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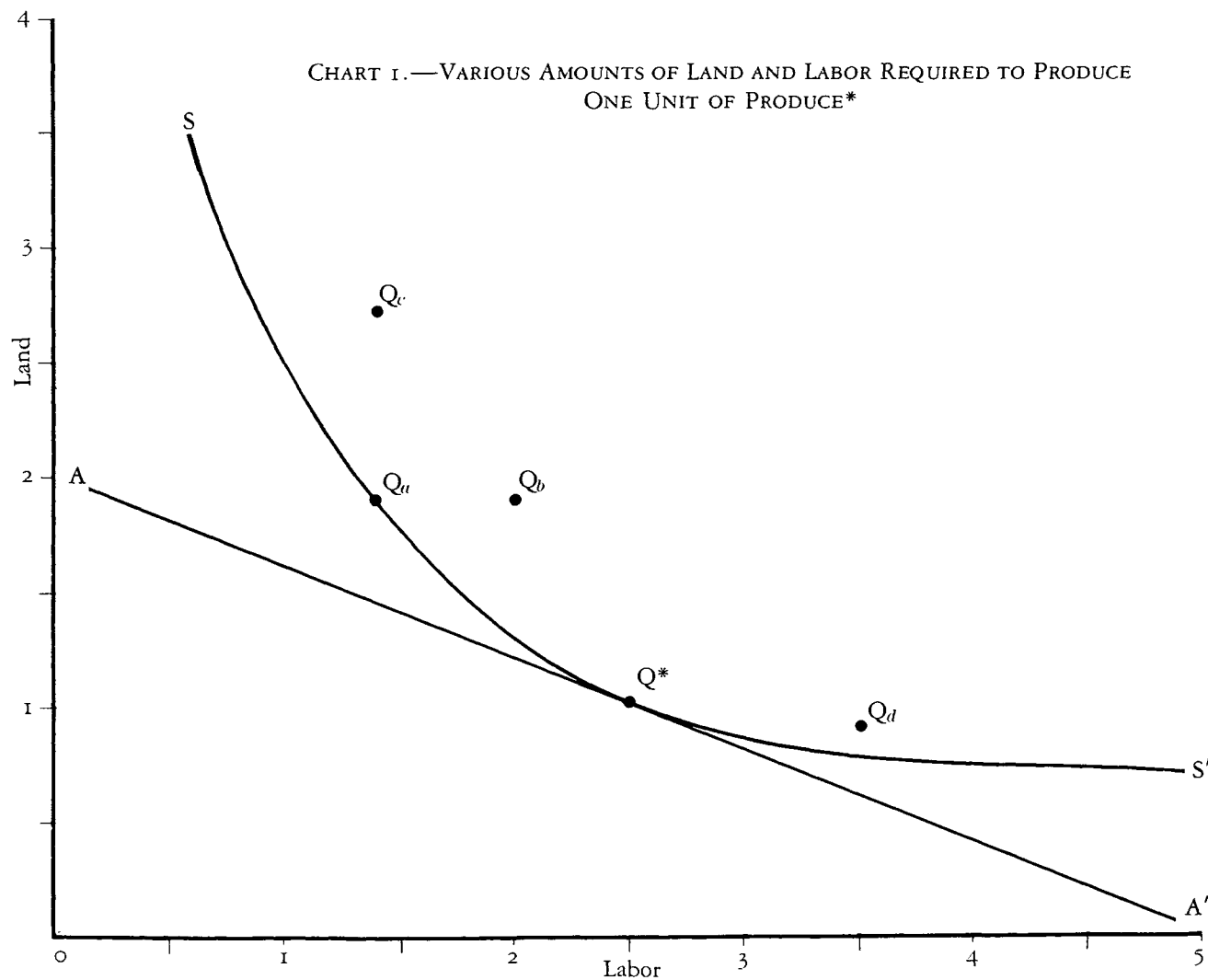# TURNIPS, THE SEVENTH DAY ADVENTIST PRINCIPLE, AND MANAGEMENT BIAS*

For a variety of reasons it has become fashionable to seek the development of tropical African agriculture in new technical discoveries and in massive injections of modern science-based technologies. This point of view has its principal origin in the technical achievements of American agriculture, particularly the spectacular mechanization of field operations. It is strongly reinforced by the achievements of plant breeders, first in Japan (rice), the United States (corn), and later in the great international agricultural research institutes of CIMMYT and IRRI,[1] in constructing new varieties of the major cereal grains that are highly responsive to chemical fertilizers. Technical changes in the manufacture of nitrogen that permitted its production at greatly reduced cost also played a part. The global emphasis on change in the technical coefficients of production continues in the network of agricultural research institutes that were established in the 1960s and early 1970s.

