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## Alternative Methods of Programming

By Ronald L. Mighell

*Linear programming is rapidly finding a place in every working economist's tool chest. Experience with this research technique has reached the point at which the relative efficiency of alternative methods of programming needs careful study. In the accompanying paper such an evaluation is made for one type of problem.*

LINEAR programming is one of the promising new research techniques that agricultural economists have been exploring and adapting to their needs. Analysis so far has centered mainly on what the method is and how it works. Less attention has been directed to the problem of the relative efficiency of linear and other methods of programming. The main purpose of this paper is to compare alternative methods of programming (or budgeting) as applied to a special type of problem in the economics of production.

It may be true, as McCorkle and Boles point out, that "linear programming can be used to analyze any economic problem that is susceptible to budgetary analysis," but they would be among the first to acknowledge that at times other procedures may be more efficient.[1] We need to be able to identify more certainly the types of problems in which linear programming is more appropriate and those in which other methods are likely to be more efficient.

This choice among alternative economic tools lies at the heart of the practicing economist's own business of being an efficient technician. Like other entrepreneurs, to make the most effective use of his resources, he must choose between alternative methods of analysis in the light of the best information available. He must decide when to shift from the arithmetic spade to the algebraic power shovel. Much spadework is still required in places where power machinery is too clumsy for efficiency, but power multiplies the output greatly wherever it can be used appropriately.

### Terminology

The semantics in this area of production economics are in a rather unhappy state. Many of us are like Jourdain, the rich tradesman who set up as a gentleman in Moliere's *Le Bourgeois Gentilhomme.* Just as Jourdain discovered that he had been using prose all his life without knowing it, we are suddenly finding out that we have been *programming* for a long time without becoming aware of it. Before we can appreciate the place of *linear* programming, we need to understand, in terms of a common language, what we have done heretofore.

In a general sense, any systematic procedure for finding the optimum economic combination of resources used in production may be termed programming. Budgeting, scheduling, coordinating, planning, and similar terms, when used with reference to a systematic way of finding the most profitable combination of resources used in production in a given time period, all are equivalents to programming. This makes programming broad enough to cover almost any systematic technique or procedure used in the field of production economics. In a still broader sense, one might include the whole of economics and refer

[1] McCorkle, Chester O., Jr. and Boles, James N. Use of linear programming in cotton acreage and adjustment research in California, 1954, Western Farm Economic Assoc. 27th Annual Meeting. Proc. July 1954.

to programming in relation to the maximum utilization of resources for human wants. But *linear* programming is evidently intended to be restricted to a narrower field.

Dorfmann has suggested *mathematical* programming as a better term in order to avoid the linear restriction.[2] But this term runs into another difficulty. Systematic mathematical programming to determine highest profit and least cost combinations of resources has been in use for a long time, if arithmetic is part of mathematics. Hence, mathematical programming may easily be construed to include much that linear programming has excluded. For example, it would include all systematic budgeting, all production function techniques, and all the systematic arithemetic and statistical approaches that have been developed through the years.

The linear programming analysts have in mind a special kind of mathematical programming restricted to a class of relationships best handled by a new form of matrix algebra, which in most applied work uses what is known as the *simplex method* of solving a set of linear inequalities to minimize costs or to maximize returns. Linear programming can be illustrated arithmetically or graphically for simple problems. In many instances, such problems could be more quickly solved by arithmetic. Practical use is indicated in many-variable problems in which matrix algebra is more efficient than arithmetic.

To repeat, "programming" may be defined as any *systematic* approach to the solution of the key economic problem of economic combination of resources. "Mathematical programming" is any method of programming that makes use of mathematics. For convenience, we may divide mathematical programming into *arithmetic* and *algebraic* programming. "Linear programming" in its fully developed form is a kind of algebraic programming which uses matrix algebra. It is characterized by linear assumptions, although such assumptions are also found in other kinds of programming.

In what follows, arithmetic programming and linear programming are applied alternatively to one problem as an example of the kind of analysis needed for many different problems before we can know when to use one or the other procedure. In each instance, the choice will depend on the nature of the problem and the number of variables.

## Choice of the Optimum Broiler Program

Producers of commercial broilers have a complex economic problem of deciding how many broilers to grow in each lot, how many lots to grow in a year, and at what weight to market each lot. These choices are interrelated, because in a given area of pen space fewer broilers can be raised if they are held to higher weights. Similarly, the number of lots that can be raised in a year is related to the weight at which the broilers are marketed; the higher the weight, the more time needed for each lot and the fewer the numbers of lots.

