GOVERNMENT POLICY AND TECHNICAL CHANGE:
AN ENDOGENOUS TECHNOLOGY STUDY
OF U.S. AGRICULTURE

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CHAPTER I

INTRODUCTION

Background

This research deals with the econometric estimation of supply and input demand elasticities. The use of an endogenous technology approach is this study's distinctive feature, and the implications for policy analysis of such estimates are its main concern. This first chapter will provide background information on the relevance of the study, anda detailed specification of the research objectives and organization.

The long-term problem of agriculture is its inability to clear, in the short run, the amount of resources available with those used in production. Following T.W. Schultz's (1953) definition, the farm problem is characterized by a trend of supply outgrowing demand and excess resources committed to agriculture need to be taken out. Studies by Heady, Haroldsen, Meyer and Tweeten (1965), Tweeten (1979, 1989), Hallberg (1989) indicate that agricultural adjustments are slow and easily disrupted by exogenous shocks. This lack of a quick resource adjustment is the cause of low returns and excess capacity in agriculture. Slow resource adjustment also is a reason for government intervention.

Technological change in agriculture has become both a solution and burden to the farm problem and to society's welfare. Cochrane's tread mill is a graphic image of the relationship between technical progress and agriculture's long-term problem. The increase in productivity achieved during the past half century, while providing low cost food stuffs, has added new pressures to balance productive resources in agriculture.

It is unclear if government policy has contributed to alleviating or aggravating the situation in agriculture; there are strong arguments on both sides. However, policy analysts must recognize the current trend to move away from government intervention. Therefore, it is necessary to sort out what is needed from what is accessory in agricultural policies.

Often, the analysis of agricultural policy implies looking into each of its components separately: income support, supply control, research policy, export enhancing mechanisms. Most studies ignore the links among the different components, although some of those links do have a significant impact. For example, research output affects the performance of income support or supply control programs; new technologies allow changes in the production function which in turn changes the quantity and kind of the resources used. On the other hand, income support or supply control programs might have an impact on speeding or slowing the adoption of new technology. Isolated evaluations of policies which are closely related are likely to render misleading results. The above calls for an integrated assessment of the effects of public policy.

Two major areas of government intervention have been supply control and disposal and scientific and technological research support. An apparent contradiction seems to exist between these two components, which is a matter of this research and is discussed later.

Most studies of these policies focus on only one of the two components, either supply control and disposal, or scientific and technological research support. Since the late 1960's, several studies by Houck, Ryan, Abel, Gallagher, Penn, Subotnik and others have focused on commodity programs and primarily investigated the expected price formulation induced by policy intervention. On the other hand, studies by Griliches (1958; 1963; 1964), Peterson (1967; 1971), Evenson (1967; 1968; 1974; 1984), Cline (1975), Huffman and Miranowski (1981), among many others, focus on the measures, determinants, and of the rate of return on public research policy. While both areas of research have produced significant contributions to the agricultural policy literature, there is a need for incorporating the interaction effects among different sets of policy mechanisms.

The work of Gardner (1988), Oehmke (1988), Oehmke and Yao (1990), and Oehmke and Chan Choe (1991) are the best, but yet incomplete, attempts to take into account the link between public research and commodity programs in agricultural policy evaluation. Oehmke and Yao's empirical study lacks consistency insofar as the elasticities' estimates used do not take into account the interaction between public research and income support or supply control policies.

From a different angle, studies by Alston, Edwards and Freebairn (1988), Lichtenberg and Zilberman (1986), Oehmke (1988), and de Gorter and Norton (1989), focus on farm programs' effects on benefits from research. The basic conclusion of these studies is that ignoring government policies overestimates benefits from research. De Gorter and Norton (1989) also argue that the overestimation is not significant.

The implications of the government policies in question, income support and public research, reach beyond the issue of economic efficiency. Rausser (1982) views public policy as a mixture of two types of policies. Policies whose primary objective is to improve economic efficiency, i.e., increase the size of the pie; and policies which objective is to redistribute wealth among social groups, i.e., allocate the portions of the pie.

These two types of policies, which Rausser calls PERT and PEST[1] respectively, reflect different and opposite ways to view public policy. The first type is the more traditional view which holds that government intervenes to overcome market failures. The basic assumption is that government is benign, and its intervention improves efficiency.

The second view, based on the public choice literature, considers that government policies are introduced to transfer wealth from one group in society to another. The government is viewed purely as a mechanism to transfer wealth. The government is not an autonomous neutral entity. Powerful interest groups seeking their own benefit manipulate public policies in their behalf. The policy process is then a competition among interest groups to dictate the design and implementation of government policies.

Rausser's joint approach to public policy not only avoids the two extremes positions, but provides a framework to integrate efficiency (welfare) and distributional issues as two sides of the same coin. PERT and PEST policies are inseparable and complementary in a policy decision.

Public policy is a mixture of PERT and PEST policies. The proportion of the mixture will depend on the way the intended government intervention net benefits (costs) are distributed among social groups, and on the relative political influence of each group. Efficiency outcomes of PERT policies do not have a neutral impact on wealth distribution. Therefore, PEST policies could be necessary to compensate losers. So PERT activities become not only applicable, but also Pareto optimal.

Consequently with Rausser's view, research policy is a PERT activity, whose the objective is to achieve a higher degree of efficiency and social

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[1] Rausser (1982) defines PERT and PEST as Political Economic Resource Transaction, and Political Economic-Seeking Transfer respectively.

welfare. Meanwhile, income support programs are PEST policies, whose basic objective is to transfer resources to producers in order to allow them to adopt the new technology available and fulfill society's goal.

