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Production economics: Worthwhile investment?

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ABSTRACT

Agricultural production economics research is examined within a broad framework of scientific development and utilization. Recent findings in selected areas of the subdiscipline are examined and opportunities for further fruitful inquiry are identified. A few 'stylized facts' emerge from recent work and suggest the need for much careful hypothesis testing, model exploration, and empirical sensitivity analysis in the future.

"*The secret of science is to ask the right question, and it is the choice of problem more than anything else that makes the man of genius in the scientific world.*"

Sir Henry Tizard

Research investment in the field of agricultural production economics has been extensive. In fact, the agricultural sector may well be the most analyzed sector of the economy and agricultural production the most analyzed part of this sector. With so many other important areas of inquiry not yet pursued to the same extent, one may legitimately ask whether a continuation of relatively heavy investment in the subdiscipline of agricultural production economics is warranted.

Providing a reasoned response to such a question requires that we have a basis for judging among alternative research areas. Of all scientists, economists ought to have some clues about how to make such judgments. Certainly the marginal principle of economics should be relevant, at least

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as a management criterion. We simply examine the production functions for discovery and utilization of new knowledge, consider the prices of inputs and outputs, and equate marginal cost with marginal revenue (or the marginal rate of product transformation with the ratio of output prices when input levels are fixed). It is a simple and powerful economic concept; but, when applied to non-repetitive production processes for which output occurs in very lumpy increments and for which output prices are unknown (like scientific discovery), it is not even modestly useful. The fundamental problem is not with the marginal principle but with the extremely large confidence intervals associated with nearly every piece of data needed for a relevant analysis. Only current input prices are reasonably certain.

Partially because of these large confidence intervals, much problem selection by individual scientists is driven more by curiosity than by a priori assessments of potential knowledge 'production.' This effect gives to some rationally-minded production types (like taxpayers) the impressions of research being conducted in ivory tower withdrawal from the real world and of an elite scientist class of people responsible only to their peers and protected from the competitive performance pressures of the private sector.

Since the marginal principle is not helpful, perhaps the best that can be done pragmatically is to establish a general framework for assessing what economists are about, examine what has been learned from the subdiscipline of agricultural production economics, and consider what might be learned in the future. That is the approach I will take in this essay. I will review in very broad terms the general purpose of the discipline, examine what has and has not been learned in a few selected (and only lightly reviewed) areas of recent production economics research, and suggest some remaining opportunities for agricultural production economics research. [1]

DISCIPLINARY PURPOSE

Agricultural economists are clearly both creators and users of science. A particularly informative model of scientific creation is found in a book by Walter L. Wallace (1971): *The Logic of Science in Sociology*. He suggests five informational components in the development of a science – theories, hypotheses, observations, empirical generalizations, and decisions to reject

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[1] Since the entire domain of production economics could be overhauled at any time, such opportunity forecasts are inherently risky. They are also value laden based on the forecaster's own unique set of experiences, preferences, and notions. Thus, what follows clearly fits that cast.

or not reject hypotheses. He arranges these components in a circular diagrammatic model to suggest that there is no inherent beginning or end. He does place the theory component at the top, but this placement is arbitrary and he emphasizes that many theories have developed only because of careful initial observation. However, the direction of movement between various subsets of the components is unambiguous and is determined by procedures which act upon the components. For example, logical deduction is used to derive testable hypotheses from theories; interpretation, instrumentation, scaling, and sampling to obtain observations for judging the hypotheses; measurement, sample summarization, and parameter estimation to draw empirical generalizations from observations; concept and proposition formation and arrangement to organize theories from empirical generalizations; formal tests of hypotheses to make decisions to reject or not reject hypotheses; and logical inference to develop or revise theories based on test results.