This problem was analyzed by several economists at about the same time.[3, 4, 5] The basic data used differ slightly and some of the assumptions varied, but the problems were essentially the same. Hansen used arithmetic programming. Judge and Fellows also used it, but they attached an annex with an alternative solution in linear programming. King, using data from Connecticut as did Judge and Fellows, presented the problem in linear programming fashion only.

The objective in these and other early linear programming studies was primarily methodological, but the coincidence of alternative methods of programming applied to the same problem presents the intriguing question of which is the more efficient. In the discusson that follows, the data in Hansen's article are used to present a more complete parallel comparison of the two methods.[6] The tables given in the Hansen article are arranged with the budgets for each process in horizontal lines. The budgets might have been placed in vertical columns, as in the linear programming

[2] Dorfmann, Robert. mathematical or "linear" programming: a nonmathematical exposition. Amer. Econ. Rev., Dec. 1953.

[3] Hansen, Peter L. growing broilers for maximum returns. Agricultural Economics Research. 5: 69–76. 1953.

[4] Judge, George G., and Fellows, Irving F. economic interpretations of broiler production problems, Conn. (Storrs) Agr. Expt. Sta. Bul. 302. July 1953.

[5] King, Richard A. some applications of activity analysis in agricultural economics, Jour. Farm Econ. 35: 823–833. 1953.

[6] A few changes were made to correct minor errors in the data as originally presented.

TABLE A-1.—*Inputs and outputs per broiler at 9 different marketing weights*

| Estimated age | Weight | Feed used: Quantity | Feed used: Cost [1] | Cost of chicks, fuel, mortality, and medicine [2] | Returns per broiler above direct costs, when price per pound is—[3] 25 cents | 30 cents |
|---|---|---|---|---|---|---|
| *Days* | *Pounds* | *Pounds* | *Cents* | *Cents* | *Cents* | *Cents* |
| 58 | 2.25 | 5.4 | 27.0 | 21.3 | 7.9 | 19.2 |
| 62 | 2.50 | 6.2 | 31.0 | 21.5 | 10.0 | 22.5 |
| 66 | 2.75 | 7.1 | 35.5 | 21.7 | 11.6 | 25.3 |
| 70 | 3.00 | 8.0 | 40.0 | 21.9 | 13.1 | 28.1 |
| 75 | 3.25 | 8.9 | 44.5 | 22.1 | 14.6 | 30.9 |
| 80 | 3.50 | 9.9 | 49.5 | 22.3 | 15.7 | 33.2 |
| 85 | 3.75 | 11.0 | 55.0 | 22.6 | 16.2 | 34.9 |
| 90 | 4.00 | 12.3 | 61.5 | 22.9 | 15.6 | 35.6 |
| 96 | 4.25 | 13.7 | 68.5 | 23.3 | 14.4 | 35.7 |

[1] Price of feed at $5 per 100 pounds.
[2] Mortality estimated at one-half of 1 percent a week, with cost of fuel, medicine, and chicks estimated at 20 cents per chick.
[3] Direct costs include feed, chicks, mortality, fuel, and medicine, but not labor and fixed costs such as buildings, equipment, interest, taxes, and insurance. Cost of litter is estimated to offset value of manure.

TABLE A-2.—*Annual returns above direct costs at 9 different marketing weights*[1]

| Estimated age plus 2 weeks | Weight | Space per bird | Broilers per lot [2] | Lots per per year [3] | Production per year | Annual returns, above direct costs, when price per pound of broilers is—[4] 25 cents | 30 cents |
|---|---|---|---|---|---|---|---|
| *Days* | *Pounds* | *Square feet* | *Number* | *Number* | *Number* | *Dollars* | *Dollars* |
| 72 | 2.25 | 0.50 | 20,000 | 5.1 | 102,000 | 8,058 | 19,584 |
| 76 | 2.50 | .57 | 17,544 | 4.8 | 84,211 | 8,421 | 18,947 |
| 80 | 2.75 | .64 | 15,625 | 4.6 | 71,875 | 8,338 | 18,184 |
| 84 | 3.00 | .71 | 14,085 | 4.3 | 60,566 | 7,934 | 17,019 |
| 89 | 3.25 | .78 | 12,821 | 4.1 | 52,566 | 7,675 | 16,243 |
| 94 | 3.50 | .85 | 11,765 | 3.9 | 45,884 | 7,204 | 15,233 |
| 99 | 3.75 | .92 | 10,870 | 3.7 | 40,219 | 6,515 | 14,036 |
| 104 | 4.00 | .99 | 10,101 | 3.5 | 35,354 | 5,515 | 12,586 |
| 110 | 4.25 | 1.06 | 9,434 | 3.3 | 31,132 | 4,483 | 11,114 |