Technical changes are possible if, and only if, new basic knowledge is produced and transformed into applied knowledge. Public research policy has made an important contribution to the productivity growth of American agriculture. Whereas, generating technologies that increase or maintain productivity levels, the contribution of public research has been significant. The complexities of generating and adopting new technologies will be addressed later.

Recent studies put public research rate of return estimates in a range from 31% (Ortiz and Norton,1990) to 202% (Smith, Norton and Havlicek, 1983)[2]. A recent study by Pray and Neumeyer (1990) suggests that public research stimulates private research.

As depicted by most economists, the farm problem is a production economics issue. Most agricultural products are own price inelastic and inferior goods. Also, the level of consumer satiation of food stuff is rapidly achieved. Moreover, export demand is not only a function of structural variables such as income and population; it also is greatly influenced by random events such as weather and third-country policies. Tweeten (1979), argues that there is not much to be done in the domestic demand structure; and due to the instability of export demand, researchers have to investigate the production side to uncover answers to the farm problem.

The relative sizes of the supply and input demand elasticities are

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[2] A complete set of estimates for different agricultural products can be found in IR-6 Information Report No. 90-1, "Economic Evaluation of Agricultural Research," May 1990. Report drafted by the subcommittee of the Technical Committee of Interregional Hatch Project 6 (IR-6).

indicators of the structural economic characteristics of agriculture. Given declining prices and the structure of demand described above, a low supply elasticity implies a low opportunity cost for fixed assets (fixed-resource assets) and a high cost of resource adjustment. Hence, the elasticity provides key information to determine the ability of production resources to adjust , as well as the expected relative cost of the adjustment.

Supply and input demand elasticities are derived from an optimization problem. The central element of that problem is the existence of a well behaved production function, or its dual, the cost function. Therefore, supply and input demand elasticities depend upon the characteristics and dynamics of the production function (cost function) which is the basic expression of the prevalent technology. As technologies are adopted by producers, the production function changes. Therefore, the supply and input demand elasticities also are likely to change. The continuous input substitution induced by the implementation of new techniques changes the degree of resource use response to market events. A new input mix represents a different degree of qualitative and quantitative resource adjustment.

As supply elasticities change due to technology innovation and other variables, the relative performance of a specific policy will also change. Under Rausser's (1982) Policy Preference Function framework, varying elasticity estimates will imply that the relative policy weight of the different interest or social groups will also change. Therefore, a time path describing the evolution of government policy preferences might be derived and used to improve the explanatory power of the model.

Depending on agriculture's supply and demand structure, consumers may receive a larger share of the benefits from research and technological change than producers. Another distributive consequence of technical change is that as production and productivity increase, the need for agricultural resource adjustment also increases. Farmers claims for government compensation depend on the structure of agricultural production and consumption. The social cost of farmers income-support programs need to be compared with the social benefits of research expenditures. This comparison would provide a consistent measure of the overall welfare impact of these agricultural policies.

Archibald's (1988) work incorporates externalities into the evaluation of productivity gains. Research activities and technological change create some externalities, including soil erosion, increases in soil salinity, diminished pests vulnerability to pesticides, and underground water contamination due to fertilizers use. Therefore, these byproducts of technological adoption also are social costs to research. Although the existence and importance of externalities are recognized, the present research has not dealt with it. This research is focused on the relationship between income support programs, public research policy and technology adoption.

Problem Statement

Agricultural support programs and research policy could be considered as two faces of the same policy. Synthesizing support and research policies in turn would allow integrating the analysis of two related issues. The first issue deals with the farm problem, as defined by T.W. Schultz (1953) and reflects the existence of what Cochrane (1958) called the myth of a self-adjusting or easy-adjusting agriculture. The second refers to the level of consumers' agricultural food prices.

Some economists consider government intervention to be the cause of the farm problem because it does not allow for agricultural markets to clear. They argue that removing all government intervention would result in the farm problem's automatic elimination. Among other things[3], this position does not assign the government any role in agriculture's technological development.

It is a popular belief that agricultural prices would be lower if agricultural price and income support policies were removed. In fact, the last one hundred years has seen a trend of diminishing consumer prices, which only altered during short periods of time. This trend has been feasible, in part, due to the adoption of new farm technology, which at large has benefited consumers. One view is that to make PERT policy feasible, society must compensate producers by easing the adjustment process while still adopting the new technologies. Moreover, in the absence of the compensating policies it could be argued that adoption may have been slower, and consequently consumers would not have benefited as much as they have.

To tackle the problem described above in a more consistent way, new supply and input demand elasticity estimates are necessary. Available producer-response parameters generally have been estimated without taking into account the synergism between government support policies and technological change. Therefore new estimates should incorporate the impact of technological change into the estimation process and thus link farm programs, public research policy, and technical change.

Research Objectives

The purpose of this research is to estimate producers-response

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[3] For a complete discussion of this issue, the reader is referred to the second chapter in Cochrane(1958).

parameters from a framework which encompasses the role of public policies such as farm programs and public research in the technology adoption process. The stydy's specific objectives are:

1. Assess the relative size of the net benefits to agriculture, and their distribution among farm and non-farm groups, from the policies described previously.

2. To develop supply elasticity functions useful to describe the changes in the elasticity parameters across time, due to the adoption of new technology.

3. To determine the characteristics of the interaction between farm programs and public research policy in fostering technical change.

4. To estimate an aggregate government Policy Preference Function for the agricultural sector.

Research Hypotheses

Achieving this dissertation objectives will test the following hypotheses:

1. Government policies have compensated producers in order to adopt new technologies, from which consumers have benefited.