The long-term solution for increasing farm output and efficiency in the tropical African countries undoubtedly does require the development and adoption of new techniques and new inputs that will loosen the constraints imposed by shortages of labor and of land. That technical change—new technologies—will ultimately be required, should not blind us to the possibilities of increasing productivity by other means.

It is helpful to distinguish two kinds of changes in production methods. Suppose that among all the ways known in which yams can be planted, farmers have selected the best, and that they all pursue it in exactly the same way and with exactly the same results. Suppose the same thing to be true for weeding yams and for planting yams. Suppose it is also true for manioc, rice, and other crops that might be grown. For each farmer the ratio of inputs to output—the technical coefficients—are the same. One acre of yams requires 11 hours to plant, 16 hours to weed, and 22 hours to harvest and produces four tons of yams. Under these circumstances farms will vary in overall productivity only as they differ in the

CHART 1.—VARIOUS AMOUNTS OF LAND AND LABOR REQUIRED TO PRODUCE
ONE UNIT OF PRODUCE*

amount of land and labor they allocate to the production of each of the crops. That is, their allocative efficiency may vary but not their technical efficiency.

Now contrast this with another situation in which the technical coefficients differ from farm to farm, being significantly lower for some than for others. Those with the lowest ratio of inputs to output are technically more efficient than other farmers; in a formulation of the problem by Farrell in 1957 (9), they are thought of as lying on the productivity frontier, the line representing the minimum combinations of inputs required to produce a unit of output. This is the line S-S' in Chart 1. Any farm that lies on S-S' is technically efficient, under the state of the arts of the society in which it operates. Farmers lying to the right and above line S-S' are technically less efficient than they could be without any change in the prevailing technology. The farms at points Q_a and Q^* both lie on the S-S' and are equally efficient technically. But if A-A' represents the exchange rate between land and labor, the farm at point Q^* will be more efficient than farm Q_a, because it allocates its resources, between land and labor, so as to minimize their total cost.

The productivity of the existing technology is measured by the closeness of S-S' to the point of origin, and the technical efficiency of an individual farm by its closeness to S-S'. Allocative efficiency, on the other hand, is determined by the closeness of points that lie on S-S' to the "price line" A-A' representing the relative prices of land and labor. Q_a is both technically and economically more efficient than Q_b, which employs as much land but more labor, and than Q_c, which employs as much labor but more land to produce a unit of product. Q_a is economically less efficient than Q_d, although technically more efficient, because it spends more in value terms to produce a unit of output.[2] All four points are economically less efficient than Q^* and points Q_b, Q_c, and Q_d, are technically less efficient. All that can be said about relative allocative efficiency is that it is higher at Q^* than at Q_a. The relative allocative efficiency of farms can only be determined for those that are at the same level of technical efficiency; where allocative efficiency is estimated, it is implied that the comparison is with farms of the same degree of technical efficiency.

If all farms lie on or near the technical production frontier, their technical efficiency can only be increased by moving the frontier; if many farms lie some distance from the frontier, their efficiency can be increased by moving them closer to it. The allocative efficiency of farms on the frontier may be increased by moving them closer to point Q^*, the lowest cost point. The allocative efficiency of farms lying above S-S' cannot be appraised from the diagram; they may be allocating their resources optimally considering their technical efficiency.

[2] The cost of one unit of output at each of these points, expressed in labor units at the ratio of 2.5 units of labor for one unit of land as shown by line A-A', is:

Point	Labor	Land	Land in labor units	Total cost in labor units
Q_a	1.4	1.9	4.75	6.15
Q_b	2.0	1.9	4.75	6.75
Q_c	1.4	2.7	6.75	8.15
Q_d	3.5	0.9	2.25	5.75
Q^*	2.5	1.0	2.50	5.00

If African farming is characterized better by the second situation, in which technical coefficients differ, the immediate need may not be simply to press outward the frontiers of technical knowledge, but to devote more effort to bringing farmers up to the present frontiers.[3] In a rather special sense the problem may be one of allocative efficiency rather than of technical efficiency, for it has to do with the allocation of skills among farmers.

It is generally recognized that improved allocation of output and resources among farms will be achieved as the system for marketing farm products improves, but the possibilities for increasing productivity by better choice of products and allocation of inputs within the farm itself tends to be overlooked. Schultz's hypothesis that "There are comparatively few significant inefficiencies in the allocation of the factors of production in traditional agriculture" (*18*, p. 37) has been extended to many farming communities that he would not have considered to be "traditional." This term he reserves for "poor agricultural communities in which people have been doing the same thing for generations" (*18*, p. 36); communities that are adjusting to changes in their social, economic, and technical environment are "excluded from traditional agriculture to which the *efficient but poor hypotheses* applies" (*18*, p. 38). Clearly most African agricultural communities are members of the excluded class.[4] Nevertheless attempts to test the allocative efficiency of African farmers have frequently seemed to show them to be allocatively efficient, either in the sense that the marginal value products of the various inputs corresponded roughly to their costs, or in the sense that optimal cropping patterns devised from linear programming models corresponded reasonably well with observed cropping patterns.[5]

One consequence of the widespread acceptance of the efficient-but-poor hypothesis has been the belief that any significant increase in productivity—any agricultural development—requires technical changes in production methods, including the greatly increased use of purchased inputs.[6] It creates the impression that all farmers organize their production in the best possible way, an impression much at variance with observation either of African or American farmers.[7]

The matter can be understood better if we consider first an analysis of what happened at a critical time in the English "agricultural revolution" and then examine some correlates of agricultural change in tropical Africa.

