# Evaluating Agricultural Research and Productivity

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# ECONOMIC EVALUATION OF POSTHARVEST (MARKETING) RESEARCH: CONCEPTUAL AND EMPIRICAL ISSUES

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Economic returns to food and agricultural research have been of long standing interest to the U.S. Congress, state legislatures, and other appropriating agencies, and USDA and Land Grant College administrators. However, attempts to quantify economic returns to agriculture (ag)-food-kindred[1] research are of relatively recent vintage (reviews of this research are available in Ruttan and Norton and Davis). Moreover, most of the effort to quantify returns to ag-food research has been directed to production related research. This focus is understandable in that most of the government appropriated funds have been spent on primary production problems - specifically, crop and animal production. Genetics and/or breeding, nutrition, and protection are the areas of central focus of most of the primary production oriented research.

To date, very little of the effort to evaluate returns to ag-food research has been directed to the postharvest or marketing sector of the ag-food-kindred system. This too is understandable in that only a small proportion of the publicly appropriated funds are devoted to marketing research.

However, as the 1980s roll on, increasing interest is being focused on the preservation, fabrication and distribution of foods. In addition, there is an apparent increasing awareness of exchange, equity, policy, competitiveness, international trade, and rural decay issues, to name a few. The financial crisis in U.S. agriculture during the 1980s verifies that many of the researchable issues confronting the U.S. ag-food system lie before and beyond farm production.

Nevertheless, research directed to the marketing, trade, policy and related issues is difficult to formulate and execute. And it is even more difficult to evaluate and quantify the returns to or determine the value of marketing oriented research.

Freebairn, Davis, and Edwards have demonstrated that innovation in one stage of a multistage production system provides benefits throughout the system. Using some rather strong assumptions to simplify their argument, they find that the distribution of benefits is the same regardless of where cost reductions occur in the system. And their conclusion held when they relaxed the assumption of competitive behavior, although the degree of competitiveness did alter the proportion of the benefits passed on to other segments of the system.

Freebairn et. al. further conjectured that, "There is little reason to argue that research opportunities are greater or research costs are less at the farm level than at the marketing and input levels." They concluded, "...that the choice of agricultural research projects should recognize opportunities at all levels in the system." To the extent that there is less competition and substantially larger firms in the marketing channels than on farms, incentives for public investments in marketing research are weakened. However, larger sizes of firms in the marketing stages provide incentives for private investments. This is especially true where firms can capture profits through product development and differentiation.

There may be less pressure for publicly supported research from firms in some stages of the marketing system because the knowledge created would be in the public domain and more freely available. However, the ability of a firm to capture benefits from publicly supported research is becoming increasingly possible because of institutional innovations (e.g. university research parks) which encourage joint public-private research efforts.

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To the extent that incentives for investment in marketing research have led to underinvestments in research beyond the farm gate, higher marginal rates of return to research in the nonfarm than in the farm production stages of the food chain are expected.[2]

## ECONOMIC PROGRESS AND RESEARCH

Joseph Shumpeter observed long ago that economic progress (rising affluence) stems from doing the old things better and spawning new goods and services. Thus, economic progress and research (advancement of knowledge) have slept together for a long time.

Research contributes to economic progress in three basic ways by permitting a society to:

1) save resources to use in the production of other goods and services,
2) increase output that adds to the stock of wealth contributing to rising real incomes per capita. (Wealth is defined as those things - goods and services - that provide people with sustenance, comfort, convenience and pleasure), and
3) helps to mitigate inflationary pressures by increasing productivity of labor, management, and resources.

Although there is little doubt that research provides substantial benefits to the greater society, there is no clear pathway to accurately quantify the benefits or value of research.

Food needs of the highly developed nations are near satiety and problems of food surpluses are more prevalent in such countries than are problems of food shortages. This situation does not preclude the fact that agricultural research can still lead to significant net benefits to such countries through knowledge of how to use resources more efficiently and provide additional services to consumers. Little information is available on the quantities and qualities of goods and services created via resource savings in the food system. Although basic food needs may be fully satisfied, our human wants never are.

## IMPORTANCE OF MARKETING TO A COMMERCIAL FOOD SYSTEM

Marketing was relatively unimportant in the subsistence type agriculture-food system that dominated our U.S. society until well into the 20th Century. Only the preservation of food, in addition to production, was considered important. Moreover, research effort was devoted to making relatively small geographic areas and even households nearly self-sufficient in foodstuffs.

