farm numbers:

(a) Assuming existing numbers of farms and resources.

(b) Assuming that 25 percent of the farm families either retire or obtain nonfarm opportunities and that the remaining farm units are combined into larger units.

(c) Assuming that 50 percent of the farm families leave farming and that the remaining farm units are recombined into larger units.

The choice of families who would presumably retire or accept nonfarm employment was based on the household head's age, tenure status, capital position, education, nonfarm experience, preferences, and farm income. Generally, the procedure used resulted in those families with household heads 60 years of age or older retiring and those who would have a better opportunity in nonfarm employment leaving agriculture. Thus, younger families without much farm experience or capital investment were assumed to accept other opportunities. These assumed shifts are consistent with actual migration patterns.

After reducing the number of families, the land and other resources of these farms were combined to form larger farm units, or in some instances the procedure simply resulted in less labor per farm due to a reduction in the number of tenants or hired workers. In recombining land and other resources, consideration was given to geographic proximity, interdependencies of farms with respect to land, labor, and other resources, and to the family characteristics mentioned above such as age and health.

Table 1 shows some of the characteristics of the farm household heads and the results of applying the criteria and procedures to the farms in one of the sample units. Complete information such as that presented in this table is essential if the complexities of firm behavior and their consequent effects on area production potentials are to be adequately analyzed. Data of this type are also essential in the evaluation of nonfarm opportunities or policy alternatives.

(4) The results from step 3 were extrapolated to the county level by two methods. The first method recognizes that potential production is related to past production because of traditional patterns of behavior, nonmonetary incentives, and risk aversion. Enterprise aggregates by this method were obtained by adjusting the linear programming results by the amounts of the actual enterprise in the sample and the county at the time of the survey. Estimates by this procedure, referred to as ratio estimates, were obtained by using the following formula:

$$(1) \qquad ECA = \frac{\sum_{hi=1}^{n} Y_{hi}}{\sum_{hi=1}^{n} X_{hi}} T_x$$

where ECA = estimated county aggregate total; Y_{hi} = the totals for a given enterprise in a sample unit obtained from programming (where h = a particular stratum and i = a particular sample unit); X_{hi} = the sample unit values for a given enterprise which were actually produced at the time of the survey, and T_x = the actual population or county total for a given enterprise at the time of the survey.

This procedure for "weighting" potential production by past output increases the accuracy of our estimate, compared with estimates based purely on profit maximization procedures. In cases where new enterprises were being considered or past production data were not complete for other reasons, the following alternative formula was used:

$$(2) \qquad ECA = \frac{N}{n}(t) = \frac{244}{12}(t) = 20.333(t)$$

where N = the total number of sampling units in the county; n = the number of sampling units in the sample;

Table 1.—Characteristics of farm household heads and estimates of farm income and total farm acreage, survey and programmed situations 2 and 3, sample unit