[3] In 1967, Mosher examined the reasons why the "achievement distributions" of farmers tended to be so far below the economic and technical "ceilings" (*14*). His economic ceiling apparently corresponds with Q^* in Chart 1. It is similar in concept to our economic efficiency and combines the effects of allocative and technical efficiency. His achievement distribution records the extent to which the economic achievement of farmers approaches this ceiling. Mosher's technical "ceiling," however, is quite different from the technical "frontier" of Farrell (*9*) and Timmer (*23*). For Mosher the technical ceiling is the maximum output per unit of land that can be achieved if there is no limitation on the use of other inputs, that is, if all other inputs are free. Farrell and Timmer, on the other hand, measure technical efficiency in terms of the minimum amount of all factors, specifically including land, that must be used to produce a given output.

[4] Whether there are any contemporary communities that would not be excluded is another question.

[5] Massell and Johnson (*13*) provide an example of production function analysis and Igwebuike (*10*) of linear programming analysis leading to this sort of conclusion.

[6] Principally improved seed, agricultural chemicals, and farm machinery.

[7] Also somewhat at variance with Schultz's conclusion in 1949 that "American agriculture by and large is very inefficient" (*17*, p. 61).

TURNIPS[8]

One of the great changes in English farming occurred in the eighteenth century. It involved a new crop rotation that eliminated the fallow and an increase in the production of livestock. As the story is usually told, it was a major technical change that took the form of the introduction of a new crop. This initiated the agricultural revolution that paved the way for the Industrial Revolution of the nineteenth century. Depending on whether earlier or later versions of the story are accepted, the increased productivity made possible either a great release of labor to industry or a great increase in food supplies for urban workers.

In 1700 the three-field system of rotation for cropland was nearly universal in England, with livestock fed essentially from permanent pasture (Table 1). Timmer opens his description of the situation with words that sound faintly familiar to the student of African agriculture, although the farming system he is describing is quite different from the African one (22, p. 377):

> A very primitive and ancient form of farming gripped the early eighteenth century English countryside. "The three-year rotation system was practically the only one in use: one year out of three the fields lay bare." [Mantoux 1961, p. 151]. A vicious circle existed in agriculture; open field cultivation meant the arable lands had been subjected to the same crop for generations, and despite the fallow, the lands were "plough sick." Since every farmer had to raise exactly the same crop as his neighbor, and plough, sow, till, and reap at the same times, no opportunity existed for varying the rotation or introducing new fodder crops, if indeed they were even known. The livestock, huddled together on the weed-overrun common, had to be thinned out before winter because insufficient fodder was available for winter feed. Without fodder crops the livestock capacity of a farm was too small for its manure output to maintain the fertility of the fields, even with a fallow every three years. The primary problem was the inability to carry livestock over the winter.

"Between 1700 and 1800 the deepening cycle of declining fertility due to 'grass sick' and 'plough sick' lands and insufficient manuring" (22, p. 382) was broken, and English farms provided enough additional grain to feed a population (England and Wales) that grew from 5.8 million to 9.2 million, with only modest imports (22, p. 382). The first lines of Tables 1 and 2 show the nature of the change. The turnip gets star billing because it became the principal fodder crop in the new system, while at the same time, meticulous hoeing of the growing crop cleared the field of weeds.

In fact the turnip was not the only crop so used, and leguminous crops like clover and alfalfa were also important fodder crops besides increasing available nitrogen in the soil. Nor did turnips and the leguminous crops suddenly appear on the scene from experiment stations at home or abroad. They had been around for a long time and the roots of the new agriculture were well back in the sixteenth century (22, p. 382).

[8] This section is based on Timmer (22).

TABLE 1.—AGRICULTURE OUTPUT AND
ALLOCATION OF INPUTS UNDER THE OLD HUSBANDRY*

Input	Wheat	Barley	Fallow	Grass	Manure	Animal-units	Total
Land (*acres*)	120	120	120	140	—	—	500
Labor (*man years*)	7.7	8.8	2.9	2.8	—	1.0	23.2
Capital (*pounds sterling*)	84	84	12	14	3	525.5	722.5
Fodder (*feed units*)[a]	—	—	—	—	—	67	67
Manure (*loads*)	1,700	0	0	700	—	—	2,400
Animal-units[b]	5/-	5/-	1/-	5/-	1/67	—	17/67
Output	2,988 bushels	3,732 bushels	—	67[b] feed units	2,400 loads	67 units	—

*Based on C. Peter Timmer, "The Turnip, the New Husbandry, and the English Agricultural Revolution," *Quarterly Journal of Economics*. August 1969, p. 391.