2. Producer-support programs have stimulated technology adoption during periods of low farm income.

3. Technology adoption is positively related to export demand expansion.

4. Consumer agricultural prices would be higher in the absence of government intervention.

Some of the above hypotheses will be tested directly from the estimated coefficients in the econometric model. Others will be tested based on judgments made from results obtained on secondary estimations and/or calculations. Finally, some hypotheses will be tested on informal judgments based on trends of predicted or computed variables.

Organization of Study

This chapter introduced the dissertation's subject matter. Chapter II examines key concepts in policy analysis and technological change and reviews selected studies. Topics reviewed are applied welfare economics, endogenous technical change, and the economics of technical change.

The methodological foundations of the empirical model used are discussed in Chapter III. Chapter IV contains the specification of the empirical model and its empirical characteristics, the specification of the model variables, and their correspondent data sources. Chapter IV also discusses the identification of each model equation and the estimation procedure.

Chapter V examines the output of the estimation process and its statistical validation, as well as the derivation of the relevant producers' response parameters. The production-response parameters presented in Chapter V, will be used to estimate an aggregate policy preference function for the U.S. agricultural sector in Chapter VI. The dissertation ends with Chapter VII, which contains a summary of the study, its conclusions, and topics for further research.

CHAPTER II

THEORETICAL BACKGROUND AND LITERATURE REVIEW

The objective of this chapter is to present previous research and theoretical considerations on three major issues. The first issues is the use of applied welfare economics as a valid tool for policy analysis. A review of some relevant studies, their weaknesses and strengths, and recent developments regarding policy analysis will be discussed. The second major topic deals with the recent literature of simultaneous analysis of public research and farm programs. The most relevant research is evaluated in terms of its findings and shortcomings. Finally, this chapter looks at two key issues in the economics of technical change: the technology-generating process, and the adoption of new technology.

Welfare Economics and Agricultural Policy

Economists have made welfare economics their primary tool for policy analysis. Operationally, welfare analysis provides economists with an indicator of economic effects of alternative decisions. Applied welfare economics can guide policy-makers in evaluating actual policies in real markets, using available data and reasonable methods (Hallam,1988).

The agricultural policy analysis literature is rich in welfare studies on a variety of policy issues. Specifically, regarding welfare applications to farm programs, there is the work of T.D. Wallace (1962), in which he estimates the social cost of three characteristic and alternative farm policies; Cochrane's production quotas; Brannan price subsidies; and an input restriction to reduce agricultural output. Tweeten (1987) and Gardner (1987a) provide an analytical scheme to evaluate the welfare consequences of farm programs. Following the work of Peltzman (1976) and Becker (1983) regarding interest groups political influence, Gardner (1983,1987b) studied the efficiency of commodity programs as an income transfer mechanism.

Applied welfare economics concepts also have been used widely to measure benefits from research and compute the rates of return to research investments. Examples of these are the pioneer work of Griliches (1958) dealing with hybrid corn; Peterson's (1967) study on the poultry industry; Schmitz and Seckler's (1970) analysis of the tomato harvester; and Freebairn, Davis, and Edwards' (1982) study on the distribution of research benefits. The common denominator of these studies is their use of economic surplus to measure the benefits due to the adoption of new technology. These measures of economic surplus were constructed using either previous estimates or arbitrary values of the elasticity parameters.

As summarized by Just (1988), applied welfare economics faces three major obstacles. First, the failure of competitive equilibrium to achieve Pareto efficiency, especially in the case of incomplete risk markets and imperfect information. The second obstacle is the inability to make interpersonal comparisons, and the third, the separation of efficiency (economic) and equity (political) decisions.

Hart (1975) found that under the presence of incomplete markets, the usual continuity and convexity assumptions do not ensure the existence of an equilibrium. Moreover, if an equilibrium does exist it will not be fully Pareto optimal and consequently, applied welfare economics analysis would produce misleading results. However, Hallam (1988) argues that theoretical models can take care of stylized policies and market arrangements; therefore, the limitation of welfare economics is basically a problem of using imperfect but rigorous theory and implementable empirical methods. Innes and Rausser (1989) and Innes (1990) evaluated the same policies as Wallace (1962) but considered a stochastic production economy with incomplete markets in agriculture. These studies concluded that distributional and welfare implications might be reversed from competitive equilibrium.

Agriculture is characterized as an stochastic production economy; and contrary to the pure exchange case, no general theory of production behavior for the case when markets are incomplete has been developed (Hart,1975). Therefore, economic theory limitations constrain the ability of applied welfare economics to deal with agriculture's problems.

Diamond's (1980) study on the efficiency implications of uncertain supply provides some interesting results applicable to agriculture. Based on a production uncertainty framework, he found that where producers are risk averse and demand elasticity is different from one, suppliers do not maximize expected profits; instead, for any given price, they produce more in the low income state than they would if they were risk neutral. Whether they produce more relative to risk neutrality in the high or low output state depends on the elasticity of demand. In fact, an inelastic demand implies a higher production relative to risk neutrality in low output states. Diamond's results seems to reinforce the inelasticity of agricultural supply for low-income states, e.g. when downward production adjustments are needed.

When providing information for policy-makers, Buccola (1988) argues that is not possible to avoid judgements about interpersonal utility correspondences or desirable tradeoffs. Furthermore, economics lacks the objective means of making interpersonal comparisons (Just,1988). Therefore, in the absence of objective support for change, the ability of applied welfare economics to provide policy prescriptions is limited.

An important contribution of the public choice literature is to emphasize the fact that economists do not need to worry about making interpersonal comparisons. That is the responsibility of the actual decision makers.

