Potential Benefits of Rice Variety and Water Management Improvements in the Texas Gulf Coast

Ching-Cheng Chang, Bobby R. Eddleman, and Bruce A. McCarl

The welfare benefits from potential rice yield-enhancing and water-saving research programs and their distributional implications under alternative farm program provisions are compared. This is done in an *ex ante* surplus maximization framework by using a multiregional, price-endogenous mathematical programming model of U.S. agriculture. The simulation results indicate that government price support policies have profound impacts on the distribution of research benefits and distort interest group incentives and rankings for allocation of resources to research.

Key words: farm programs, returns to research, sector analysis, technological change, Texas rice.

Many studies have indicated substantial public benefits from research investments (e.g., Arndt and Ruttan; Ruttan; Eddleman). However, the social return from public investments in agricultural research and technology can be biased by government farm programs (Alston, Edwards, and Freebairn; Miller and Tolley; Oehmke; McCarl, Chang, and Eddleman). Furthermore, in the appraisal of potential research initiatives, distributional effects are important (e.g., Akino and Hayami; Schmitz and Seckler; White, Eddleman, and Purcell), as are impacts on government farm program costs (Gardner). This article addresses these issues in the context of the U.S. rice industry. Specifically, the impacts of research to improve variety and water management techniques in the Texas Gulf Coast region are examined, both with and without government program interventions.

C.-C. Chang is a visiting assistant professor in the Agricultural Economics Department, Texas A&M University. B. R. Eddleman is a professor and Resident Director of the Corpus Christi Agricultural Research and Extension Center. B. A. McCarl is a professor in the Agricultural Economics Department, Texas A&M University. All are employees of the Texas Agricultural Experiment Station.

Technical paper TA 30052 of the Texas Agricultural Experiment Station.

Theoretical Considerations

The impact of technological change stemming from research investment is illustrated in figure 1, where D represents the aggregate demand and S_0 the aggregate supply curves for a single commodity. Based on the standard Marshallian framework, the returns to research can be measured in terms of the changes in consumers' and producers' surpluses resulting from the supply shift due to the technological change. In the absence of government price supports, price falls and both the quantity consumed and the quantity produced increase as the supply curve shifts to S_1. Here, consumers gain while producers may gain or lose depending on the absolute value of the price elasticity of demand and the nature of the research-induced supply shift (Lindner and Jarrett; Miller, Rosenblatt, and Hushak). The total economic benefits from research is equal to area $A\ B\ C\ E$.

Factoring in government programs changes the situation. Suppose in figure 1, P_t is the target price of the commodity announced by the government.[1] Social deadweight loss oc-

[1] For simplicity, the acreage set-aside, compliance cost, slippage effects, and other program provisions are not considered in the graph. They are, however, included in our empirical analysis.

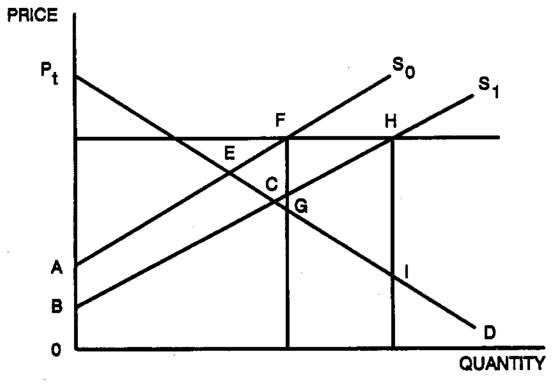

Figure 1. Welfare implications of technological change

curs as a result of government program intervention, where area *E F G* is the deadweight loss before the technological change and area *C H I* the deadweight loss afterwards. Therefore, the total social benefits from research under the government program include the area *A B C E* (benefits without government program) plus the difference between the areas *E F G* and *C H I* (additional deadweight loss arising from research and farm program). The magnitude of the latter depends not only on the shapes of the supply and demand curves but also on the level of farm program provisions.