[a]Feed required for one animal unit for one year.

[b]Measured in terms of feed requirements and dung production. One animal unit is the equivalent of one horse, two oxen, or ten sheep.

TABLE 2.—AGRICULTURAL OUTPUT AND ALLOCATION
OF INPUTS UNDER THE NEW HUSBANDRY*

Inputs	Wheat	Barley	Turnips	Clover	Grass	Manure	Animal-units	Total
Land *(acres)*	120	120	120	120	20	—	—	500
Labor *(man years)*	8.3	9.2	12.4	2.3	0.5	—	1.0	33.7
Capital *(pounds sterling)*	84	84	18	12	2	4	787.5	1,021.5
Fodder *(feed units)*[a]	—	—	—	—	—	—	100	100
Manure *(loads)*	1,080	0	2,400	0	120	—	—	3,600
Animal-units[b]	5/-	5/-	6/-	5/-	1/-	3/100	—	25/100
Output	3,288 bushels	4,104 bushels	30 feed units	60 feed units	10 feed units	3,600 loads	100 units	—

*Based on C. Peter Timmer, "The Turnip, the New Husbandry, and the English Agricultural Revolution," *Quarterly Journal of Economics.* August 1969, p. 390.

[a] Feed required for one animal unit for one year.

[b] Measured in terms of feed requirements and dung production. One animal unit is the equivalent of one horse, two oxen, or ten sheep.

The essence of the change was the widespread "development of convertible agriculture, including the alternation of arable and grass in place of the ancient division of the cultivated area between permanent arable and permanent grass which tended to undermine the fertility of both" (22, p. 382). The precise change varied from one part of England to another. "The dry eastern counties were the home of the strict four-course (Norfolk) rotation, but local variants developed in countries with wetter, stiffer soils." In some areas "the new grasses were more important than turnips . . . in others turnips were raised in small plots rather than as an integral part of the rotation" (22, p. 383).

Clearly, what had occurred was a change in factor proportions, that is, in the allocation of inputs. It was accompanied by, or resulted in, a change in product mix, essentially an increase in animal production, and this, too, can be regarded as an allocative change. Most important of all may have been the great change in the attitude of landlords to their farms. A new enthusiasm for farming seemed to sweep the country, with a great deal of experimenting, and even "King George III rejoiced in the title 'Farmer George' " according to Lord Ernle (8, p. 207).

An interesting by-product of this change was that employment in agriculture increased, primarily because of the greater labor requirement of turnips, a hoe crop, but also because of more manuring and larger harvests. This result is contrary to what was once thought to have happened, but it is well supported by Timmer's analysis. It is a particularly intriguing consequence to the student of African literature.

It is not easy to classify the English agricultural revolution of the eighteenth century in terms of allocative change and technical change. None of the elements of the new husbandry was novel. Turnips and leguminous fodder crops were a part of English farming long before 1700. The basic change was a rearrangement of inputs—a change in allocative efficiency—but it could be argued that the new organization of production itself was a technical innovation. Timmer (22, p. 383) says "This system of convertible husbandry . . . is clearly a significant innovation on traditional farming practice." If it is considered to be a technical innovation, it implies that farmers may not perceive all points on a known production frontier as feasible. It is as if the point $Q*$ could not be reached although farmers knew that they would be better off if they could reach it.

If this is to be regarded as a change in allocation of resources that had always been technically feasible but had not been generally perceived, it remains to determine what changes made its perception possible and what brought about this new way of looking at things. It may be that we have been misled, and that the change simply represents a shift to a new point of tangency between A-A' and S-S' as a result of a rise in the price of land relative to the price of labor and capital. Timmer does not answer this question but the fact that the new husbandry based on the turnip rotation was soon followed by labor saving mechanization suggests that more was involved than a simple change in relative factor costs (22, p. 395).

The change in attitude of landlords toward their farms must be taken seriously in any attempt to explain why it was suddenly realized that productive factors and known techniques could be combined in a new and more profitable fashion. This

change in attitudes and aspirations, however it came about, clearly was of great importance in the adoption of the New Husbandry.[9]

THE SEVENTH DAY ADVENTIST PRINCIPLE

The circumstances under which there is a change in perception of what is feasible is partially illuminated by some accounts of successful innovation in Kenya and Zambia.