As agricultural economists we collectively seek to develop an economic science that will be more useful for the solution of real world problems in the future than the science is now. Nevertheless, there is no requirement in the Wallace model that the same scientist contribute to all components of the scientific process. Although few new theories come out of agricultural economics departments, many hypotheses are formulated and much data are collected to test hypotheses that help determine whether or not existing theories have empirical credibility. Each of us can make a contribution to the development of science even though we do not cover all parts of the scientific process. This process requires that our contributions fit in with components of other general and agricultural economists that necessarily precede or follow ours. [2]

While we cannot do a better job of serving relevant audiences in the future without current development of the science, the pertinent question is, "How likely is that to happen through agricultural production economics research?" Because of data availability and quality, agricultural production has long been a focal point for applying and testing micro and macro economic theories. Yet we have few 'stylized facts' in agricultural produc-

[2] The fitting together of various components of the scientific process could occur as a result of the individual's conscious effort to organize his/her personal place within the building block scheme of science. Alternatively, the market for ideas could accomplish this organization indirectly. It is entirely possible that Einstein did not know Eddington or any other empirical physicist who could test the general theory of relativity when he first introduced it. Yet, the competition for ideas insured that others were there to test his remarkable idea. The competition for ideas is likely also sufficient now to insure that capable people are present to test and ultimately apply useful ideas.

tion economics (or in any of our other principal subdisciplines). A stylized fact may be defined as an empirical hypothesis that has been tested rather thoroughly and has not been disconfirmed. Nearly all important production hypotheses have been rejected by one test or another. Nevertheless, because of the lack of real constants in our systems, hypotheses must be carefully tested in many settings and from many perspectives before we can conclude that the theory does not adequately describe the real world. Significant contribution to the development of the science may require going full cycle through the Wallace model many times.

In addition, the same procedures can often be used to test theories and also to help users of the theories be more effective managers. For example, observations must be collected, parameters estimated, and generalizations drawn both to test hypotheses and, when the hypotheses are maintained, to give relevant guidance to decision makers.

SELECTED FINDINGS FROM AGRICULTURAL PRODUCTION ECONOMICS

I will turn now to a discussion of selected areas of recent production economics research, what I think has been discovered in the U.S. literature, and what remains unclear or inadequately dealt with. In doing so, I am not going to even pretend to be comprehensive in either areas covered or depth of coverage in any area. Some very important literature, even in the U.S., may be entirely overlooked or inadequately treated, for which I apologize in advance. My only defenses are limited space and ignorance. There has been no attempt to bias the conclusions or misrepresent the preponderance of evidence by deliberately failing to consider some studies.

I will consider only two areas – behavioral objective and analytic simplification. These areas were chosen because of their importance in model specification and because they profoundly impact the value of the guidance we give to public and private decision makers.

Behavioral objective

The classical theory of the firm presupposes that producers seek to maximize (expected) profits. Fundamental micro and macro implications of the theory of the firm have been shown to rely critically on this behavioral assumption. Changing the underlying motivation can change producer behavior and industry performance, often drastically.

Because of the extreme uncertainty facing agricultural yields and prices, considerable attention has been given in recent years to determining farmers' goals and motivations. Much of the work has focused on the alternative hypothesis of utility maximization where utility includes arguments of both profit and risk. Some of the work has also addressed leisure and consumptive objectives as well as hierarchical goals. Research has included both firm-level and aggregrate studies. Findings have been mixed.

For example, consider the results from 17 studies reported in Table 1. Each of three studies based on firm and individual respondent data found that the amount of risk faced was an important consideration in decision making. Considerable evidence of risk-averse behavior was found. The one firm-level study that did not formally address risk found that a hierarchy of goals was considered in the behavioral objective of farmers. Four of the 13 studies using aggregated data also reported important roles of risk variables in determining commodity supplies. And, one study rejected the hypothesis of profit maximization in favor of expenditure-constrained profit maximization for explaining aggregate behavior.

In studies using aggregated data (for North Dakota, South Dakota, Iowa, Texas, Oklahoma, Arkansas, Louisiana, Mississippi, Georgia, the ten USDA farm production regions, and Ontario Canada), the monotonicity and convexity properties implied by the profit maximization hypothesis were consistently not rejected by parametric test. The profit maximization hypothesis was also not rejected by stochastic non-parametric tests for each of the contiguous 48 states. Although individual nonparametric violations of the hypothesis were observed in all geographic units investigated, the extent of violation was minor. In all but one state, measurement errors of 3% would have been sufficient to give complete consistency of the observed data with the hypothesis of profit maximization. In very recent work, Lim obtained comparable results using data for the United States and each of the ten USDA farm production regions.