Potential Rice Technologies

Now we turn to the specific evaluation of a project involving improved rice production in the Texas Gulf Coast region. The project is designed to increase long-grain rice yields while simultaneously reducing water, fertilizer, and pesticide requirements. The project involves both varietal and water management (including a shallower and more timely flood system) improvements. It is expected that these technological innovations when developed and fully adopted would reduce total cost per hundredweight (cwt.) by 25% (Texas Agricultural Extension Service; Texas Agricultural Experiment Station). This cost reduction results from a 27% yield increase and a 7.5% decrease in total variable cost per acre (table 1). The changes in variable cost per acre include a 67% increase in seed cost, an 18% increase in custom harvesting and drying cost, a 25% reduction in nitrogen fertilizer and application cost, a 33% decrease in irrigation pumping and labor cost, and a 23% decline in pesticide material and application cost.

In assessing technological advances in rice production, both varietal and water management improvements were assumed to be applicable in Texas and transferable to the Mississippi Delta states. Yields and production costs in the Mississippi Delta states were assumed to change in the same proportion as in Texas. Due to different varieties and production practices, California rice production was assumed to be affected by the water management innovation only.

The Agricultural Sector Model

A multicommodity agricultural sector model (ASM) is used to appraise the technological improvements. The model embodies a price-endogenous, mathematical programming approach as described by McCarl and Spreen. The ASM simulates the agricultural sector under a given set of supply and demand conditions generating estimates of agricultural prices, quantities produced, consumers' and producers' surplus, exports, and imports.

The objective function of ASM is the nonlinear sum of the area under domestic and export demand curves after subtracting the variable cost of production and the summed area under the factor and import supply curves. ASM constraints involve market supply-demand balances and resource limitations. In this general framework, the interrelationships among the commodities both in consumption and production and across different geographical regions are simultaneously incorporated. The model disaggregates the U.S. into 10 large production regions which are further broken down into 64 subregions for the endowment of land, labor, and water. There are 32 primary commodities and 34 secondary commodities in the model. Subregional production budgets and national processing alternatives are used to represent sectoral production and processing. The farm program features in ASM include acreage set-aside, target prices, Commodity Credit Corporation (CCC) loans, marketing loans, generic Payment in Kind, 50/92, 0/92, acreage diversion, deficiency payments, and slippage. A description of the mathematical structure of ASM is available

Table 1. Texas Rice Budget under Different Types of Technology Conditions

	Current Technology	Variety Improved	Water Management Improved	Both Variety & Water Management
Yield Per Acre (cwt.)	59	69	65	75
Variable Cost Per Acre		($)		
Nitrogen	64.80	48.60	64.80	48.60
Seed	18.00	30.00	18.00	30.00
Herbicide	44.00	44.00	44.00	44.00
Fungicide	25.68	9.66	25.68	9.66
Harvest, Haul and Dry	124.17	138.37	132.69	146.89
Irrigation Fuel	61.15	61.15	45.86	45.86
Irrigation Labor	30.86	30.86	15.26	15.26
Other Cost	111.24	105.69	108.85	103.84
Total Variable Cost	479.90	468.33	455.14	444.11
Fixed Costs Per Acre	216.43	216.43	216.43	216.43
Average Cost Per Cwt.				
Total	11.80	9.93	10.33	8.81
Variable	8.13	6.79	7.00	5.92
Fixed	3.67	3.14	3.33	2.89

Sources: Texas Agricultural Extension Service and Texas Agricultural Experiment Station.

from the authors upon request. ASM can be used to simulate the way in which government price and income support policies distort markets and welfare distributions under a given set of supply and demand conditions (Chang et al.). For comparison purposes, table 2 lists the demand elasticities of eight major field crops, including rice, used in the model.