In 1966 and 1967, Kenneth Anthony, Bruce Johnston, and Victor Uchendu, all then on the staff of the Food Research Institute, carried out studies of change in eight African farming communities. Two of these communities stood out for their enterprise, their receptivity to new ideas, their technical skill, and their economic achievement: the Gusii of East Kitutu, Kisii District, Kenya, and the Tonga of Mazabuka District, Zambia.

East Kitutu farming had experienced very rapid economic change since World War II (25). By 1966 farmers had successfully adopted the cultivation of pyrethrum, passion fruit, and tea. They had also learned how to care for exotic dairy cattle, a task that required the acquisition of a number of new skills. On a final reconnaisance of the area with Anthony and Uchendu in July 1967, I found the Department of Agriculture to be experiencing no difficulty in persuading farmers to adopt new production methods, but it was having a hard time providing the requisite inputs. Tea stumps and heifers were in particularly short supply.

When Anthony and Uchendu asked farmers why they were so eager to try out new methods and why they were so successful, the answer most often received was "the church." The people of East Kitutu are Seventh Day Adventists and the influence of the church is easily visible. On a Saturday men and women can be seen walking home from church services side by side in their Sabbath best, with Bible and Hymnal in their hands. No work is done on the Sabbath, and we were not even permitted to walk around the farms and admire the growing crops and prospering dairy cows until Uchendu had pocketed his notebook and thus confirmed that this was a social call. It was then that the "Seventh Day Adventist Development Principle" was enunciated as a fanciful proposition.[10] We did not seriously consider attributing so much credit to the church for the success of East Kitutu, however, until Elizabeth Colson called our attention to the fact that most

[9] Sexauer finds a principal explanation of the superior productivity of English agriculture over French agriculture in the late eighteenth century in organizational changes: larger farms, longer leases, and a higher "level of entrepreneurship." These, he argues, permitted much greater output per acre and per man day. "The English gentry increasingly viewed the management of their estates as a business . . ." whereas "the French nobility normally ignored their estates completely" and were concerned only with receiving their rent and seigneurial dues (19, pp. 502-05).

[10] The story is told of a social scientist in Nairobi in the 1960s who found that nearly all of the successful farmers in a rather large sample reported having worked on a farm operated by Europeans at some time in their lives. The ensuing "European-settler Theory of Agricultural Development" enjoyed a certain vogue until reexamination of the survey schedules revealed that most unsuccessful farmers had also worked on European farms.

successful farmers in Mazabuka District, Kenya, are also Seventh Day Adventists.[11] These farmers had the highest income of any field crop farmers in our eight studies and they had been aggressive commercial farmers since the railroad was opened through their area in 1906 (3).

The conviction that there was a connection between church and agricultural achievement was much reinforced by Norman Long's study of innovation in Serenje District, Zambia, in 1963-66 (11).[12] Here it was not Seventh-Day Adventists but congregations of Jehovah's Witnesses who occupied "a prominent place in the economic organization of the parish" and who constituted "an important group of socioeconomic innovations" (11, p. 6). Long identified three levels of economic success based on Guttman scales derived from inventories of capital goods and inventories of household durable goods and property.[13] More than 20 percent of adult male Witnesses fell in the wealthiest class on each scale as compared with 7 percent and 4 percent of non-Witnesses. Forty percent of the Witnesses were classed in the lowest category as compared with 55 percent (capital) and 54 percent (household) of the non-Witnesses.

Clearly there is some sort of association in these three societies between church membership and prosperity. Are these grounds for believing that prosperity is a consequence of church membership? Is this the *Protestant Ethic and the Spirit of Capitalism* all over again (26)? Perhaps. Long says (11, p. 239): "the religious ethic of Jehovah's Witnesses . . . legitimized and provided religious sanctions for the mode of life, achievements and socio-economic aspirations of members of the sect, and was used ritualistically to justify the repudiation of certain social relationships (often of a so-called 'customary' nature) and to sanction the utilization of ties of a different kind."

Behavioral changes reported for the Witnesses in Serenje included movement from villages of uterine siblings to small settlements based on nuclear, sometimes three-generation, families that were more convenient to the farms. Cash cropping had brought a decline in the status of headmen and created new hostilities among matrilinear kin (11, pp. 3, 4).

It is not intended to imply that the teachings of the church induced members to change their economic behavior. Attitudinal change can be a consequence of behavioral change as well as a precondition for it (6, p. 67). It is at least possible that the progressive farmers in East Kitutu, Mazabuka, and Serenje are Seventh Day Adventists and Jehovah's Witnesses because they are progressive, rather than being progressive because they belong to the church, although joining the church may have made it easier for them to adopt new ways that conflicted with traditional standards of behavior.[14]

[11] In a *Survey of Land Holding and Land Usage Among the Plateau Tonga* in 1945, Allen and associates report: "The correlation of membership of the farmer category with membership of the Seventh Day Adventist Church is perfect . . ." (1, p. 178). "The farmer category" is made up of "families cultivating large acreages, three times the acreage that would be cultivated under subsistence agriculture or more." They were believed to make up less than one percent of all families (1, p. 1).