However, as agricultural production technology evolved, the U.S. ag-food-kindred system became more commercialized and industrialized. The bulk of the population (consumers) and agricultural production became progressively separated. In fact, evolving technologies could not have been implemented without a simultaneous commercialization of the food system. A market and cash in-flow are required to implement most farm production technologies.

Agricultural production technologies that evolved mostly during the mid-two quarters of the 20th Century vastly enhanced labor efficiency on farms and were of a labor displacing character. Labor requirements on the farm declined drastically; but labor requirements increased in the prefarm sector to provide industrial inputs for farms, and in the post farm sector, to assemble, fabricate, and distribute food to a rapidly growing urban population. Thus, the importance of marketing to the implementation of on-farm production technology cannot be over emphasized.

The relative importance of the postharvest or marketing component of the ag-food-kindred system is contained in a study conducted by USDA's ERS (Harrington, et. al. 1986). This study revealed that the U.S. ag-food-kindred system accounted for $648 billion GNP and 21.3 million employment in 1984. The pre-farm sector accounted for 2 million employed and nearly $64 billion GNP. The farm sector accounted for 2.7 million employment and nearly $65 billion GNP. The relative importance of the post farm (marketing) sector is emphasized by this sector accounting for 16.6 million employment and nearly $520 billion GNP. On a per person employed basis, the pre-farm sector accounted for $31,900 GNP, the farm sector $23,963 GNP, and the post farm sector $31,295 GNP. The proportion of total ag-food-kindred GNP attributed to the three sectors was pre-farm 9.8%, farm 10.0%, and post farm 80.2%.

## APPROACHES TO EVALUATION OF RESEARCH

Two basic ex post evaluation approaches have been employed in an effort to quantify or place a value on research:

1) the production function approach (or, its more modern counterparts, the indirect-profit and indirect-cost function approaches), and
2) the estimation of economic surplus.

Both these approaches have sound theoretical underpinning and are conceptually linked, but both are subject to near insurmountable empirical estimation problems. Norton and Davis (pp.685-92) provide a review of studies using these two approaches.

The production (or indirect profit) function approach attempts to measure the rate of change of production (profits) attributed to research expenditures. The objective is to determine how research affects value added in production, and value added is the source of producers' surplus. This approach is haunted by the problems of collinearity among factors that contribute to production which stems in part from profit maximizing behavior. The production function approach is also subject to problems of input and output variables being simultaneously determined which can result in least-squares bias. In addition to the knowledge gained through research, technical innovation requires capital expenditures for machinery and specialized equipment, seeds, fertilizers, pesticides, growth stimulants and the like. In fact, the benefits to welfare result from both the new knowledge and the new inputs which are necessary to carry the knowledge to the production process. To the extent that the benefits represent a joint product, the knowledge and the new inputs may be so wed that divorce is near impossible in the empirical estimation of the source of benefits.

There are two conceptual problems in attempting to measure returns to marketing research from the production side alone. First, aggregate industry behavior affects product prices so one cannot consider output prices and perhaps some input prices as exogenously determined. This situation creates problems for both the production function and the indirect-profit-function approach. Second, estimating from the production side ignores any effects on the consumer demand side of the market and marketing research which can, as we argue later, function as a quasi-demand shifter.

The economic surplus approach is based on the theoretical concepts of a supply and a demand function. In a competitive environment and for a given product, the intersection of these two functions establishes equilibrium price and quantity and determines economic surplus which can be partitioned into consumers' and producers' surplus.

A partial market equilibrium model which incorporates demand and supply functions and market clearing conditions provides an empirically operational approach to measuring returns to market research. Another economic surplus approach on the producers' side of the market is to measure value added at each production activity along the multimarket chain and attempt to relate the value added to research expenditures. This approach is demanding in terms of accounting data and effort. This direct value-added approach would also need to be augmented to include welfare gains from final consumption to obtain a measure of total benefits from research.

These two economic surplus approaches are useful for different purposes. The partial market equilibrium approach represents a gross abstraction of reality and masks complex microeconomic activities. As a consequence, the results from such an approach would be most useful for estimating aggregate rates of return on investments in research in a given sector of the food-and-fiber portion of our economy. The approach can also provide insights into the distribution of net benefits from research activities. Such measures would be of benefit for broad policy and allocative decisions at the interindustry level but would be of less use at intraindustry levels.