New technologies are appraised by altering technical coefficients in terms of land, labor, water, national input use, and product yield in ASM for each technological possibility. Simultaneously, the farm program parameters in ASM are modified to allow study of the interaction of technological development and commodity programs. Net social benefits stimulated by the various technologies are estimated as the changes in total social welfare minus government program costs for deficiency payments and marketing loans.[2] The investment costs for technology innovations are not deducted but will be used for later discussion on rates of return.

[2] Due to the long-run equilibrium nature of ASM and the assumption that costs of government CCC loans would eventually be recovered when government disposes the stocks, we do not subtract the CCC loan costs. Neither do we consider the excess opportunity cost raised from government spending as discussed in Alston and Hurd and in Fox. Thus, our government program costs are likely to be underestimated.

Experimental Design

In order to distinguish policy and technological effects, ASM result comparisons are made separately for the rice technology improvements under four sets of farm program scenarios. These are: 1986 farm program (I), 1986 farm program with a 10% and 20% across-the-board target price and loan rate reduction (II, III), and no farm program (IV). All were imposed on 1986 production and demand conditions. Each set of comparisons can be interpreted as benchmark results that are used in

Table 2. Price Elasticities of Selected Commodities in ASM

	Elasticities of		
Commodity	Domestic Demand	Export Demand	Import Supply
Cotton	−.22	−2.00	NA
Corn	−.23	−.33	NA
Soybeans	−.15	−.82	NA
Wheat	−.07	−.35	NA
Sorghum	−.20	−.80	NA
Rice	−.09	−.46	NA
Barley	−.30	−.20	NA
Oats	−.21	−.20	.20

Sources: Previous model versions and mathematical programming work groups within the U.S. Department of Agriculture (USDA). NA = not available.

evaluating the potential impacts of the rice technology changes. The overall comparison across four policy scenarios demonstrates the sensitivity of welfare responses to the changing policy environment.

However, two premises should be recognized in interpreting these results. First, the analysis is an *ex ante* analysis in the sense that experimental data for the new technologies are used and the evolutionary process of technology adoption is not considered. Second, the model results arise from market-clearing conditions and therefore a long-run solution concept so that the comparisons are of the comparative statics type. Short-run impacts and adoption-related dynamics are not captured in this study.

Results

The ASM is validated for actual production and prices in 1986. The validation comparison for prices, quantities, and deficiency payments is given in table 3. The results for all the commodities are within a 5% deviation from their actual levels (Chang et al.). Based on these results, the ASM is considered to be applicable for further experimentation.

Technology Experiments

Table 4 summarizes the technology-induced welfare changes from the ASM results under the varietal only (*VAR*), water management only (*WAT*), and both varietal and water management improvements (*BOTH*). Under the 1986 program provisions (scenario I), rice production increases 29%, 32%, and 74%, respectively, from the three technological advances. Despite the higher per-acre yield from new technologies, the harvested acreages of rice also increase 15%, 18%, and 43%. The market price of rice declines along with the increased domestic rice consumption and exports. Rice producers, though facing a declining market price, are compensated by higher deficiency and marketing loan payments. Therefore, both consumers and producers experience substantial welfare gains from the technological advances. Unfortunately, the increase in government program payments outweighs these welfare gains, with a net loss for society both in total and in the domestic arena. Comparing the three technological advance scenarios, the *BOTH* case has the largest social benefits before considering government costs. *WAT*, on the other hand, exhibits the smallest net social benefit losses after deducting government costs. The *BOTH* case has the largest net social losses domestically and world wide.