[12] I am indebted to Thayer Scudder for calling my attention to Long's book.

[13] The scale for capital goods was based on possession of a hand corn-grinding machine, farm implements other than a plow, four or more cows, a plow, and a bicycle. Items in the household scale were a motor vehicle, a radio, western-style furniture, a sewing machine, and a brick house (11, p. 246).

[14] Raikes says that this is an important reason why farmers in North Iraqw, Tanzania, are

Long has examined some of the characteristics of the Jehovah's Witnesses among the Serenje. A necessary requirement for becoming a Witness, of course, is that the candidate know something about the sect. Because literacy makes it easier for him to learn the teachings of the society, he will probably have had at least three years of school. Schooling will also help him to rise to a position of authority in the Society. These characteristics of Witnesses are less revealing than the next two. Long says ". . . those individuals who have greater expectations of succeeding to some position of authority within the kin group [because of the order of their birth] will be less likely to be attracted to the church . . . younger brothers . . . seem more inclined to become Jehovah's Witnesses . . ." (*11*, p. 227). The fourth significant factor is the nature of the individual's urban experience. Those who become Witnesses differ from others in the "marked discrepancy between their job expectations and the type of employment they usually find" (*11*, p. 228).

In sum, those who become Jehovah's Witnesses are most likely to be young men whose ambitions have been stimulated by schooling but thwarted in the city and are unlikely to be realized through the traditional lineage system. This is at least consistent with the hypothesis that the ambitious and able become Jehovah's Witnesses so that they can employ their talents more effectively.

MANAGEMENT BIAS

The relation between the output of a farm and the resources employed in its production may be expressed as an algebraic relationship, most often of the form:

$$Y = A \prod_{i=1}^{n} X_i^{a_i}$$

where Y = output
X_i = input of the ith factor.
It has been recognized that if one of the inputs is overlooked in fitting such a function, the coefficients of other inputs, that is, their importance to the production process, will be exaggerated.[15] One of the most difficult of the inputs to observe is management, and it is therefore frequently left out or its importance is underestimated. When this happens the equation is said to suffer from "management bias."

Roman Catholics (*16*, p. 244, note 9):

> As in many other areas and walks of life, there appeared to be definite pressures to engage in quite heavy social drinking. One socially accepted means of avoiding this was to join the Roman Catholic temperance society. It was most striking that almost every successful large farmer in the area wore the badge of this society. One Catholic missionary expressed the opinion that a number of people had joined the church for the express purpose of avoiding obligations to drink heavily. . .

Similar reasons have been reported for leaving the Catholic church and embracing a Protestant faith in Mexico. As Protestants, villagers were no longer required to support the fiestas in which all good Catholics were expected to participate (7, pp. 249-50, 270, 281-82).

Peters, however, presents information about mission schools in Zambia consistent with the hypothesis that causation runs the other way, that the Seventh Day Adventist schools do in fact make their pupils more self-reliant and innovative, whereas the effect of the Catholic schools is the reverse (*15*).

[15] It may also lead to underestimates of the value of some coefficients depending on their relationship with the omitted variable.

The concept of management includes both the skill with which resources are allocated among tasks and the efficiency with which each individual task is performed. It is a combination of allocative and technical skill (cf. *13*, pp. 36-37). If for some reason technical coefficients vary little from farm to farm, so that all farmers lie on or near the efficiency frontier, their economic performance will be affected only by their skill in allocating resources among tasks. Under these circumstances a fitted production frontier that shows farmers to be using inputs in amounts that make their marginal value products equal to their cost is reasonably good evidence that farmers are allocatively efficient. But this conclusion does not necessarily follow. The production function tests whether gains in net returns are possible on the average farm but not on any particular farm. Massell and Johnson say (*13*, p. 53):

> Efficient allocation on the average farm is a necessary but not sufficient condition for efficiency on individual farms. For example, some farms may use too much land for one crop and other farms may use too much for another crop; yet the average allocation of land may conceal these inefficiencies. Although . . . results . . . [may] provide little evidence of potential gains from reallocation on the average farm, there may be scope for considerable gains to individual farmers.

Massell and Johnson are implicitly assuming that the technical coefficients for each input in each case are the same on all farms. If technical coefficients differ from farm to farm the situation may be more complex.

Consider three farmers who are growing yams and manioc. Assume that an acre of yams can be sold for $300 and an acre of manioc for $100. Assume further that the average number of labor days required for planting, weeding, and harvesting one acre of yams and one acre of manioc are as follows:[16]

Crop	Plant	Weed	Harvest
Yams	11	16	22
Manioc	3	7	4

Under these circumstances a farmer could maximize his return by planting all of the land to yams that his labor supply would permit and the rest to manioc. If he had six acres of land and 100 workdays available for each field operation, his allocation of land and labor would be

	Yams	Manioc	Excess[17]
Land (*acres*)	4	2	0
Labor (*workdays*)			
Plant	44	6	50
Weed	64	14	22
Harvest	88	8	4

[16] After Igwebuike (*10*, pp. 81, 94).