Farm		Characteristics of present resident								Acreage and income per farm[1]					
Ident. No.	Tenure	Age	Education	Health	Nonfarm experience		Ownership status[3]	Opportunity cost of labor[4]	Interests	Survey		Situation 2		Situation 3	
					Type	Status[2]				Size of farm	Net farm income	Size of farm	Net farm income	Size of farm	Net farm income
	Yrs.	*Yrs.*	*Yrs.*					*Dol.*		*Acres*	*Dol.*	*Acres*	*Dol.*	*Acres*	*Dol.*
1	NR	61	9	Fair	Fertilizer dealer	A	O	NR	NR	544	7,416	467	6,690	467	6,095
2	NR	24	3	Fair	NR	C	t	NR	Prefer farm	–	2,757	–	3,347	–	4,222
3	2	54	7	Fair	NR	C	t	NR	NR	–	2,410	–	5,533	–	–
4	1	35	9	Good	Mechanic	B	t	400	Mechanic	–	2,717	–	3,782	–	–
5	5	51	7	Fair	Brickyard	B	t	([5])	NR	–	2,315	–	4,316	–	5,546
6	16	42	13	Good	Fishery	A	O	NR	NR	408	10,181	467	6,983	467	8,424
7	10	48	8	Good	NR	C	t	NR	Farm	–	3,127	–	4,051	–	5,889
8	2	25	7	Good	Fishery	B	t	250	NR	–	1,954	–	4,647	–	–
9	2	24	5	Good	Sheet metal shop	B	t	360	Factory	–	2,052	–	–	–	–
10	1	25	9	Good	Peanut factory	B	t	320	Construction	–	1,827	–	–	–	–
11	14	47	7	Fair	NR	C	t	NR	NR	–	1,902	–	5,981	–	–
12	18	54	12	Good	Merchant	A	O	NR	Merchant	69	2,453	–	3,142	69	2,598
13	18	50	5	Good	Sawmilling	B	t	NR	Farm only	–	2,087	–	3,172	–	5,314
14	9	48	10	Fair	NR	C	O	NR	Farm	84	4,484	97	6,922	69	6,360
15	NR	56	10	Fair	Carpenter	B	O	NR	NR	54	3,971	54	5,214	252	9,416
16	15	31	9	Fair	NR	C	O	300	None	40	2,675	60	5,314	69	6,360
17	32	54	8	Poor	Construction and garage	B	t	NR	NR	200	2,052	200	7,789	–	–
18	4	29	12	Good	None	C	t	NR	NR	–	2,052	–	–	–	–
19	6	40	6	Good	None	C	L	NR	NR	–	–	–	–	–	–
20	3	51	11	Good	None	C	O	NR	NR	270	7,777	249	7,068	249	4,227
21	4	28	6	Good	Fishery	B	t	320	NR	–	2,216	–	4,932	–	–
22	8	38	4	Good	None	C	t	NR	Farm only	–	3,293	–	4.469	–	5,869
23	2	39	6	Poor	None	C	t	250	None	–	1,866	–	–	–	–
24	12	40	5	Good	None	C	t	340	NR	–	2,145	–	4,998	–	–
25	4	25	6	Good	Logging	A	L	NR	NR	–	–	–	–	–	–
26	30	71	4	Good	None	C	O	NR	Farm	285	7,594	249	4,127	249	4,531
27	11	51	4	Good	None	C	t	NR	NR	–	2,379	–	6,317	–	–
28	10	51	4	Poor	Peanut factory	B	t	260	Peanut factory	–	2,088	–	–	–	–
29	5	51	4	Good	NR	C	t	NR	Farm only	–	2,259	–	4,541	–	5,565
30	7	36	0	Fair	Logging	B	t	NR	NR	–	1,356	–	6,458	–	–
31	38	40	10	Good	Electrician helper	B	O	300	Shipfitter	100	5,847	97	3,805	121	5,544
32	4	28	6	Fair	None	C	t	NR	Prefer farm	–	1,579	–	4,566	–	5,476
33	20	56	11	Poor	Merchant	A	O	NR	Farm	73	2,390	60	1,979	121	4,084
34	1	40	6	Good	None	C	O	NR	Farm	–	1,915	–	4,235	–	6,936
35	4	43	8	Good	Carpenter	A	R-t	([6])	NR	–	–	–	–	–	–
36	9	35	12	Good	Merchant	A	R-O	([6])	Merchant and buyer	–	–	–	–	–	–

[1] Situations 2 and 3 represent 25 and 50 percent reductions in the number of farm families, respectively. Differences in acreage occur because (1) farms may be combined when families leave the farm and (2) similar farms were averaged together before programming. Dashes indicate no acreage or zero income from given enterprise situation.

[2] A = Presently in indicated nonfarm employment, B = at least 1 year previous experience in indicated nonfarm employment, C = not applicable or none.

[3] O = Owner, t = tenant, L = Laborer, R-t = rural resident-tenant, R-O = rural resident-owner.

[4] Monthly take home pay required by husband and wife before they would leave the farm.

[5] According to living costs.

[6] Now working off farm.

Note: NR = not reported or nonresponse.

and t = the sample total of the item being estimated. The sample totals for the various items were obtained by summing the linear programming results of the individual farms in each of the situations.

Standard error estimates were computed for each enterprise total estimated by the first procedure shown above. The following formula was used in computing the standard errors (*2*):

$$S.E.(t) = \sqrt{N_h^2(1 - f_h)\ \frac{\sum s_h^2}{n_h}}$$

where t = the sample total of the enterprise being estimated, N_h = total number of sample units in each stratum, f_h = the sampling rate in each stratum, n_h = number of sample units actually drawn in each stratum for the sample, and s_h^2 = the variance for a given enterprise for each stratum and is estimated by the following formula:

$$s_h^2 = \left(\sum Y_{hi}^2 - 2\hat{R}\sum Y_{hi}X_{hi} + \hat{R}^2\ \sum X_{hi}^2\right),$$

where

$$\hat{R} = \frac{\sum_{i=1}^{n} Y_{hi}}{\sum_{i=1}^{n} hi}$$

Confidence intervals were then calculated at the 95

Table 2.—Enterprises at the time of the survey and in three programmed situations, county level