[1] Time and space are the only limiting factors; labor and capital are available in ample quantities.
[2] Based on a broiler house of 10,000 square feet.
[3] Number of lots per year obtained by dividing 365 by estimated age plus 2 weeks in each weight group.
[4] Return per bird above direct costs as in table A-1.

approach. The choice of arrangement is mainly a matter of convenience.

### *Arithmetic Programming*

Let us first consider the arithmetic approach. The essential data and computations are given in tables A-1 and A-2. Table A-1 shows everything essential for reaching a decision for a single lot of broilers if subsequent lots or other enterprises were not conflicting elements. For this example, it is assumed throughout that the selling price per pound is constant regardless of weight or season. Table A-2 shows the essential steps in estimating the annual production that is possible with birds carried to different weights in a broilerhouse of 10,000 square feet. Annual returns above direct costs are shown for two prices of broilers—25 and 30 cents a pound. The most profitable combination by this measure can be selected at once for each price.

TABLE L-1.—*Input-output budgets per straight-run broiler at 9 different weights*

| Item | Production process | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I |
| Weight...pounds | 2.25 | 2.50 | 2.75 | 3.00 | 3.25 | 3.50 | 3.75 | 4.00 | 4.25 |
| Age+2 weeks...days | 72 | 76 | 80 | 84 | 89 | 94 | 99 | 104 | 110 |
| Space per bird...sq. ft. | .50 | .57 | .64 | .71 | .78 | .85 | .92 | .99 | 1.06 |
| Total pen space—days...sq.-ft. days | 36 | 43 | 51 | 60 | 69 | 80 | 91 | 103 | 117 |
| Feed per bird...pounds | 5.4 | 6.2 | 7.1 | 8.0 | 8.9 | 9.9 | 11.0 | 12.3 | 13.7 |
| Feed costs per bird [1]...cents | 27.0 | 31.0 | 35.5 | 40.0 | 44.5 | 49.5 | 55.0 | 61.5 | 68.5 |
| Other direct costs per bird [2]...do | 21.3 | 21.5 | 21.7 | 21.9 | 22.1 | 22.3 | 22.6 | 22.9 | 23.3 |
| Total direct costs...do | 48.3 | 52.5 | 57.2 | 61.9 | 66.6 | 71.8 | 77.6 | 84.4 | 91.8 |
| Total returns at 25 cents...do | 56.2 | 62.5 | 68.8 | 75.0 | 81.2 | 87.5 | 93.8 | 100 | 106.2 |
| Returns above direct costs...do | 7.9 | 10.0 | 11.6 | 13.1 | 14.6 | 15.7 | 16.2 | 15.6 | 14.4 |
| Total returns at 30 cents...do | 67.5 | 75.0 | 82.5 | 90.0 | 97.5 | 105.0 | 112.5 | 120.0 | 127.5 |
| Returns above direct costs...do | 19.2 | 22.5 | 25.3 | 28.1 | 30.9 | 33.2 | 34.9 | 35.6 | 35.7 |

[1] Price of feed at $5 per 100 pounds.
[2] Mortality estimated at 0.5 percent a week; costs of fuel, medicine, and chicks @ 20 cents per chick.