[17] Excess in the sense that land or labor would not be used for growing yams or manioc. It might be employed in other ways.

Suppose another farmer with the same resources uses his harvest labor more efficiently so that he can harvest an acre of yams in 18 workdays and an acre of manioc in 3 workdays. He can grow 5 acres of yams (5 x 18 = 90) and will do so. A third farmer who must spend 26 hours harvesting an acre of yams and 5 hours harvesting an acre of manioc has enough harvest labor for only 3 acres of yams (3 x 26 = 78). The optimum allocation for each farmer depends on his technical efficiency.

All of this is obscured when a production function that aggregates the behavior of all farmers is tested for efficiency. It is also obscured when optimal crop patterns calculated by linear programming solutions based on technical coefficients that are average values for all farms are compared with the aggregate observed crop pattern.[18] In the illustration just given the first farmer's technical coefficients for harvesting are the average of those of his neighbors. His optimal allocation of land is two-thirds in yams, one-third in manioc. This is also the way the total land of the three farmers is allocated.[19]

Enough has been said to suggest that tests of allocative efficiency based on average coefficients, as most such tests are, can conceal great inefficiencies and that these inefficiencies may be either technical or allocative or both.

Timmer has employed Farrell's concept of an efficiency frontier to design a procedure for measuring technical efficiency. When he applied it to state data for American farms, he found the degree of technical inefficiency to be small, with an average loss of efficiency of about 3 or 4 percent (23, p. 158). When Shapiro used the same procedure on data for 76 farm households in Geita District, Tanzania, however, he found a much wider range of technical efficiency for individual farms. The technical efficiency scores on a scale of 100 of 37 farmers for which the calculation could be made, were (20, p. 95):

Score	Number of farmers
23-38	3
39-54	12
55-69	6
70-85	6
86-100	10

[18] This arithmetic correspondence between the optimal cropping pattern based on average technical coefficients and the observed aggregate (average) cropping pattern is most likely when the range of choice of crops and activities is small, as it is on most African farms.

[19] In commenting on this paper Timmer points out that a full solution has slightly different properties than this integer solution. In the full solution optimal acreages for the three farmers become:

	Yams	Manioc
Least efficient	3.33	2.67
Average efficient	4.22	1.78
Most efficient	5.47	0.53
Overall average	4.34	1.66

He adds, "Of course, it would be possible to re-specify the example so that it worked exactly. The general point is valid either way—that each farmer's technical efficiency determines his appropriate allocative decision, and none of this shows up in the average data normally used for this type of analysis" (24, p. 2a).

American farmers seem to operate close to the efficiency frontier. A number of Geita District farmers, too, are near the frontier, but many more are far from it. The great differences in results may reflect the very high level of aggregation of Timmer's data and the detail of Shapiro's analysis. There is some reason, however, to expect this kind of difference between systems that differ so much in the composition of farm inputs.

The principal productive unit on Geita farms is a man or woman with a hoe or cutlass. American production levels by contrast are dominated by tractor-powered machines. In America farmers experience something like the production-line phenomenon in which the machine sets the pace to which men must conform. The discipline imposed by farm machines is not usually as strict as that of the production line,[20] but it is certainly much greater than any that is imposed on the man with a hoe. For this reason alone technical inputs might be expected to vary much more in traditional than in mechanized agriculture. The machine and agricultural chemicals also bring stability to technical coefficients in another way. The technical coefficients of the machine itself—hours of running time per acre cultivated for example—are fixed within rather narrow limits as are the coefficients for fertilizers, pesticides, and herbicides. As these make up an increasing share of total inputs the coefficients for various operations become less variable.

American farmers are also subject to an entirely different kind of discipline—the possibility of bankruptcy—that is remote for most African cultivators because of the semi-subsistence nature of their operations. A consequence is that those who succeed as farmers in the United States tend to be more skillfull and more ambitious than those who fail, quite a different situation than prevails in tropical Africa where most of the population is engaged in farming (2, pp. 118-19).

The magnitude of the variation in technical coefficients among African farms is suggested by data provided by Igwebuike on the basis of intensive study of 76 farm households in farm villages in Abakaliki area, Nigeria. The average number of man-hours required to plant an acre of yams varied from 102 hours in Echara village to 231 hours in Umuaka village. The number of hours required by 22 Echara farmers varied as much as 210 hours, for the 19 farmers in Umuaka it varied by 1,020 hours. Similar variation is reported for rice and manioc and for the various operations of cleaning, tilling, staking (yams), and weeding.[21] Harvesting time, too, varies widely but this is due in part to differing yields. Igwebuike says that "tremendous variations" in inputs have been reported by many African farm surveys (10, p. 253-61).