Rausser's (1982) policy framework, described earlier, is based on three premises: a) political and economic markets are not separable; b) pure transfers do not exist; and c) this is a second best world. This framework is an indirect charge to policy analysts to expand their concerns beyond the concept of paretian efficiency.

Public choice emphasizes a positive role for economists in the policy decision process, contrary to the normative character of welfare economics. Buchanan (1988) strongly argues that the only positive role of economists is to diagnose social situations and present the choosing individuals a set of feasible changes. The policy proposed is then subject to a conceptual test, which takes the form of consensus. If a consensus towards the implementation of a policy is achieved, then a Pareto efficiency situation has been reached. The measure of "wellness" in this context, is not an improvement in an independently observable characteristic but rather on agreement among decision-makers. The economist's task is completed when he/she has shown the parties concerned the existence of gains from trade. The economist has no function in suggesting contract terms in the bargaining range itself (Buchanan, 1989).

Despite the abundant policy analysis research based on applied welfare economics and the policy advice derived from it, policy-makers continue to implement policies which apparently are contrary to welfare economics principles (Just,1988). One explanation is that policy-makers tend to focus on broader issues than economists do (Ray and Plaxico,1988). On this issue, Little (1957) states there is no part of well-being called economic well-being. The term economic qualifies the causes of well-being, therefore economic welfare concerns are limited to the economic basis of welfare, in other words, to the economic efficiency of alternative policies. The politicians' objective function emphasizes social and political issues, such as income distribution. The estimation of the distributional impacts of government policies, in and out of agriculture, within the farm sector, and between rich and poor farmers, is a challenge for welfare economics (Bigman, Newbery, and Zilberman, 1988).

Applied welfare economics is far from a trouble free approach. Despite its limitations, it continues to be the best available tool for policy analysis (Currie et.al.,1971; Harberger,1971; Bigman et.al.,1988; Hallam,1988).

Agricultural Research and Other Market Intervention Policies

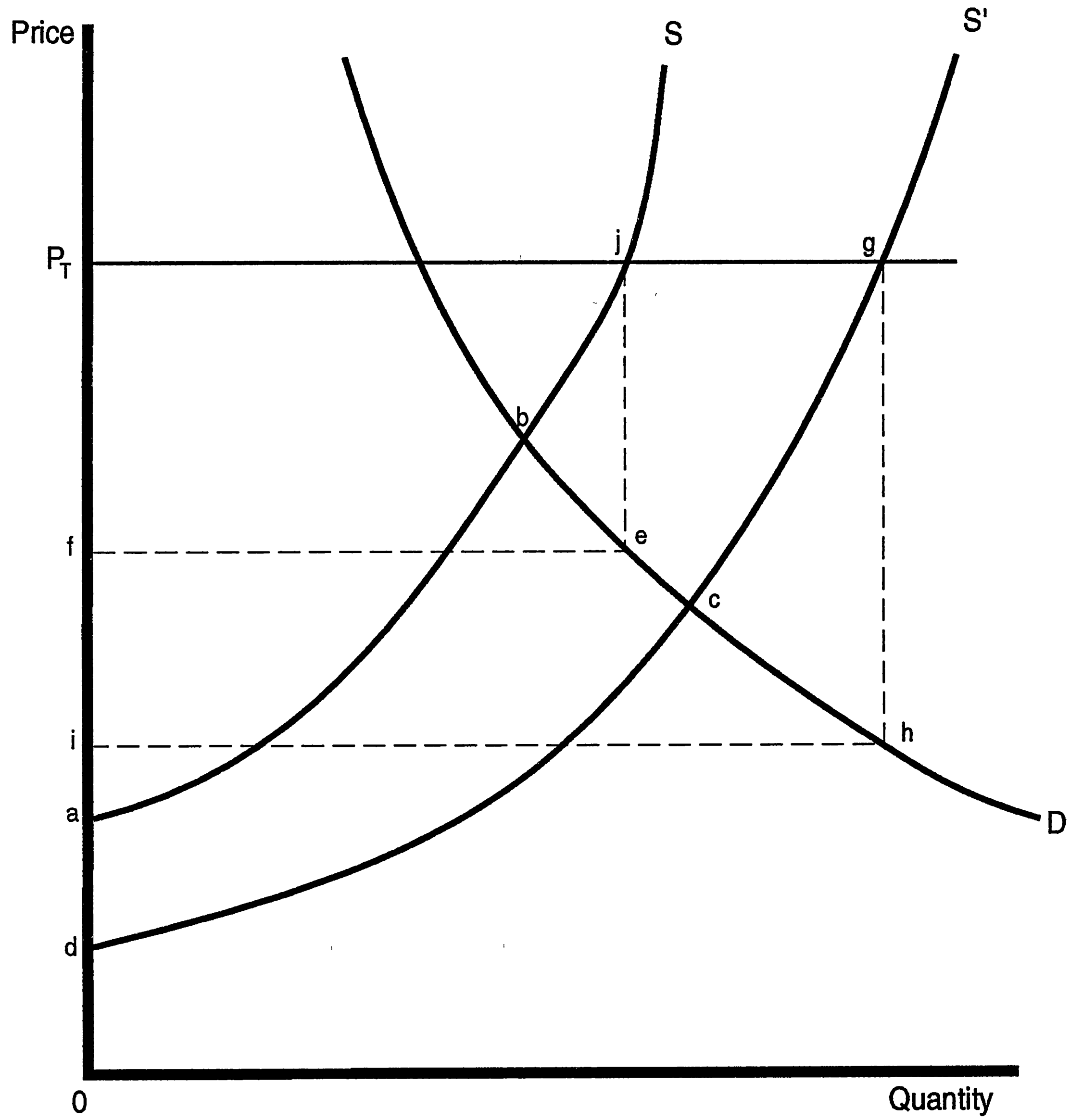
There are three groups of studies which have set the foundations for the simultaneous analysis of public research and government income support programs in agriculture. These are, first, the studies by Gardner (1987; 1988); second, the work of Alston, Edwards and Freebairn (1988); and finally, the research by Oehmke (1988), Oehmke and Yao (1990), and Oehmke and Chan Choe (1991). Although all three groups of studies are generally concerned with the appropriate determination of research benefits under government market intervention, it can be argued that the same methodologies can be applied for the simultaneous evaluation of public research and government support programs. This section will present the main features and conclusions of those studies as they relate to the objectives of this research.