Further, Pope (1981), Estes, Blakeslee and Mittelhammer (1981) and Taylor (1986) each cautioned that some of the evidence for significant risk-motivated behavior is questionable. Biased standard errors, stochastic random variables, and the nonlinear influence of stochastic variables on a risk-neutral behavioral objective were cited as reasons for apparent risk-motivated behavior when producers may have really sought to maximize expected profits. In addition, while violations of the closely related expected utility hypothesis of consumption theory have been found in experimental data, violations of all other tested behavioral hypotheses (e.g., regret, prospect, generalized expected utility, rank-dependent expected utility, and lottery-dependent expected utility theories) have also been found (Harless, 1992; Starmer and Sugden, 1987, 1989; Camerer, 1989; Battalio, Kagel and Jiranyakul, 1990).

Despite the large amount of economic research that has gone into examining producer behavioral objectives, we still have not clearly established which types of farmers are or are not expected profit maximizers.

TABLE 1

Behavioral objective test results

Source	Unit of observation	Type of data	Test results
Lin, Dean and Moore (1974)	Six California farms	Firm	Improved predictions with risk in utility function
Just (1974)	California field crops	District	Significant risk parameters in supply
Traill (1978)	U.S. onions	National	Improved predictions with risk in supply
Harper and Eastman (1980)	New Mexico small farmers	Firm	Goal hierarchies evident
Binswanger (1981)	330 Indian farmers	Experimental	Considerable risk-averse behavior
Weaver (1983)	North and South Dakota	State	Profit maximization not rejected [a]
Lee and Chambers (1986)	U.S.	National	Profit maximization rejected against expenditure-constrained profit maximization
Antle (1987)	Indian farmers	Firm	Risk-averse behavior evident
McIntosh (1987)	Texas and Iowa	State	Profit maximization not rejected [a]

Moschini (1988)	Ontario, Canada	Province	Profit maximization not rejected [a]
Shumway and Alexander (1988)	Ten U.S. farm production regions	Regional	Profit maximization not rejected [a]
Aradhyula and Holt (1989)	U.S. broilers	National	Price variance important determinant of supply
Polson (1989)	Five South Central States	State	Profit maximization not rejected [a]
Lim (1989)	48 U.S. states	State	Profit maximization not rejected by stochastic nonparametric test [b]
Maligaya and White (1989)	Georgia	State	Profit maximization not rejected [a]
Chavas and Holt (1990)	U.S. corn and soybeans	National	Risk important determinant of acreage allocation decision
Shumway, Alexander and Talpaz (1990)	Texas field crops	State	Profit maximization not rejected [a]

[a] Estimated output supply and input demand (or share) equations tested for consistency of the profit function with convexity and monotonicity in prices. These properties are implications of the assumption of price-taking profit-maximizing behavior of firms.
[b] In all but one state, measurement errors of 5% or less in the quantity data were sufficient for consistency with the hypothesis of profit maximization.

Nor have we clearly established which farmers who are not profit maximizers nevertheless act as if they are. The hypothesis of profit maximization has been seriously challenged but not unambiguously ruled out as the 'best simple theory' of motivation for firm-level decisions. Further, although not all empirical results agree, the preponderance of evidence examined here suggests that the macro manifestations of agricultural firm decisions are not inconsistent with the implications of this hypothesis.