This matter seems important enough to justify a careful review of the reports of African farm enterprise studies and comparison with results from areas of mechanized and irrigated farming.[22] But regardless of the findings outside of Africa, the variation in technical coefficients suggested by the two African studies

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[20] It may be little different for crews working on a tomato-harvesting machine or following a lettuce field-packing machine.

[21] S.R. Jones comments that farmers may use a generalized notion of the time required for each operation that approximates the average time used by all farmers when they are making their planning decisions, but the amount of time they actually use may vary with competing demands for their labor when the operation is being performed.

[22] Irrigation, too, might be expected to impose a work discipline.

cited here has important implications for African agricultural development. It suggests that the problem is at least as much one of bringing more farmers closer to the frontier as it is one of expanding the frontier. This may be as much a matter of improving allocative efficiency as of improving technical efficiency, despite statistical evidence purporting to demonstrate the contrary. It is not possible to measure the relative allocative efficiency of farms with differing technical efficiency, and there is no particular reason to expect farmers to be more or less efficient in allocating their resources than they are in the technical use of them.

In the inevitably painful decision of how to allocate agricultural development funds this seems to tip the balance a little more toward measures that will assist farmers in improving their grasp of the existing technology and against reliance on large-scale technological research. In the allocation of research funds it speaks for more money to support the study of farm systems and farm decision making, less for strictly technical research.[23]

SUMMARY

The story of the turnip, the Seventh Day Adventists of East Kitutu and Mazabuka, and the Jehovah's Witnesses of Serenje, remind us of the essential humanity of man, something that tends to be forgotten in discussions of human capital and labor resources. Men vary in their desires, their perceptions, and their skills, and they vary greatly. How well they do a job depends on all three attributes. There are good farmers and bad farmers. Their goodness or badness consists in how often and how well they sharpen their tools, how well they allocate resources of labor, food, and money over time and among tasks, how skillfully they select the crops and animals that will be grown. It also consists in their willingness to try new tools, seeds, and chemicals, and new ways of organizing them for production, whether this concerns time of planting, use of hired task labor rather than communal work gangs, or plant population in the field.

Where all this leads is to a renewed and reinforced concern about the farmer himself. Some of the startling developments in plant breeding, fertilizer manufacture, and disease control—pesticides, herbicides, cheap nitrogen, miracle plant varieties—may have drawn our attention away from the critical contributions of the men and women who plan and execute the farms' productive activities. Their accomplishments depend on a blend of will, knowledge, and ability. For the development strategists the differences in managerial skills raise questions of how far to attempt to alter them and how far to attempt to cash in on them.

Are we to pitch our development plans at these more perceptive groups of individuals—these more economically relevant men? Are we to adopt measures that will permit the less perceptive to recognize the new economic benefits and capture them? Or are we to pursue programs that will strengthen the will, broaden the knowledge, and enhance the skill of all? If so much better understanding is needed of how aspirations and abilities are shaped. One thing is

[23] The original mandate of the International Institute of Tropical Agriculture at Ibadan, Nigeria, was to develop farming systems that would be viable alternatives to existing systems. Its research achievements in this direction up to 1978 have been small.

sure—there is no simple way, either church, or ideology, or school, or revolution. Hill says of the rural residents of Batagarawa in Northern Nigeria that the factors determining success include good organizational powers, inherited advantages, good luck, wisdom in lending, training, trustworthiness, and hard work (9a). She stresses that there are no primal causes and that success or failure depends on a combination of factors all working together.

We seem to come back to questions that are just as critical for California or Nebraska farming as they are for farming in the many countries of tropical Africa.

> How does a man learn to farm?
> How does he learn to farm well?
> How can he be helped to farm better?

Perhaps the most valuable contribution would be an intensive build-up of instruction in farm management for those who wish to learn and who can put their knowledge to work, accompanied by thorough study of how farmers in fact conduct their operations.

Farm management training has been tried in Africa in the past but with limited success. Collinson says that in East Africa there was a general disillusionment with peasant agriculture and with colonial development plans, a tendency to identify machinery and large-scale operations with progress, a lack of sympathy with investigative work in general and farm management research in particular (5, pp. 9-10). More fundamental he found to have been equating of agricultural improvement with increasing yields, a bias toward pure research and isolation from the farming community, and failure to study existing systems. (There are still extremely few competent farm enterprise studies for all of tropical Africa.) But in recent years the disenchantment with farm management training in tropical Africa may stem in part at least from unselective acceptance of notions about the efficiency and economic motivation of African farmers. Too great faith in the efficiency of poor farmers has tended to persuade agricultural planners that development can only be achieved by expanding the technical frontier.

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