Alston, Edwards, and Freebairn (1988)

Alston, Edwards, and Freebairn (1988) evaluated research benefits under government intervention as if public research was not a form of market intervention. From the several scenarios in Alston et. al, two are the most relevant for our purpose: the analysis of target prices with deficiency payments for nontraded goods, and the analysis of production subsidies for an export good. Alston's et. al study assumes that research causes a downward shift in the supply curve, and investment in research is exogenous, therefore independent of market distortions.

Let's look first to the case of target prices with deficiency payments for a nontraded good. In figure 1, D represents the domestic demand and *S* the supply of a nontraded good. On the price axis, P_T is a government fixed target price which is supported by deficiency payments. The effect of research (technology) is to shift S to S'. With no government intervention, benefits of research are given by *abcd*, which is the area beneath the demand curve and between the supply curves. With the introduction of the target price, P_T, producers' and consumers' benefits increase due to a higher quantity produced and a lower price. The amount of government payments increase due to the outward shift in the supply curve caused by the implementation of a successful public research program, from area P_Tjef to area P_Tghi.

Net benefits to research due to target price program are measured by subtracting the increase in government cost from the sum of benefits to



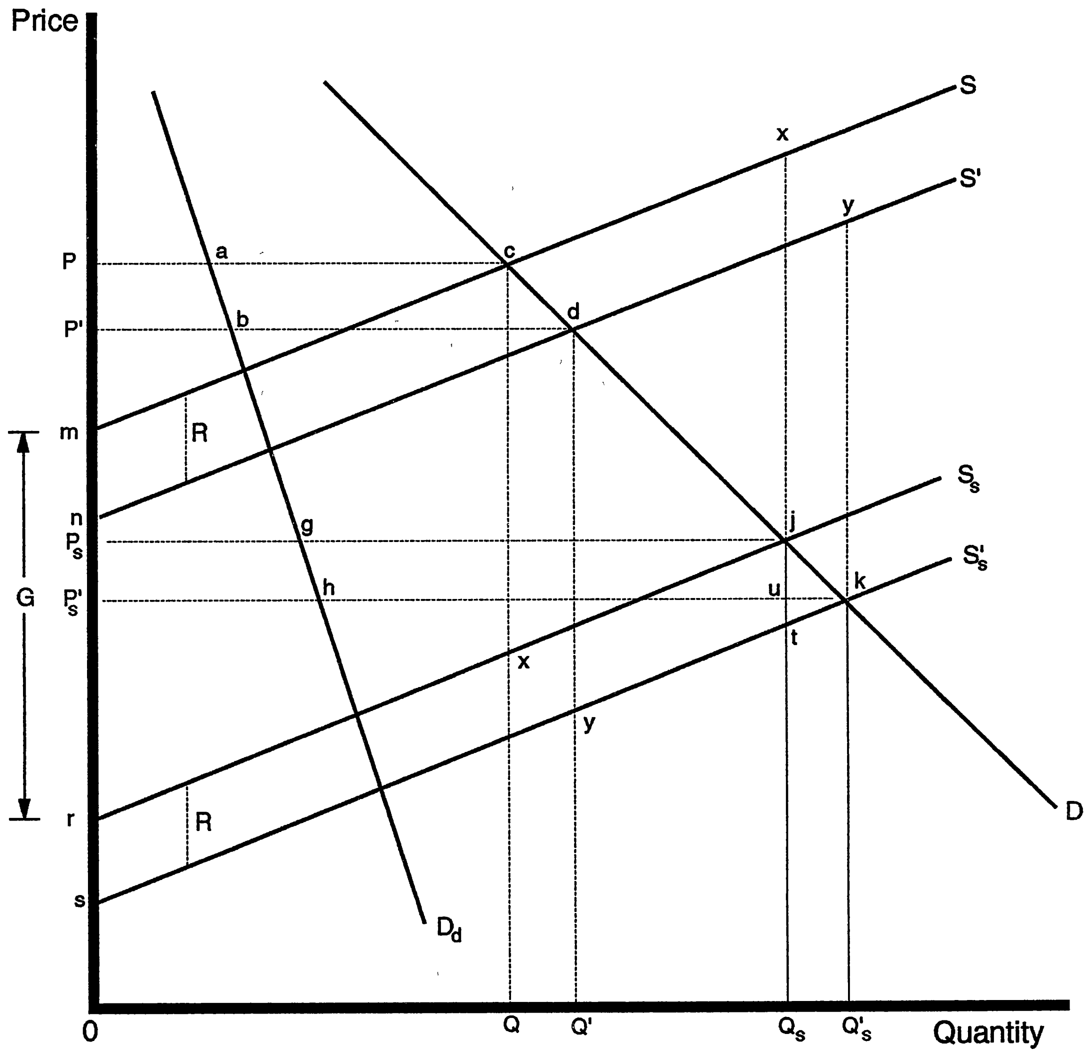
Source: Alston, Julian M., Geoff W. Edwards, and John W. Freebairn. 1988. "Market Distortions And Benefits From Research." American Journal of Agricultural Economics. 70:281-288.