TABLE L-2.—*Inputs required to yield $1,000 returns above direct costs for straight-run birds*

[At 25 cents a pound]

| Item | Production process | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I |
| Broilers...number | 12,658 | 10,000 | 8,621 | 7,634 | 6,849 | 6,369 | 6,173 | 6,410 | 6,944 |
| Pen space...sq. ft. | 6,329 | 5,700 | 5,517 | 5,420 | 5,342 | 5,414 | 5,679 | 6,346 | 7,361 |
| Pen space-days...1,000 sq.-ft. days | 455.7 | 433.2 | 441.4 | 455.3 | 475.4 | 508.9 | 562.2 | 660.0 | 809.7 |
| Feed...cwt. | 683.5 | 620.0 | 612.1 | 610.7 | 609.6 | 630.5 | 679.0 | 788.4 | 951.3 |
| Feed costs...dollars | 3,417.7 | 3,100.0 | 3,060.5 | 3,053.6 | 3,047.8 | 3,152.7 | 3,395.2 | 3,942.2 | 4,756.6 |
| Other direct costs...do | 2,696.2 | 2,150.0 | 1,870.8 | 1,671.8 | 1,513.6 | 1,420.3 | 1,395.1 | 1,467.9 | 1,618.0 |
| Total direct costs...do | 6,113.9 | 5,250.0 | 4,931.3 | 4,725.4 | 4,561.4 | 4,573.0 | 4,790.3 | 5,410.1 | 6,374.6 |

TABLE L-3.—*Production process that maximizes returns above direct costs over a 1-year period for straight-run boilers* [1]

[25 cents a pound]

| Item | Production process | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I |
| Percentage of available pen space [2] | 63.3 | 57.0 | 55.2 | 54.2 | 53.4 | 54.1 | 56.8 | 63.5 | 73.6 |
| Percentage of available pen space-days [2] | 12.5 | 11.9 | 12.1 | 12.5 | 13.0 | 13.9 | 15.4 | 18.1 | 22.2 |
| $1,000 lots...number | 8.00 | 8.40 | 8.26 | 8.00 | 7.69 | 7.19 | 6.49 | 5.52 | 4.50 |
| Annual returns above direct costs...dollars | 8,000 | 8,400 | 8,260 | 8,000 | 7,690 | 7,190 | 6,490 | 5,520 | 4,500 |

[1] Assumes 10,000 square feet of floor space and 3,650,000 sq.-ft. days of time available. Other inputs are not limited.

[2] Quantity of each factor used by each production process (at the $1,000 net return level) as a percentage of the total supply of that factor.

**TABLE L–1.**—*Input-output budgets per straight-run broiler at 9 different weights*

| Item | Production process | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I |
| Weight ____ pounds | 2. 25 | 2. 50 | 2. 75 | 3. 00 | 3. 25 | 3. 50 | 3. 75 | 4. 00 | 4. 25 |
| Age+2 weeks ____ days | 72 | 76 | 80 | 84 | 89 | 94 | 99 | 104 | 110 |
| Space per bird ____ sq. ft. | . 50 | . 57 | . 64 | . 71 | . 78 | . 85 | . 92 | . 99 | 1. 06 |
| Total pen space—days ____ sq.-ft. days | 36 | 43 | 51 | 60 | 69 | 80 | 91 | 103 | 117 |
| Feed per bird ____ pounds | 5. 4 | 6. 2 | 7. 1 | 8. 0 | 8. 9 | 9. 9 | 11. 0 | 12. 3 | 13. 7 |
| Feed costs per bird [1] ____ cents | 27. 0 | 31. 0 | 35. 5 | 40. 0 | 44. 5 | 49. 5 | 55. 0 | 61. 5 | 68. 5 |
| Other direct costs per bird [2] ____ do | 21. 3 | 21. 5 | 21. 7 | 21. 9 | 22. 1 | 22. 3 | 22. 6 | 22. 9 | 23. 3 |
| Total direct costs ____ do | 48. 3 | 52. 5 | 57. 2 | 61. 9 | 66. 6 | 71. 8 | 77. 6 | 84. 4 | 91. 8 |
| Total returns at 25 cents ____ do | 56. 2 | 62. 5 | 68. 8 | 75. 0 | 81. 2 | 87. 5 | 93. 8 | 100 | 106. 2 |
| Returns above direct costs ____ do | 7. 9 | 10. 0 | 11. 6 | 13. 1 | 14. 6 | 15. 7 | 16. 2 | 15. 6 | 14. 4 |
| Total returns at 30 cents ____ do | 67. 5 | 75. 0 | 82. 5 | 90. 0 | 97. 5 | 105. 0 | 112. 5 | 120. 0 | 127. 5 |
| Returns above direct costs ____ do | 19. 2 | 22. 5 | 25. 3 | 28. 1 | 30. 9 | 33. 2 | 34. 9 | 35. 6 | 35. 7 |

[1] Price of feed at $5 per 100 pounds.
[2] Mortality estimated at 0.5 percent a week; costs of fuel, medicine, and chicks @ 20 cents per chick.