On the other hand, the direct value-added approach could conceptually provide insights into successive economic activities at any level in the system. And, since value added can be aggregated without bias, the direct value-added approach provides a way of determining

benefits to society by economic activities by states or other regional delineations. For examples, we do know (Harrington, et. al. 1986) that opportunities for direct labor saving in the food-fiber-kindred marketing system is more than five times that in primary agriculture and nearly four times that upstream from the farm gate. We also, know that the value added in the postharvest sector is about eight times the value added in the farm sector.

## CONCEPTUAL ISSUES

Of the many conceptual issues involved in attempting to measure returns to research beyond the farm production level, two seem most critical - particularly with reference to the partial market equilibrium approach. Markets by their very nature vertically integrate activities from factors used in farm production to consumers. Also, the economic activities along this multimarket chain are each capable of generating surpluses to society. The partitioning of producers' and consumers' surplus to particular activities is a conceptual puzzle if one is to identify the distributional effects of marketing research. We will refer to this problem as that of "partitioning surplus".

A second issue concerns how research shifts structural parameters to generate surplus. In measuring returns to purely production research, it seem fairly clear that research shifts the cost structure and hence the supply side of the market. However, marketing research can shift the demand for a product. This capability creates another puzzle which we refer to as "supply and demand effects."

### Partitioning Surplus

In a partial equilibrium framework, the work by Just and Hueth (p.952) indicates that if one estimates ordinary supply and demand functions, the surplus obtained is for consumers and producers in that market only. However, if surplus is based on a general equilibrium model (i.e. prices in other industries in the multimarket chain are not fixed but left free to adjust), then price induced changes in welfare are general and estimates of changes in surplus will include that for consumers and producers at all levels in the multimarket, vertically-integrated chain.

The work of Just and Hueth is helpful in clarifying the conceptual issue of partitioning surplus. Whether one can partition producers' surplus by markets depends critically on whether one can empirically obtain partial equilibrium estimates (directly or indirectly).

This partitioning problem does not create a conceptual or empirical problem if value added is estimated from accounts for each industry in the marketing process. However, the task of estimating value added in this manner is very demanding in terms of both data and effort for even one production period. To estimate value added by years which would be required to estimate the effect on value added as a consequence of changes in research investments is a task of monumental proportions.

### Supply and Demand Effects

In addition to the objective of increasing technical and economic efficiency in production activities, marketing research is often directed toward objectives of increasing the demand for a product. An example is advertising research directed toward obtaining a maximum increase in demand for a given outlay for advertising and promotional activities.

To complicate matters further, changing consumer tastes and preferences are sometimes a recognized objective in research directed primarily toward farm production processes. An example is provided by tomato breeding research and development activities designed to improve the retail shelf quality and appearance of the product. This research as been coupled with educational programs to instruct consumers on how best to ripen the tomatoes in the home so as to enhance color and flavor.

Tastes and preferences of consumers may also be a factor in the rate of adoption of a new technology and hence will affect the lag in response to the technology. Perhaps the clearest

example here is provided by preferences for traditional varieties of rice and corn over high yielding hybrid varieties in societies where rice and corn are basic food crops.

Some will argue that the above examples simply represent changes in product quality and that market activities and research are simply being directed toward supplying the qualities demanded and hence that the benefits still derive from the supply side of the market. Undoubtedly marketing activities and research have developed to a level of sophistication to permit the recognition and exploitation of consumers' wants. However, from an empirical point of view where changes in product quality are very difficult to quantify, it is more tractable to treat these "quality aspects" as being reflected in the market as shifts in the demand for a homogeneous product. Perhaps such shifts in demand should be identified with a new term, e.g. quasi-demand shifts.

## EMPIRICAL ISSUES FROM CURRENT STUDIES

This section focuses on the earlier discussion of conceptual issues. We will also use studies in progress in Florida and Georgia to focus our remarks.

The first attempt to measure the returns to postharvest research in Florida (Stranahan, Shonkwiler and Stranahan) recognized only the processing of frozen concentrated orange juice (FCOJ). The research treated FCOJ as a homogeneous product and attempted to measure the extent to which research expenditures shifted processing cost. The approach represented a partial look at the producer surplus side of the issue. Product price did not enter their model so their estimate measured the rate of change in cost, given the quantities produced, as a consequence of changes in research expenditures. Consumer benefits were not included and one would expect that the authors underestimated the benefits to research. Also, by ignoring the demand side, the model did not capture the effects of advertising and promotional research and the effects of changes in product quality.