Turning to more specific results, most of the producers' surplus gains are capitalized into the value of cropland. However, water returns vary by technology with *VAR* and *WAT* having different implications. While *VAR* generates more rice production through yield-enhancing technology, it also enhances the economic rent accruing to water. *WAT* reduces the demand for water use and hence its on-farm value. This result, of course, may be different if the external benefits from diverting the water saved into crops in the model or nonagricultural usages were fully incorporated. The welfare implications stemming from technological changes are altered when 1986 target prices and loan rates of all farm program commodities are simultaneously lowered by 10% and 20% (scenarios II and III). Under a 10% reduction, the signs and relative rankings of the welfare impacts remain unchanged, but the magnitudes are smaller than they are in scenario I. However, when farm program provisions are reduced by 20%, the welfare benefits from technological changes rise along with some sign reversals and ranking changes for individual sectors. Most of the welfare expansions are for domestic and foreign rice consumers. The results indicate that the welfare changes from such an across-the-board cut in per-unit payment rates are not uniformly distributed among commodities. Since rice is a commodity with relatively inelastic demand that receives relatively more government subsidies (on a per-unit basis), the technological advances in rice production stimulate considerable price and government payment responses. Although the technology-induced social losses are lowered with the reduction in farm program provisions, the welfare responses from private sectors are not necessarily reduced.

Under the last policy scenario where all farm program provisions are eliminated (decoupled) from farm commodity markets, all the technological advances have positive welfare implications for rice consumers, but domestic rice producers lose. Since the demand for rice is relatively inelastic, a large share of gains is passed on to the consumers in the form of

Table 3. Actual and Model 1986 Prices, Production, and Per-Unit Deficiency Payments for Major Crops and Livestock

Commodity		Prices		Production		Deficiency Payment	
		Model	Actual	Model	Actual	Model	Actual
Crops	Units	($/unit)		(million units)		($/unit)	
Cotton	(bale)	250.35	250.56	9.74	9.73	124.80	125.42
Corn	(bu.)	1.51	1.50	8,218.43	8,252.83	1.11	1.11
Soybeans	(bu.)	4.65	4.65	1,950.98	2,007.03	NA	NA
Wheat	(bu.)	2.42	2.40	2,037.34	2,086.78	1.96	1.98
Sorghum	(bu.)	1.37	1.36	943.99	941.63	1.14	1.14
Rice	(cwt.)	3.87	3.93	133.11	134.42	4.70	4.70
Barley	(bu.)	1.56	1.56	615.13	610.50	1.04	1.04
Oats	(bu.)	1.16	1.16	388.73	384.55	0.44	0.44
Livestock							
Milk	(cwt.)	12.49	12.59	1,400.68	1,440.80		
Pork	(cwt.)	160.83	162.26	141.62	140.63		
Beef and Veal	(cwt.)	185.64	183.13	249.58	248.95		
Poultry	(GCAU[a])	236.85	236.15	32.55	32.59		

Sources: Model results; *Agricultural Statistics, 1987* (USDA 1987); and a special tabulation summary provided by the Agricultural Stabilization and Conservation Service (USDA 1988).
Note: NA = not available.
[a] GCAU = Grain-consuming animal units.

relatively lower commodity prices. Apparently, the revenue losses due to market price reductions stimulated by increased production outweigh the value of the cost savings and yield enhancement. *BOTH* ranks the highest in both domestic and foreign accounts. These results contrast the previous simulations which have been intervened by government farm programs.

Finally, table 4 shows that some of the welfare benefits or losses from rice technological advances are also shared by non-rice producers and consumers domestically as well as overseas. These welfare effects come from the production and consumption relationships in the agricultural commodity and factor markets. The magnitudes of these spillover effects are, in some cases, critical to the overall and individual benefit estimates and, thus, should not be ignored in research evaluations.