Analytic simplification

Based on heuristic and formal hypothesis testing, considerable evidence exists to support some degree of analytic simplification in primal and dual modeling of agricultural production technologies. Among the important properties of the technology that justify analytic simplification are nonjointness, separability, homotheticity, constant returns to scale, Hicks-neutral technical change, and twice differentiability. The modeling implications of each of these properties will be reviewed briefly, and then recent evidence based on empirical tests will be presented. [3]

If outputs are nonjoint in inputs, the production, cost, profit, output supply and input demand functions for one output can be estimated without considering the impact of decisions made on other outputs. It is the hypothesis of nonjoint production that has been implicitly maintained so often in the vast literature in which production and supply relationships for individual agricultural commodities have been estimated without including alternative output quantities or prices as explanatory variables in the estimation equation. [4]

If outputs are produced by separable technologies, consistent aggregation and two-stage optimization is possible. That is, two models can be constructed (an aggregate model and an allocation model), each using a smaller dimension of exogenous variables, that collectively give exactly the same solution for an economic optimization as a single model with complete output and input disaggregation. Separability of outputs and of

[3] Analytic simplification is not the only motivation for conducting tests of these properties. Sometimes particular data do not permit detailed estimation, e.g., grouped data. Generalized separability test results from other data then could provide justification for the study of groups using data which lack detail. In addition, tests of technical properties facilitate the search for regularities in micro data that constrain macro behavior.

[4] The recent agricultural economics literature has included several theoretical contributions to the development of nonjoint concepts [Shumway, Pope, and Nash (1984, 1988), Lynne (1988), Paris (1989), Chambers and Just (1989), Moschini (1989), Leathers (1991)].

output prices is the implicitly maintained hypothesis underlying the estimation of aggregate agricultural supply functions. [5]

A homothetic production function implies that expansion paths are linear out of the origin and requires estimation of fewer parameters to fully represent the technology. It is an implicitly maintained hypothesis in the extensive literature in which a Cobb–Douglas (or other homothetic) production, cost, profit, output supply, or input demand function has been estimated without first testing for functional form.

When production exhibits constant returns to scale, the average and marginal cost curves are horizontal and equal, and optimal output level is indeterminate for the competitive firm. In the aggregate, the elasticity of input price response to a change in output price is equal to the competitive industry's partial production elasticity for the input (Jorgensen and Fraumeni, 1981).

When technical change is Hicks-neutral, technological improvements do not affect the marginal rates of substitution of any pair of inputs or outputs. [6] When time series data are used, Hicks neutrality reduces the number of independent parameters that must be estimated to fully reveal the technology.

If the technology is twice continuously differentiable, so is its corresponding dual model and the second derivatives of each function are invariant to the order of differentiation. Thus, price parameters in the system of output supply and input demand (or share) equations are symmetric.

None of these properties are implied by economic theory. They are all empirical hypotheses that may or may not apply to a particular production system. With the obvious analytic simplification that is justified when one or more of these properties apply and the possibility of substantial error in inference occurring when they are assumed to apply but really do not, the need for careful testing is apparent. Several recent empirical tests for each of these properties are reported in the 21 studies noted in Table 2.

Short-run nonjoint-in-inputs production of all agricultural outputs was rejected using parametric tests for the U.S., Ontario Canada, six of ten USDA farm production regions, four of five South Central states, and

[5] Consistent aggregation of both quantities and prices into indices requires homothetic separability of the technology (Lau, 1978). For an excellent treatise on alternative primal and dual tests of sufficient conditions for consistent aggregation, see Pope and Hallam (1988).

[6] When technical change is indirectly Hicks-neutral, technological improvements do not affect input quantity ratios. Indirect Hicks neutrality implies Hicks neutrality if the production function is homothetic or if it is additive in time.

TABLE 2

Analytic simplification test results

Source	Unit of observation	Short-run nonjoint in inputs	Separability	Homotheticity	Constant returns to scale	Hicks-neutral technical change	Symmetry
Lau and Yotopoulos (1972)	Indian farms				R [a]		
Weaver (1977)	North and South Dakota		R outputs R crops R capital-petroleum R materials-petroleum F materials-fertilizer	R		R	
Brown (1978)	U.S.					R [b]	
Lopez (1980)	Canada			R	R		F
Ray (1982)	U.S.	R crops, livestock [c]	R outputs, inputs		R		
Shumway (1983)	Texas field crops	R field crops R wheat and hay F wheat	R variable inputs R 4 crops F cotton-sorghum-corn	F variable inputs F outputs			R
Chalfant (1984)	U.S.			R			
Lopez (1984)	Canada	F crops, livestock					R [b]
Rossi (1984)	Italy						F
Antle (1984)	U.S.			R		R	F [b]
Grisley and Gitu (1985)	Mid-Atlantic turkeys			R			