**TABLE L–2.**—*Inputs required to yield $1,000 returns above direct costs for straight-run birds*

[At 25 cents a pound]

| Item | Production process | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I |
| Broilers ____ number | 12, 658 | 10, 000 | 8, 621 | 7, 634 | 6, 849 | 6, 369 | 6, 173 | 6, 410 | 6, 94[illegible] |
| Pen space ____ sq. ft. | 6, 329 | 5, 700 | 5, 517 | 5, 420 | 5, 342 | 5, 414 | 5, 679 | 6, 346 | 7, 3[illegible] |
| Pen space-days ____ 1,000 sq.-ft. days | 455. 7 | 433. 2 | 441. 4 | 455. 3 | 475. 4 | 508. 9 | 562. 2 | 660. 0 | 809. 7 |
| Feed ____ cwt. | 683. 5 | 620. 0 | 612. 1 | 610. 7 | 609. 6 | 630. 5 | 679. 0 | 788. 4 | 951. 3 |
| Feed costs ____ dollars | 3, 417. 7 | 3, 100. 0 | 3, 060. 5 | 3, 053. 6 | 3, 047. 8 | 3, 152. 7 | 3, 395. 2 | 3, 942. 2 | 4, 756. 6 |
| Other direct costs ____ do | 2, 696. 2 | 2, 150. 0 | 1, 870. 8 | 1, 671. 8 | 1, 513. 6 | 1, 420. 3 | 1, 395. 1 | 1, 467. 9 | 1, 618. 0 |
| Total direct costs ____ do | 6, 113. 9 | 5, 250. 0 | 4, 931. 3 | 4, 725. 4 | 4, 561. 4 | 4, 573. 0 | 4, 790. 3 | 5, 410. 1 | 6, 374. 6 |

**TABLE L–3.**—*Production process that maximizes returns above direct costs over a 1-year period for straight-run boilers* [1]

[25 cents a pound]

| Item | Production process | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I |
| Percentage of available pen space [2] | 63. 3 | 57. 0 | 55. 2 | 54. 2 | 53. 4 | 54. 1 | 56. 8 | 63. 5 | 73. 6 |
| Percentage of available pen space-days [2] | 12. 5 | 11. 9 | 12. 1 | 12. 5 | 13. 0 | 13. 9 | 15. 4 | 18. 1 | 22. 2 |
| $1,000 lots ____ number | 8. 00 | 8. 40 | 8. 26 | 8. 00 | 7. 69 | 7. 19 | 6. 49 | 5. 52 | 4. 50 |
| Annual returns above direct costs ____ dollars | 8, 000 | 8, 400 | 8, 260 | 8, 000 | 7, 690 | 7, 190 | 6, 490 | 5, 520 | 4, 500 |

[1] Assumes 10,000 square feet of floor space and 3,650,000 sq.-ft. days of time available. Other inputs are not limited.

[2] Quantity of each factor used by each production process (at the $1,000 net return level) as a percentage of the total supply of that factor.

TABLE L-4.—*Inputs required to yield $1,000 returns above direct costs for straight-run birds*

[At 30 cents a pound]

| Item | Production process | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I |
| Broilers..........number.. | 5, 208 | 4, 444 | 3, 953 | 3, 559 | 3, 236 | 3, 012 | 2, 865 | 2, 809 | 2, 801 |
| Pen space..........sq. ft.. | 2, 604 | 2, 533 | 2, 530 | 2, 527 | 2, 524 | 2, 560 | 2, 636 | 2, 781 | 2, 969 |
| Pen space-days..........1,000 sq.-ft. days.. | 187. 5 | 192. 5 | 202. 4 | 212. 3 | 224. 6 | 240. 6 | 261. 0 | 289. 2 | 326. 6 |
| Feed..........cwt.. | 281. 2 | 275. 5 | 280. 7 | 284. 7 | 288. 0 | 298. 2 | 315. 2 | 345. 5 | 383. 7 |
| Feed costs..........dollars.. | 1, 406. 2 | 1, 377. 6 | 1, 403. 3 | 1, 423. 6 | 1, 440. 0 | 1, 490. 9 | 1, 575. 8 | 1, 727. 5 | 1, 918. 7 |
| Other direct costs..........do.... | 1, 109. 3 | 955. 5 | 857. 8 | 779. 4 | 715. 2 | 671. 7 | 647. 5 | 643. 3 | 652. 6 |
| Total direct costs..........do.... | 2, 515. 5 | 2, 333. 1 | 2, 261. 1 | 2, 203. 0 | 2, 155. 2 | 2, 162. 6 | 2, 223. 3 | 2, 370. 8 | 2, 571. 3 |