Figure 1. Effects of a Target Price/Defficiency Payment Scheme on Research Benefits in a Closed Economy

producers and consumers. Research benefits decrease by the absolute value of the difference between area *bje* and area *cgh*, which are the social cost without research and with research respectively. Alston et al. conclude that this policy changes the distribution of research benefits and only affects net research benefits to the extent that the shift in supply changes the cost of the policy.

Figure 2 represents a production subsidy in an export product. In the same study, Alston et al., assumed that supply and demand curves are linear, and that shifts in the supply curve due to the producer's subsidy and research are parallel. Starting from a free-trade setting, the supply is given by S, domestic demand by D_d and total demand by D; P and Q are initial price and quantity. The supply curve shifts by R to S' due to research, the price falls to P' and the quantity rises to Q'. The effects are: domestic consumers surplus increases by area *PabP'*; domestic producers gains are equal to the sum of areas *mcfn* and *edf* minus *PceP'*; foreign consumers gain area *acdb*; the net world effect is a gain of area *mcdn*.

The government sets a production subsidy of*G* per unit. Then, by assumption, the supply shifts from S to S_s without research and from S' to S'_s with research. In this case domestic consumers' surplus gains due to research area $P_s ghP'_s$; domestic producers gains are given by area *rjts* plus *ukt* minus $P_s juP'_s$. Foreign consumers gain area *gjhk*. The gains for all, consumers and producers, are greater now than in the absence of the subsidy because the subsidy has generated a lower market price, and a larger quantity. On the other hand, the research-induced expansion of output increases government outlays by $G(Q'_s - Q_s)$, which represents the subsidy per unit times the increase in output. In this subsidy case, the extra benefits to producers and consumers due



Source: Alston, Julian M., Geoff W. Edwards, and John W. Freebairn. 1988. "Market Distortions And Benefits From Research." American Journal of Agricultural Economics. 70:281-288.

Figure 2. Effects of a Production Subsidy on Research Benefits in an Open Economy with Linear Curves and Parallel Supply Shifts

to research are equal to the extra government subsidy payment[4].

Therefore, for the case above the net world social cost is not affected by the subsidy. In fact, the excess production cost triangle under the production subsidy is the same without research (*cxj*) as with research (*dyk*). However, net domestic research benefits are lower with the subsidy because the increase in the government outlays is greater than the additional domestic gains; and it is equal to the increase in benefits in the rest of the world (area *gjkh* minus area *acdb*).

The study concludes that market intervention reduces benefits from research. However, the results are in part dependent on the linearity and parallel shifting assumptions. Moreover, the approach used in the study implies that market intervention has no impact on research effects, or government policy has no influence on technology adoption.

Gardner's 1987 and 1988 Studies

Gardner's research introduced the political analysis of government intervention into agricultural economics. In his 1987 study he looked at farm programs as efficient measures for income redistribution (Gardner,1987). In a later study he introduced the idea that research spending and market intervention must be analyzed simultaneously in a public choice context[5]. The basic idea in that paper is that price or income support programs, although sometimes inefficient means are necessary. They are necessary to increase social economic welfare when research by itself is politically infeasible, as in

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[4] This is a simple consequence of the assumptions of linearity and parallel shift. For a formal presentation see footnote 5 in Alston, Edwards, and Freebairn (1988).

[5] Gardner, Bruce. "Price Supports and Optimal Agricultural Research." Working Paper #88-1. Department of Agricultural and Resource Economics, University of Maryland. January, 1988.