Capalbo and Denny (1986)	U.S.		R partial materials-technical		F	F gross output R net output	
	Canada		R partial materials-technical		F	R net output	
Kuroda (1987)	Japan			R	R	R	F
Pope and Hallam (1988)	Westside, CA cotton		F nitrogen-water				
Shumway and Alexander (1988)	Ten U.S. farm production regions	R in six regions F in four regions				R in all regions	
Moschini (1988)	Ontario, Canada	R unrestricted outputs			R		
Chavas and Cox (1988)	U.S.		R[d] outputs R[d] inputs R[d] capital-labor F[d] capital F[d] labor F[d] materials			F[c]	
Ball (1988)	U.S.	R	R outputs	R affine homotheticity			
Howard and Shumway (1988)	U.S. dairy						F
Lim (1989)	48 U.S. states		F[d] inputs in 24 states F[d] outputs in 11 states F[d] subsets of 3–5 inputs in 41 states F[d] subsets of 2–18 outputs in 44 states		F[d,e] in 47 states		

To be continued...

TABLE 2 (continued)

Source	Unit of observation	Short-run nonjoint in inputs	Separability	Homotheticity
Chambers and Just (1989)	Israeli farms	R [f]		
Polson and Shumway (1990)	Five South Central states	F outputs in LA F subsets of 1–5 outputs in TX, OK, MS R each output in AR	F fertilizer-misc. inputs in LA R each input pair in TX, OK, AR, MS F subsets of 2–5 outputs in TX, OK, AR, LA, MS	F subsets of 2 inputs in OK, LA, MS R each input pair in TX, AR F outputs in OK F subsets of 3–6 outputs in TX, AR, LA, MS

[a] F means the author(s) failed to reject the hypothesis; R means the hypothesis was rejected at the chosen level.
[b] Rejected at 5% level of significance but not at 1% level.
[c] Rejected long-run nonjoint production in inputs.
[d] Nonparametric test.
[e] Using criterion that probable measurement error in quantity data did not exceed 10 percent. Constant returns to scale would not have been rejected in 38 states with 5% measurement error as the criterion.
[f] Also rejected long-run nonjoint production in inputs.

Israeli farmers. The hypothesis of short-run nonjoint production of all agricultural outputs was not rejected for the remaining state, for the other four farm production regions, nor for Canada. Short-run nonjoint production among a variety of subsets of outputs was tested for four states; short-run nonjointness of all tested subsets was rejected in only one – Arkansas. However, among the other states, the subset of outputs exhibiting evidence of nonjoint production varies widely by state and data period. There is more evidence of short-run joint than nonjoint production in state, regional, and national data, and the empirical effect of binding allocatable inputs with decreasing returns to size is generally stronger than that of technical interdependence when short-run jointness is evident in agricultural production.

Agricultural output separability was rejected using parametric tests for the U.S. and for North and South Dakota. It was rejected using nonparametric tests for the U.S. and for 37 of the contiguous 48 states. Agricultural input separability was rejected using nonparametric tests for the U.S. and for 24 of 48 states. Separability of subsets of outputs and/or inputs was not rejected using parametric tests for the U.S., North and South Dakota, five South Central states, or Westside California cotton production. Separability in various subsets of outputs and inputs also was not rejected using nonparametric tests for the U.S. or any of the 48 states. As with nonjointness, the nonrejected separable subsets vary widely among geographic units.

Homothetic agricultural production was quite consistently rejected using parametric tests. For example, of the nine studies reporting homotheticity tests in Table 2, only two failed to reject homotheticity in all outputs and/or variable inputs. Like separability, homotheticity in subsets of outputs and/or inputs was not rejected in any area tested, and the homothetic subsets also varied considerably among geographic units.