To obtain more accurate estimates of the returns to research beyond the grove level, Suzanne H. Hinckley (a Ph.D. candidate) is developing a partial equilibrium model of the market for oranges and grapefruit. The model includes three production regions (Florida, California-Arizona, and Brazil) supplying the U.S. market. James S. Ansoanuur, another Ph.D. candidate at the University of Florida, is studying the winter tomato market. He is using a two production region (Florida and Mexico) model serving the U.S. These studies are similar in their methodology. The second model is somewhat simpler to specify and is utilized here to discuss the conceptual issues previously identified.

The tomato model has nine equations. The model encompasses three markets. A market at the packing house (shipping point) level, in Florida, a market in Nogales (shipping point) in Mexico, and the U.S. retail market for tomatoes. In each market there are ordinary demand and supply equations and market clearing conditions. The model is being estimated with time series over a 23 year period, 1962 to 1984.

Two variables representing research expenditures are included in the model. Observations on these variables are being developed from CRIS (Cooperative Research Information System) and Pre-CRIS data on research expenditures. In essence total research expenditures are being partitioned into a dichotomy, production and marketing research. The expenditures data also include known private as well as public research expenditures.

Returning to the conceptual issue of partitioning surplus, the sectors involved in the case studies roughly satisfy the small-sector economic industry assumptions of Just and Hueth. The surplus measures - utilizing supply and demand equations at the U.S. retail market level - provide an estimate of welfare benefits of the industry to society. The partial equilibrium surplus estimates at the Florida packing houses and the Nogales shipping point provide estimates of the benefits to producers and input suppliers. If we are successful in our partial equilibrium analyses, the difference between the U.S. and the shipping point surpluses should provide estimates of the surplus accruing to production activities between the shipping points and retail levels.

The work by Just and Hueth indicates that multicollinearity problems can thwart attempts to obtain partial equilibrium estimates. Indeed, if we are only able to obtain efficient estimates of linear combination of price variables, what we hoped to be partial equilibrium results could be general equilibrium measures. If this comes to pass, the estimates of surpluses at the shipping points will include all welfare benefits. The bottom line is that we cannot be certain at this time as to whether we will be able to obtain useful estimates of benefits to the four groups - producers and input suppliers in the U.S., producers and input suppliers in Mexico, handlers (agents between shipping points and consumers) in the U.S., and consumers.

By deriving surplus estimates analytically from the model, one can obtain equations of the general form[3]:

1) $PS_{FL} = f_1(RD_1, RD_2, W)$,
2) $PS_{MX} = f_2(RD_1, RD_2, X)$,
3) $PS_{USM} = f_3(RD_1, RD_2, Y)$, and
4) $CS_{US} = f_4(RD_1, RD_2, Z)$ where

$PS_{FL}$ is producers surplus accruing to producers and suppliers of inputs to producers for tomato production in Florida,
$PS_{MX}$ is producers surplus accruing to producers and input suppliers for tomato production in Mexico,
$PS_{USM}$ is producers surplus accruing to handlers in the marketing of tomatoes in the U.S.,
$CS_{US}$ is consumers surplus accruing to consumers of fresh winter tomatoes in the U.S.,
$RD_1$ is a measure of real R & D expenditures on farm level production technology, appropriately lagged,
$RD_2$ is a measure of real postharvest research expenditures on fresh winter tomatoes appropriately lagged, and
W,X,Y, and Z are vectors of other variables specified to be associated with the respective markets generating the surplus.

These equations provide a basis for estimating rates of change in net benefits accruing to the four groups as a consequence of a change in expenditures for either production or marketing research. We also hope to be able to obtain estimates of spillover effects of U.S. research expenditures from the surplus accruing to producers and input suppliers in Mexico.

The conceptual issues discussed under the heading "Supply and Demand Effects" is recognized but the effects are somewhat confounded in the model. In the definition of consumers' surplus (equation 4), one could hold supply fixed at the means of the variables and look at the partial effects of both marketing and production research expenditures on surplus when the research is permitted to act only as a quasi-demand shifter. These rates of change could be interpreted as benefits to consumers for research leading to "quality" improvements.

The fresh winter tomato model is based on the assumption of a competitive environment in the markets described by the model. John VanSickle who is quite familiar with the industry has indicated that this assumption is reasonable. However, specification errors would exist if noncompetitive behavior were present in the markets, and there would be bias in the estimation of total surplus and hence the components of surplus as a function of research expenditures.