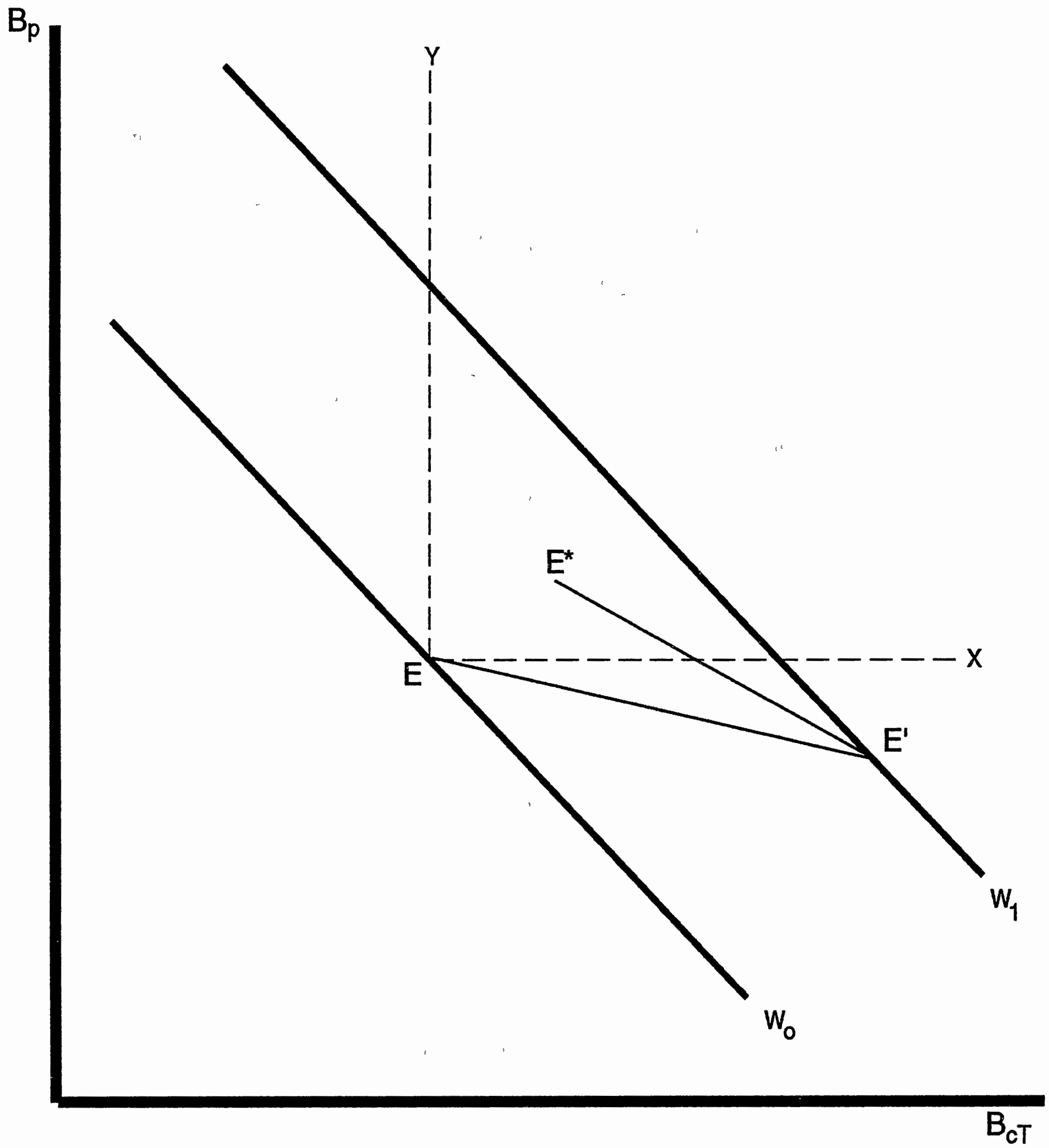
the case where research yields gains for consumers at producers' expense.

Let's follow Gardner's example of two interest groups: consumer-taxpayers and producers. For the first group, the benefits generated by research and price supports are higher consumer surplus' and lower government budgetary costs represented by B_{CT}; the benefits for the second group, producers, is given by B_P which represents the level of producers' surplus. Social Welfare, W, is the algebraic sum of B_{CT} and B_P, and it is represented by:

$$W = B_{CT} + B_P \qquad (2.1)$$

In figure 3, the no-intervention (no public research, no market intervention) situation generates a reference level of benefits, E, over the line W_o. Appropriately measured, research would be beneficial if the sum of B_{CT} and B_P increases, or if a new point at the northeast of E is achieved. The dotted lines intersecting in E show the current welfare level of each group. Points below EX imply relative losses for producers, while points above EX indicate gains. Similarly, points at the left of EY indicate lower surplus for consumers, while points to the right imply a larger surplus.

If research spending yields a point E', over $W_1 > W_o$; it implies gains for consumers but losses for producers. Political pressures might not allow this to happen. If income or price supports simultaneously are introduced, then point E^* can be reached and , $E^* > E'$. Moreover both groups are better off in E^* than in E, so there will be gains for the move and it also will be a feasible situation. However, E^* is inside the constant-sum-if surplus-line W_1, therefore it implies deadweight losses, which come from the inefficiencies of the income or price support program.



Source: Gardner, Bruce. 1988. "Price Supports and Optimal Agricultural Research." Working Paper #88-1. Department of Agricultural and Resource Economics. University of Maryland.

Figure 3. Distributional Effects of Technological Change

Three political settings are compared. The first case implies equal weights across states for consumers and producers surpluses. The second assumes equal weights at the no-research state, but weights the heaviest the one who looses in the research state; in this way it will generate compensating policies. The third case weights producers surpluses the heaviest across states. The first case is used as a reference to compare results of the other two. Case two is the most likely to occur, and its implications are described below.

The above is consistent with the following representation of the social welfare function:

$$W = B_{CT} + qB_P \text{ , } q > 0 \qquad (2.2)$$

where q represents the weight of producers benefits relative to consumers and taxpayers benefits.

Gardner found that for the cases in which the effect of research is a reduction in producers' surplus, research adoption is likely to be retarded; although price support programs partially offset this effect. The above occurs if producers' surplus is weighted heavier than or equal to consumers' at the no-research state, but heavier at the research state. Regarding support programs, Gardner's findings show that, the closer they are to lump-sum transfers, the likely they are to take research spending closer to the optimal. Furthermore, the less elastic is the supply, the redistributing efficiency of price support is greater. Consequently price supports are more conducive to research if the supply is inelastic.