Research Investment Outcomes for Rice Technology

The levels of investment in research to improve long-grain rice production that could be justified while yielding various rates of return on the investment were estimated. Previous Research and Development (R&D) evaluation studies found rates of return range from 25% to 50% annually.[3] Research cannot be readily turned on and off to influence output and productivity. Production-oriented research in the U.S. typically has had its greatest impact on farm-level productivity eight to 10 years after the initial investment and is not obsolete until 16 to 20[4] years after the initial investment (Huffman and Evenson). This benefit flow pattern has been typical of rice variety research and development in Texas for the past four decades. However, new research techniques including tissue culture, genetic engineering, and expert systems development have been incorporated in modernizing the physical rice research facilities. Thus, the lag between start-up of the research and maximum impact of the new production technologies is expected to be reduced to five to seven years. In table 5 rates of return are calculated based on assumptions that: (*a*) the consumers' plus producers' surplus without the presence of the farm program is the appropriate measure of benefits; (*b*) research investment is 50% of the max-

[3] Mansfield et al. reported an average of 25% pretax rate of return to a set of manufacturing R&D investments for private firms. Other empirical studies also reported similar high rates to private R&D. Ruttan reported recent studies on rates of return on U.S. agricultural research ranging from 28% to 37%.

[4] Fox pointed out that much of the empirical literature on U.S. agricultural research used a 16-year lag to approximate the pattern of benefits from research expenditures.

Table 4. Social Benefits from Technological Advance in Rice Production under Alternative Farm Program Provisions ($ Million)

	Varietal Only	Water Only	Both Varietal and Water
Scenario I. 1986 Farm Program Provisions			
Domestic Surplus	186	214	430
Consumers	61	130	179
Rice	99	104	152
Non-rice	−38	26	27
Producers	125	84	251
Rice	48	54	139
Non-rice	77	30	112
Government Program Payment	474	551	1,234
Net U.S. Social Benefits	−288	−337	−804
Foreign Surplus	175	228	351
Rice	206	219	353
Non-Rice	−31	9	−2
Net Social Benefits	−113	−109	−453
Scenario II. 10% Reduction in Farm Program Provisions			
Domestic Surplus	164	175	306
Consumers	68	119	192
Rice	132	118	179
Non-Rice	−64	1	13
Producers	96	56	114
Rice	33	25	69
Non-Rice	63	31	45
Government Program Payment	376	419	756
Net U.S. Social Benefits	−212	−244	−450
Foreign Surplus	178	221	330
Rice	248	218	364
Non-Rice	−70	3	−34
Net Social Benefits	−34	−23	−120
Scenario III. 20% Reduction in Farm Program Provisions			
Domestic Surplus	216	224	358
Consumers	181	258	255
Rice	217	189	281
Non-Rice	−36	69	−26
Producers	35	−34	103
Rice	31	22	52
Non-Rice	4	−56	51
Government Program Payment	560	552	905
Net U.S. Social Benefits	−344	−328	−547
Foreign Surplus	348	341	495
Rice	358	304	499
Non-Rice	−10	37	−4
Net Social Benefits	4	13	−52
Scenario IV. No Farm Programs			
Domestic Surplus	38	37	62
Consumers	26	49	105
Rice	54	48	99
Non-Rice	−28	1	6
Producers	12	−12	−43
Rice	−15	−16	−28
Non-Rice	27	4	−15
Government Program Payment	0	0	0
Net U.S. Benefits	38	37	62
Foreign Surplus	66	65	125
Rice	72	64	135
Non-Rice	−6	1	−10
Net Social Benefits	104	102	187

Note: The numbers reported here give the welfare changes as a result of three technological improvements under each policy scenario.

Table 5. Public Investment Outcomes for Technological Advances in Rice Production to Maintain Various Rates of Return ($ Million)