Constant returns to scale in agricultural production were rejected using parametric tests for Japan, Ontario Canada, and Indian farmers, but were not rejected using nonparametric tests for most of the 48 states. Parametric test results for the U.S. and Canada were mixed.

Except for gross-output Hicks neutrality for the U.S., Hicks-neutral technical change was rejected in all areas tested parametrically. It was not rejected using nonparametric tests for the U.S.

Tests of symmetric price parameters in the output supply and input demand (or share) equations (implied by a twice-continuously-differentiable technology) yielded mixed results. Symmetry was rejected for pre-World War II U.S., for Canada, and for Texas field crops. It was not rejected for Italy, post-World War II U.S., U.S. dairy production, or for Canadian or Japanese input demands.

So what are the stylized facts that emerge from these tests for analytical simplification? Consider four based on the preponderance of evidence:

(1) Little evidence supports the hypothesis that technology is homothetic in all variables or that technical change is Hicks neutral. Therefore, neither the Cobb–Douglas nor the CES functional forms are suitable for modeling agricultural production or the associated dual specifications. In addition, other functional forms that maintain homogeneity, such as the homogeneous generalized quadratic mean, are not suitable choices for modeling agricultural production.

(2) Production of some outputs is nonjoint in the short run. Thus, short-run production of some agricultural outputs can be modeled without regard for the decisions made on other outputs.

(3) Some input subsets and some output subsets are both separable and homothetic. They can be consistently aggregated for multistage optimization using either primal or dual models. These properties justify analytical simplification by reducing the number of variables required in each model. However, for complete analysis of the disaggregated variables, multiple models must be constructed.

(4) Nonjoint, separable, and homothetic subsets vary widely among observation units and model structures. Test results on constant returns to scale and symmetry are also mixed. These findings emphasize the need for widespread empirical testing of these properties prior to generally maintaining simplified analytic specifications and/or twice-differentiable production functions.

SOME OPPORTUNITIES

While there is considerable evidence of risk-averse behavior among agricultural producers, it is not so apparent in most aggregate data. Perhaps the law of large numbers is responsible for diffusing the effects of risk responsiveness when data are aggregated. There is clearly a need to conduct more rigorous tests for behavioral objectives of agricultural producers manifested in various data of concern. It may well be that the hypothesis of profit maximization can be maintained in aggregate agricultural analyses with little adverse impact on the reliability of estimated inferences relative to the inferences obtained from a more accurate behavioral objective. However, maintaining this hypothesis without formal test is less likely to be a satisfactory practice in micro-level analyses. More attention to predictive performance and more powerful tests of the implications of alternative hypotheses is needed.

The evidence cited here provides little hope for simplifying agricultural production models because of overall homothetic or Hicks-neutral structures. Nonjointness, separability, and/or homotheticity in subsets are more likely to be legitimate justifications for analytic simplification, but many more tests will be required before any generalizable guidance can be provided. Because the nature and extent of simplification has varied so greatly with the unit of analysis, observation period, and model specification, some exploration of alternatives is currently warranted in designing specific empirical models.

Because of their potentially important impacts on economic inference, additional empirical testing and sensitivity analysis for constant returns to scale, twice-continuously-differentiable technology, functional form, and adjustment dynamics should be conducted within the confines of specific empirical problems. These properties are not implications of economic theory but are frequently maintained hypotheses to facilitate econometric estimation. Because conclusions can differ based on type of production activity, observation unit, commodity aggregation level, variable specification, and data quality, a wide range of tests may be needed to guide model specification. Where empirical evidence is not very helpful in choosing from among alternatives, the sensitivity of results to a range of plausible alternatives should be examined and reported.