A more general specification could be provided by defining the supply equation as the result of a horizontal summation of marginal cost functions and $P_d$ and $P_s$ as the demand price and the ordinate of the resulting marginal cost function at the quantity consumed, respectively. Then, $P_d - P_s$ would define marginal (and average) monopoly profits at the equilibrium quantity demanded. And, $P_d - P_s = 0$ at all competitive equilibria. Since monopoly profits (and hence $P_s$) are unobservable, additional information would be required to estimate this more general model[4].

There are many other limitations to the empirical quantification of the effects of research investments on societal welfare. There is the age-old problem that analysis based on

past experiences with historical data only documents the past. We have faith that the past will reveal the future and hence what we have learned will be useful for making decisions for the future. But, new knowledge is a lumpy variable and new discoveries are by their very nature unique and projection is subject to these limitations. These limitations exist regardless of the method of evaluation used as long as it is based on data that have been passively generated by the economic system.

An econometric model of a market is also fraught with well known measurement problems which have essentially been ignored in this discussion. Identification problems which encompass specification problems are always present and the researcher can never be quite sure that he or she has captured the key elements of the complex interrelationships of interest. The lagged effects of evolving knowledge is also a knotty problem. As a community of scholars, we know something of most of these problems from past research efforts and will learn more as we grapple with measurement efforts. In whatever approach to measurement we take, two questions persist. What effects are we attempting to measure? And, will our methods and data permit us to measure these effects?

## CONCLUDING REMARKS

Knowledge created by research and its distribution via educational processes, is a part of the capital stock that enhances the creation and distribution of wealth. The cost of research and education, at least in the public sector, is relatively easy to reckon, but defensible methods of estimating benefits are more intractable.

Marketing research, education, entrepreneurship, management-labor, capital investments in buildings and equipment, government investments in transportation systems, grades and standards, sanitary inspection, a viable monetary exchange system, computerized information systems, etc., all combine to make a wide variety of wholesome foods and kindred products readily available to most consumers, with modest buying power, most of the time. All these factors that contribute to a highly efficient food system require both private and public investment.

From an empirical estimation perspective, it is most difficult to segregate the net benefits of all the necessary investments in the food-fiber-kindred system. Private investments will be made on a continuing basis only if the returns on the investments cover opportunity costs. However, there is nearly always uncertainty surrounding investment decisions. In a monetary exchange system this includes investment of people time and talents, and monetary investments.

Basically, the greater society benefits from improved labor efficiency - both hands and brains - and the spawning of new goods and services. Certain labor efficiencies can be determined rather precisely for selected innovations -- the dolly and fork-lift for example. Even here, however, the investment becomes rather fuzzy. Innovative ideas stem from people who have acquired knowledge. The creation and diffusion of knowledge required prior investment in research and education. Investment in factories to produce the dollies and fork-lifts was also necessary.

Complex interrelationships and sequences provide little insight into wise investment decisions at the margin for administrators, legislators, and actors in the system. However, there are some things that can be reckoned satisfactorily in a monetary exchange system including direct labor (hands and brains) requirements, and value added by successive economic activities by states or other geographic delineations.

The most realistic approaches to the evaluation of marketing research is that of services created (value added), and resources saved (with emphasis on people time saved). Productivity and efficiency are enhanced via knowledge creation and technical innovation. Concurrently, new goods and services are created via resources thus saved, and further advancements in knowledge and technical innovation. Advancing knowledge and technical innovation pervade the organization, structure, management and exchange processes of the food-fiber-kindred system.

The spawning of new goods and services can be realized with resources saved in producing and delivering food - the first order of business of every economy. And, new knowledge is the great facilitator of this process. As a consequence, we assert that benefits derived from research have generally been underestimated by methods employed to date. We recognize, however, the inherent dangers from agricultural scientists measuring the productivity of agricultural science and we should encourage strong professional critique - when possible from nonagriculturalists.

## FOOTNOTES

[1] Ag-food-kindred classification covers products such as cotton, wool, tobacco, industrial alcohol, and starches as well as food. Wood and wood products have, at times, also been included.

[2] However, returns to postharvest research and development activities in frozen concentrated orange juice (FCOJ) subsector of the citrus industry have been estimated at 57% (Stranahan, Shonkwiler and Stranahan) which is in the range of returns estimated for agricultural production technologies (Ruttan).

[3] Greater detail regarding the development of these equations may be found in the proposal by Ansoanuur.

[4] One might, for example, approximate $P_d - P_s$ with a function $P_s = P_d - k\,Q$ where k is a constant equal to or greater than zero and Q is the observed quantity consumed. One could estimate the model for different values of k and then choose the value k* which minimized the estimated generalized variance for the model.

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