TABLE L-5.—*Production process that maximizes returns above direct costs over a 1-year period for straight-run broilers* [1]

[30 cents a pound]

| Item | Production process | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I |
| Percentage of available pen space [2].......... | 26. 0 | 25. 3 | 25. 3 | 25. 3 | 25. 2 | 25. 6 | 26. 4 | 27. 8 | 29. 7 |
| Percentage of available pen space-days [2].......... | 5. 1 | 5. 3 | 5. 5 | 5. 8 | 6. 2 | 6. 6 | 7. 2 | 7. 9 | 8. 9 |
| $1,000 lots..........number.. | 19. 61 | 18. 87 | 18. 18 | 17. 24 | 16. 13 | 15. 15 | 13. 89 | 12. 66 | 11. 24 |
| Annual returns above direct costs..........dollars.. | 19, 610 | 18, 870 | 18, 180 | 17, 240 | 16, 130 | 15, 150 | 13, 890 | 12, 660 | 11, 240 |

[1] See footnote 1, table L-3.
[2] See footnote 2, table L-3.

### *Linear Programming*

This example of linear programming is presented in arithmetic terms, but it follows the lines of reasoning that would apply if matrix algebra were used. Table L-1 contains the same data as table A-1 in the preceding arithmetic approach.

Table L-2 is derived from L-1 by computing the inputs required to yield $1,000 return above direct costs under each process, with a selling price of 25 cents. A similar table must be constructed for any other selling price—for example, L-4 for 30 cents.

Table L-3 (for 25 cents) is the final table. The data in this table are derived from the preceding tables. They lead to the solution for each process, showing the number of $1,000 lots that can be produced annually. Table L-5 is the corresponding table derived from L-4—to show the final results with a 30-cent price per pound.

Note that the results obtained by arithmetic and linear programming are identical except for minor differences caused by rounding numbers. Carrying more digits would eliminate these differences.

### *Ray Charts*

The information in tables L-2 and L-4 can be presented in a ray chart such as figure 1. The broken lines that connect the plotted points are net revenue isoquants which show the processes that yield $1,000 net return above direct costs. In this particular example, it is not possible to select the optimum production plan from a ray chart, as might be supposed for the example given in Connecticut Bulletin 302. The Connecticut example is almost unique in this respect. The present examples are more nearly typical. The reason is that with two fixed factors already owned, there is no rational basis for establishing a price line to

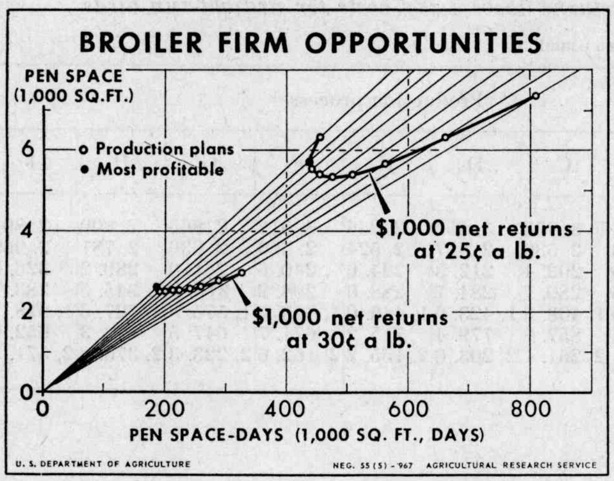


*Figure 1.*

touch one of the corners on the isoquant. Consequently, the most profitable combination cannot be ascertained graphically in this way.

## Interpretation

Our comparison shows that arithmetic programming is more efficient than linear programming for this particular problem. Why is this? Do we have here a type of problem that can be recognized in advance and for which arithmetic programming can be prescribed?