	Varietal Only	Water Only	Both Varietal and Water
A. Texas Alone:			
Benefit	12	5	7
Maximum Investment to Achieve 50%	0.89	0.37	0.52
25%	2.58	1.08	1.51
10%	5.28	2.20	3.08
B. Domestic Alone:			
Benefit	38	37	62
Maximum Investment to Achieve 50%	2.81	2.74	4.58
25%	8.20	7.98	13.38
10%	16.75	16.31	27.33
C. Domestic and Foreign:			
Benefit	104	102	187
Maximum Investment to Achieve 50%	7.69	7.54	13.83
25%	22.43	22.00	40.34
10%	45.85	44.97	82.44

imum in year 1, 75% in year 2, 90% in year 3, 95% in year 4, the maximum in year 5, and 80% from then on; (*c*) there is a five-year lag between initial investment and first adoption of the technology; (*d*) the technology adoption rate is 10% in year 6, 50% in year 7, 80% in year 8, 90% in year 9, and 100% thereafter; and (*e*) there is a 5% inflation rate. Under these assumptions, investors in Texas could afford to invest a maximum of $2.6 million annually in the rice varietal improvement research program and earn a 25% return per year. When both varietal and water advances are considered, only a $1.5 million investment could be justified on the basis of a 25% annual rate of return. When the spillover benefits to all consumers and other producers in the U.S. are considered, the U.S. investment of $13.4 million annually could be justified. If the spillover benefits to foreign countries are accounted for, the annual investment in *BOTH* research could increase to $40.3 million. These figures exceed the existing investment in rice varieties and water management research. Currently, public and private investment in "all" rice research[5] in Texas and in the U.S. is an estimated $2.1 million and $13.8 million, respectively (USDA 1989). One direct implication is that increased investment in the research projects identified here would yield favorable returns. It would also seem desirable to determine a way of evolving an appropriate mix of state, national, and international funds.

[5] Due to data limitations, the public funding for rice research cannot be partitioned into varietal, water management, and other categories.

Concluding Comments

The potential economic impacts of developing higher-yielding long-grain varieties and improving water management techniques in U.S. rice production were measured using a multicommodity agricultural sector model. The technologies were evaluated by changing per-acre yields and production costs under four alternative farm program assumptions.

Development and adoption of the new productivity-increasing technologies in U.S. rice production have differential benefits depending upon the farm program policy setting. Under a continuation of current policy, producers and consumers gain, however, the increases in government program costs more than offset these gains, and hence net social welfare decreases. On the other hand, if the farm program is eliminated, an increase in net social welfare from the new technology is realized but U.S. producers incur a welfare loss. Thus, a government program is a crucial determinant of both total benefits and their distribution. Levels of investment in the rice productivity-enhancing research studied here that would maintain a 25% annual rate of return on the investment exceed current funding levels if these distortions are ignored.

The sensitivity of the economic benefits to government programs raises the question of selecting appropriate undistorted prices for evaluating investments in agricultural research programs that are subject to policy distortions. Many of the internationally oriented studies on cost-benefit analyses and project evaluation have emphasized the importance of specifying a set of "shadow prices" that would truly reflect the relevant costs and returns of the inputs and outputs involved. Apparently, the prices in the U.S. market are significantly distorted as are returns to investments. The simulation results in scenario IV, where all farm program provisions are eliminated, correspond to the spirit of a shadow price-based, undistorted investment appraisal.

This study has many limitations. Parameter estimates and data need continuing refinement. Failure to account for private sector contributions to research benefits is another shortcoming. Nevertheless, empirical evidence of spillover effects beyond the direct technological transfers are found to be substantial. The magnitude of these external effects supports Ruttan's argument that the optimum level of investment on agricultural research should be evaluated at a national level. A more complete accounting of the spillover impacts of the technology on other markets outside the model and the technology adoption profile would be desirable but is beyond the scope of this study.

[Received June 1990; final revision received July 1991.]

References

Akino, M., and Y. Hayami. "Efficiency and Equity in Public Research: Rice Breeding in Japan's Economic Development." *Amer. J. Agr. Econ.* 57(1975):1–10.

Alston, J. M., and B. H. Hurd. "Some Neglected Social Costs of Government Spending in Farm Programs." *Amer. J. Agr. Econ.* 72(1990):149–56.

Alston, J. M., G. W. Edwards, and J. W. Freebairn. "Market Distortions and Benefits from Research." *Amer. J. Agr. Econ.* 70(1988):281–88.