Item and unit	Survey situation	Programmed situations[1] 1	2	3
Tobacco .... acres	7,250	6,700 [2] (481)	7,200 (642)	6,600 (1,369)
Confidence intervals .... do.	—	5,774-7,626	5,916-8,484	3,862-9,338
Cotton .... do.	6,210	0	0	0
Corn .... do.	33,500	4,100 (2,886)	20,400 (12,645)	62,600 (11,101)
Confidence intervals .... do.	—	0-9,872	0-45,690	40,398-84,802
Peanuts .... do.	26,200	26,000 (3,820)	24,300 (4,151)	17,200 (1,313)
Confidence intervals .... do.	—	18,360-33,640	16,498-33,102	14,574-19,826
Soybeans .... do.	6,900	0	0	5,044
Sweetpotatoes .... do.	425	0	1,026	0
Oats .... do.	500	0	0	0
Oats-soybeans .... do.	0	43,600 (7,007)	36,500 (13,647)	4,900 (5,089)
Confidence intervals .... do.	—	29,586-57,614	9,206-63,794	0-15,078
Beef .... head	[3] 2,047	0	0	0
Hogs .... do.	39,650	457,792	206,867	12,830
Pasture and hay .... acres	7,809	19,024	8,274	513
Temporary grazing .... do.	0	11,890	6,206	384

[1] Situation 1 represents all farms as they existed at the time of the survey. Situation 2 represents an assumed 25 percent reduction in the number of farm families. Situation 3 represents an assumed 50 percent reduction in the number of farm families.

[2] Numbers in parentheses are standard errors of the estimates.

[3] Breeding stock.

percent significance level by the following formula:

$$Y \pm u\ .95\ (S.E.(t))$$

where Y = estimated county aggregate, u .95 = value of u corresponding to the 95 percent significance level, and $S.E.(t)$ = standard error of the total.

Table 2 shows the results of applying the above method. The value of having estimates of error is illustrated by looking at the tobacco enterprise. Even though the acreage estimates from the survey situation appear to be different from those in the programmed situation 3, we find that when sampling error is considered they are not significantly different. Thus, we project no change in the production of tobacco, whereas with other methods we would have projected a decline. Although not shown here, results of this procedure provide individual optimum farm plans, individual and aggregate resource requirements and use, and individual and aggregate farm income estimates.

Summary and Conclusions

The need for reliable estimates of individual firm and aggregate production response continues to be a major concern for agricultural economists. It is recognized that the key to estimating production potentials depends on the characteristics of the individual farm and the behavior of the farm manager. Yet the complexities that arise when we attempt to consider individual behavior in aggregate production estimates continue to be a challenge.

The sampling and programming procedure developed in this study enables us to take account of some of the complexities of individual firm behavior. Consideration was given to past production patterns, individual farm resource situations, and the personal characteristics and preferences of the individual farmer. Thus, the constraints, alternatives, and coefficients appropriate to individual farms are more completely defined. When properly designed and implemented, the method used should help reduce the aggregation bias, discussed by Barker and Stanton (*1*), which arises when resource situations rather than managers are assumed to respond to economic stimuli. The use of observed data from a sample of actual farms enabled us to deal with the bias resulting from inadequately representing technical coefficients and resource situations by the representative firm method, a problem which Stovall (*7*) has suggested is more serious than other sources of error. The sampling procedure used in this method permits the estimation of the magnitude of error in our estimates arising from the fact that we are not observing the whole population. The critical nature of the magnitude of error in our estimates is widely recognized, but it cannot be estimated by the representative firm approach.

Sample design and size are of critical importance in determining the accuracy and cost of this method. In this application, the sample size was designed to give a high degree of accuracy for a small geographic area, which resulted in a relatively high cost. However, the required sample size and the degree of accuracy are a function of the purpose of the study. For example, when estimating the production potential in a given area for a crop for processing, the accuracy of the estimate would be extremely important. However, if policy alternatives were the main objective, a larger error in the estimates may be tolerated.

Modifications of the approach used in this study are also a function of purpose. One approach that would be especially beneficial is that of incorporating dynamics into the system. This could be achieved, as Barker and Stanton (*1*) suggest, by using a combination of recursive programming and a producer panel. Such a system would provide researchers an opportunity to study how producers actually behave under changing economic and technological conditions, and it would also give us an opportunity to apply and modify analytical models which indicate how firms ought to behave, given their goals. In addition, this system could be a useful educational tool for extension economists. Modifications to the approach presented in this paper must obviously be made on an individual project basis after consideration of the purpose of the study; the time, cost, and accuracy constraints; and the indirect benefits such as those from an extension educational program.

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