As we seek to better use economic theory to guide public and private decision makers, several questions deserve greater attention than they have received in the past. What is the impact (including program cost, producer income, and consumer prices) of governmental intervention into one commodity on supplies both of program and nonprogram commodities? What is the impact of emerging food safety, water quality, and related environmental legislation? What is the impact of changing international markets (especially those evolving because of major political change such as in Eastern Europe)? What is the distribution of benefits and costs from changing policies and international markets (a) among producers, input suppliers, value-added businesses, and consumers, (b) among income groups, and (c) among geographic areas? Since the primary concerns deal with the future impact of possible changes, what is the degree of uncertainty in the expected impacts?

CAPITALIZING ON OPPORTUNITIES

It is apparent that agricultural production remains a relevant area for economic inquiry. A rich set of potentially fruitful issues remain to be addressed which could be supported by relatively high quality and abundant data.

To be most fruitful both for the development of science and for using the science to solve societal and private problems, relatively more attention needs to be given to fundamental hypothesis testing of economic and statistical theory that permit simplified analytic models to be used. For an applied discipline such as agricultural economics, increased professional attention to technology transfer from basic to applied research is needed. We have an outstanding technology transfer infrastructure in the U.S. (the Extension Service) for getting results of applied research into implementable applications for agricultural producers. We do not have as well developed an infrastructure for transferring new discoveries and theories from the frontiers of basic research to those best equipped to do high quality applied research. [7]

Wallace's model of science does not require that the same person or even the same organizational entity do all the important types of work relevant to the development of the science, but it does require communication linkages from people working on each informational component. If we are going to help advance economic science so that it is more useful for addressing real world problems in the future than it is now, we must give more attention to communication linkages with those who work on the informational components that necessarily precede and follows ours. We must also attach more importance to efforts to advance the science at the same time we are using the science to provide guidance to current decision makers. Some of those efforts will be competitive, but many of them can be synergistic. Certainly over time they are entirely synergistic, and we could profitably take a longer view of the potential of our individual and collective efforts to help society.

How can we promote technology transfer from basic researchers to those of us who are mainly applied researchers? One way would be for applied researchers to assume the primary responsibility of this technology transfer. Basic researchers have little incentive to do it just as applied researchers seem to have little incentive within our academic infrastructure and reward systems to engage in serious technology transfer of applied research results to implementable applications. Many of us are quite content to leave technology transfer of applied research results to extension specialists. If we are going to justify this behavior by the incentive structure, then with logical consistency we cannot criticize basic researchers for not helping more to facilitate transfer of their contributions to us. While we might all benefit if they would, the incentive structures favor our doing that. If we

[7] Agricultural experiment station researchers do some of this transfer. However, the emphasis of the experiment stations is on the development of farm technology and on doing applied research, not in communicating new basic research technology to applied research implementers.

are going to do it, we need to spend some time in the basic literature and with the basic scientists in economics and other behavioral disciplines searching for theories and ideas that warrant our hypothesis testing and application to agricultural and related problems. This process could require our becoming better educated in economic and related theories and in quantitative methods and that we work to retain and improve those skills.

Our journals and journal reviewers can help by giving increased publication support for such technology transfer efforts. Those who are in the best position to communicate clearly the practical relevance of a new theoretical development to applied researchers may not be in the best position to actually apply the concepts in empirical research. Some who have an excellent grasp of theory may not be equally competent in quantitative methods or data management. Thus, some potentially relevant articles may lack empirical application when first presented in language that can be used by applied researchers. We may need to be willing not only to tolerate a few exceptions to our expectation of predominantly empirical research but also to encourage and facilitate them.

Those who work in this basic-applied technology transfer arena need to be highly skilled in at least two economic languages, the one they primarily read (highly mathematical and esoteric) and the one they primarily write in (accessible to the general body of applied economists). Some argue that to do this task well, they also need to do some personal scholarly work that cuts across basic and applied research.

It will be a continuing challenge to strive to be serious contributors to the development of the science and in using the best currently available science to provide useful information to existing decisionmakers. We will need to conduct serious and exhaustive tests of potentially relevant theories, revise or develop new ones, and use non-rejected theories for decision-making guidance. I do not know whether other areas of inquiry might be more fruitful during the next decade or two, but it is apparent that agricultural production economics is not likely to be fruitless.

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