Arndt, T. M., and V. W. Ruttan. "Valuing the Productivity of Agricultural Research: Problems and Issues." In *Resource Allocation and Productivity in National and International Agricultural Research,* eds., T. M. Arndt, D. G. Dalrymple, and V. W. Ruttan. Minneapolis: University of Minnesota Press, 1977.

Chang, C.-C., B. A. McCarl, J. W. Mjelde, and J. W. Richardson. "Sectoral Implications of Farm Program Modifications." Forthcoming in *Amer. J. Agr. Econ.*

Eddleman, B. R. "Returns on Investment in Research on Animals and Animal Products." Symposium on Food Animal Research, ed., R. H. Dutt. Lexington KY: University of Kentucky, 1986.

Fox, G. "Is the United States Really Underinvesting in Agricultural Research?" *Amer. J. Agr. Econ.* 67(1985): 806–12.

Gardner, B. L. "Price Supports and Optimal Spending on Agricultural Research." Work. Pap. #88-01. Dep. Agr. and Resour. Econ., University of Maryland, April 1989.

Huffman, W. E., and R. E. Evenson. "Science for Agriculture." Mimeo, Department of Economics, Iowa State University and Yale University. June 1991.

Lindner, R. K., and F. G. Jarrett. "Supply Shifts and the Size of Research Benefits." *Amer. J. Agr. Econ.* 60(1978):48–58.

Mansfield, E., J. Rapoport, A. Romeo, S. Wagner, and G. Beardsley. "Social and Private Rates of Return from Industrial Innovations." *Quart. J. Econ.* 91(1977): 221–40.

McCarl, B. A., C.-C. Chang, and B. R. Eddleman. "Distortions of Public Agricultural Investment Incentives by Farm Programs: The Case of Agricultural Research." Texas Agriculture Experiment Station Tech. Pap., 1991.

McCarl, B. A., and T. H. Spreen. "Price Endogenous Mathematical Programming as a Tool for Sector Analysis." *Amer. J. Agr. Econ.* 62(1980):87–102.

Miller, G. Y., J. M. Rosenblatt, and L. J. Hushak. "The Effects of Supply Shifts on Producers' Surplus." *Amer. J. Agr. Econ.* 70(1988):886–91.

Miller, T., and G. Tolley. "Technology Adoption and Agricultural Price Policy." *Amer. J. Agr. Econ.* 71(1989):847–57.

Oehmke, J. F. "The Calculation of Returns to Research in Distorted Markets." *Agr. Econ.* 2(1988):291–302.

Ruttan, V. W. *Agricultural Research Policy.* Minneapolis: University of Minnesota Press, 1982.

Schmitz, A., and D. Seckler. "Mechanized Agriculture and Social Welfare: The Case of the Tomato Harvester." *Amer. J. Agr. Econ.* 52(1970):569–77.

Texas Agricultural Experiment Station. "Less Water-More Rice." *FACT Sheets Synopsis.* Soil Conservation Service, U.S. Department of Agriculture, and Texas Rice Research Foundation. Beaumont Research and Extension Center, 1987.

Texas Agricultural Extension Service. "1988 Rice Production Guideline." Pub. #D-1253, 1988.

U.S. Department of Agriculture. Agricultural Stabilization and Conservation Service. *1986 Division C Payment System: Compliance Report for the United States.* Special tabulation summary, December 1988.

———. *Agricultural Statistics, 1987.* Washington DC: U.S. Government Printing Office, 1987.

———. Cooperative State Research Service. *Inventory of*

Agricultural Research, Fiscal Year 1988. Washington DC, September 1989.
White, F. C., B. R. Eddleman, and J. C. Purcell. "Nature and Flow of Benefits from Ag-Food Research." Office of Technology Assessment, An Assessment of the U.S. Food and Agricultural System, Volume II—Commissioned Papers, Part C, April 1982.