Careful examination of the nature of the commercial production of broilers shows that we do have a special type of problem. The number of possible processes is restricted by the limited range of marketing weights possible, and by the number of successive lots that can be grown in a given time period. Moreover, the range of choice does not extend to combinations or mixtures of processes. The problem is to select the single most profitable process or system from the limited number that are feasible—nine in this instance, if interpolations are overlooked. It is thus not a case of maximizing several linear inequalities as in linear programming. Rather, it means selecting the most advantageous of several discrete and unique alternatives. Although the problem can be solved by going through some of the routine of linear programming, it can be solved more rapidly by direct arithmetic.

It may be worth pointing out that the number of limiting factors does not greatly affect the ease of solution. In this example, there is really only one limiting factor, space-time. Suppose labor were also limited to an amount sufficient to care for a maximum of 15,000 birds. This restricts the choice to those processes that have no more birds on hand at one time than this number. No additional work is necessary, as this can be read from table A–2 as already calculated. In fact, any number of limitations could be imposed without adding work, except for the calculation of the pertinent data for the quantity of the limiting factor needed for each process.

## Application

How shall we recognize problems in which arithmetic programming of this particular kind can be applied? Perhaps the following criteria will help:

(1) Specialized single-enterprise production.

(2) Limited number of alternative production possibilities spread over the potential range.

(3) Each production possibility unique, no mixtures or combinations possible for biological or other technical reasons.

(4) Variable range in maturity and marketing dates.

(5) Several successive repetitions of production process within a given year or other time period.

Obviously, few examples in agriculture will meet these criteria as well as the production of commercial broilers. In the livestock production field, turkeys that are produced continuously like broilers come nearest. Commercial production of rabbits for meat or commercial production of any other small meat animal would offer similar choices. A few specialized hog producers who buy feeder pigs from pig hatcheries and produce continuously may have the same kind of problem.

Crop production may offer some examples, but these must be few because there are few situations in which delayed harvesting would be feasible. A few specialized types of greenhouse production might fall in this category.

## Related Problems

A type of problem that is somewhat similar is represented by less closely related systems of production. For example, several distinct systems of feeding cattle may be compared from the viewpoint of long-run returns. Or distinctly different systems of crop rotation may be studied similarly. Comparative analysis of this kind, if done systematically and carefully, deserves to be called programming, although it would not lend itself to linear programming analysis.

### Conclusion

Commercial broiler production presents a type of economic problem for which a special kind of arithmetic programming is more appropriate than is linear programming. The fact that linear programming proves to be the less efficient method in this particular problem should not be interpreted as a vote of no confidence. Rather it suggests the need for further comparative testing of alternative methods of programming as applied to each of many different types of economic problems which vary as to characteristics and in complexity. For some problems, linear programming will prove without doubt a more efficient procedure. But more testing needs to be done before we can be certain of their relative efficiencies in each set of circumstances. Eclecticism is a special virtue in this area. One of the special merits of linear programming is that the technique forces the analyst to list his assumptions in a systematic way, and, having done so, he is more likely to test them for reasonableness. This in turn helps in the selection of the most appropriate programming method.

# Validity of Objective Estimates of Corn Yield

By Walter A. Hendricks

*As part of an extensive research program, the Agricultural Estimates Division of Agricultural Marketing Service is investigating objective methods for estimating and forecasting corn yields. This paper is concerned only with one question: To what extent can differences in estimates of yield per acre, derived from weighing small samples of the crop just before harvest, be reconciled with yields reported by farmers and the official yield estimates derived from such reports? The present status of information on that question is given here without distracting attention from the main issue by including a mass of technical statistical detail. It should be emphasized, however, that the materials contained in this article represent only the preliminary findings of this particular research project, and that final conclusions with respect to the validity of official corn-yield estimates, compared with those obtained by other methods, cannot be made until the research program in this area has been completed and evaluated.*

OFFICIAL yield estimates and yields reported by farmers for corn are generally lower than those obtained by weighing small preharvest samples of the crop and adjusting the average weight to a standard moisture content. To illustrate, statewide objective yield surveys conducted by the Crop Reporting Service and cooperating State agencies in Alabama in 1948, and in North Carolina and Virginia in 1949, gave the following results in relation to present official estimates:

| | Objective estimate | Official estimate | Official estimate as percent of objective estimate |
|---|---|---|---|
| | *Bu/Acre* | *Bu/Acre* | *Percent* |
| Alabama (1948) | 26 | 21.0 | 81 |
| North Carolina (1949) | 41 | 31.5 | 77 |
| Virginia | 55 | 42.0 | 76 |

For Alabama, the objective estimate was in