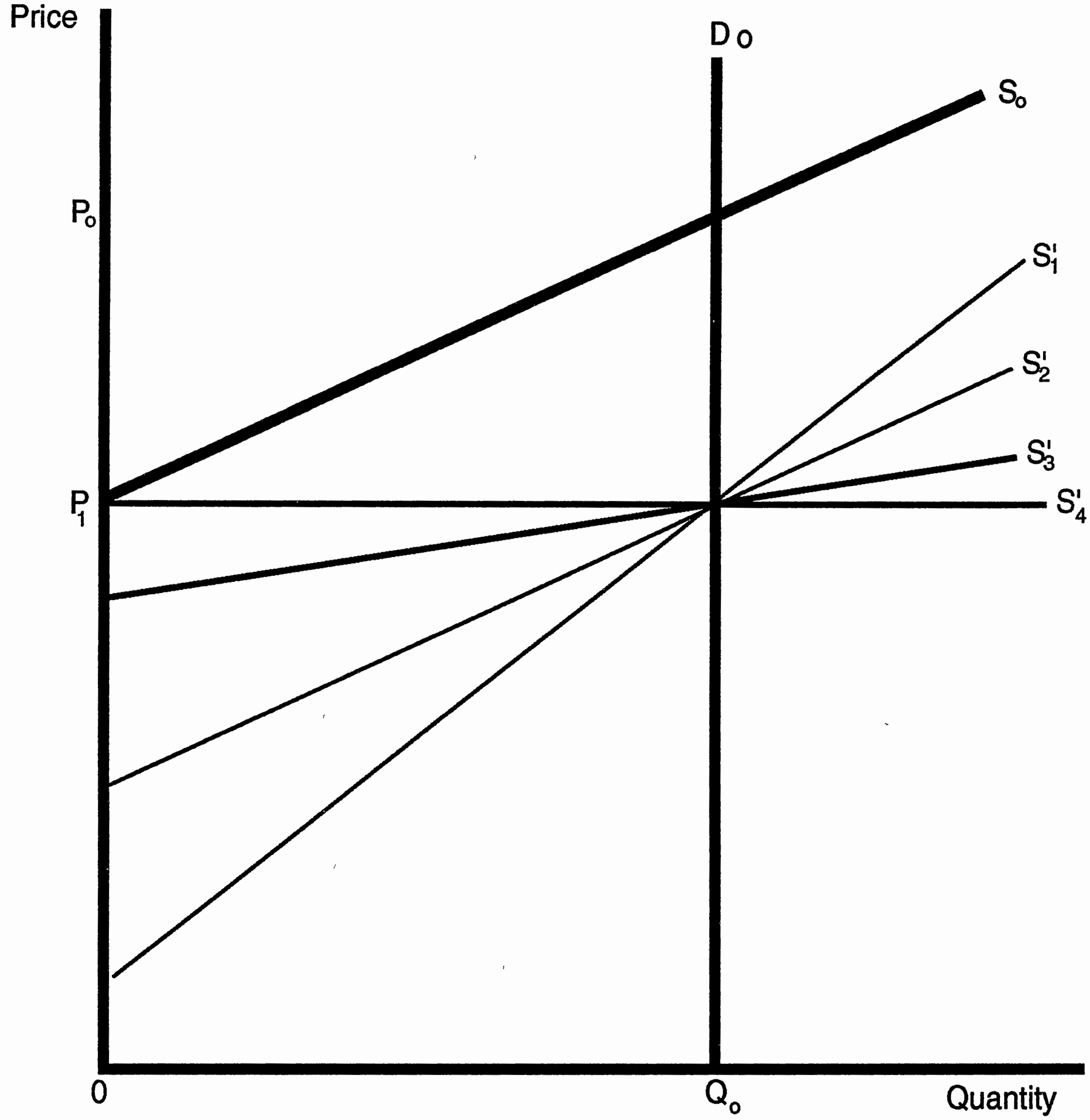
Regarding to the impact of the supply function shift on research benefits, the paper by Lindner and Jarrett (1978) explains that the benefits from research depend upon the kind of shift of the supply function. This dependence becomes evident in figure 4, where benefits from research are represented by the area to the left of the infinitely inelastic demand, and between the original supply curve S and the set of research influenced supply curves are represented by S'_1, S'_2, S'_3 and S'_4. Clearly, the size of research benefits is determined not only by the size of the shift but also by the kind of shift, whether parallel, convergent, divergent, etc.

Gardner's (1988) study calls attention to the fact that for agricultural policy analysis, agricultural supply response to price is expected to be inelastic, and that the quantity supplied is expected to fall to zero before the price falls to zero. That is, production ceases when variable costs exceed revenues. For the analysis of support programs the lack of the second characteristic can be solved safely by a linear local approximation. However, when evaluating research benefits, the problem that arises is the same described earlier by Lindner and Jarrett. Notice that in figure 4, the size of research benefits is greatly influenced by the change in the minimum price required to acquire the good produced, which is what Gardner calls the "choke price", or plainly the intercept on the price axis.

The "choke price" can be used as an indicator of the inframarginal effects of technological change in costs. In cases where the number of firms which adopt a technical innovation is larger and the more homogeneous firms are, the "choke price" will shift the most. For this case, the shift in the supply will approach a parallel shift.

<u>Oehmke's studies</u>

Oehmke (1988) shows if the effects of government market interventions are not adequately accounted for, the estimation of



Source: Lindner, R.K. and F.G. Jarrett. 1978. "Supply Shifts and the Size of Research Benefits." American Journal of Agricultural Economics. 60:48-58.

Figure 4. Type of Supply Shift and Research Benefits

rates of return (RORs) to research will be affected significantly. The RORs undertaken in period t=0 is defined to be r=1/ß -1, where ß solves:

$$\sum_{t=0}^{\infty}\beta^t\left(\frac{\partial PS_t}{\partial R_0}+\frac{\partial CS_t}{\partial R_0}-\frac{\partial G_t}{\partial R_0}\right)=0 \tag{2.3}$$

where, PS is producers' surplus, CS is consumers' surplus, G is government expenditures, R is research expenditures, and t is the time parameter.

Equation (2.3) underlines the sensitivity of RORs to the empirical specification of the supply and demand equations. If one of these functions is misspecified then RORs for research will be biased. Also from the same equation, notice the sensitivity of RORs to the definition of the government costs. Are government outlays due to market intervention a part of research cost? Successful research will induce an outward shift on the supply function. Under existing government market intervention, the cost of intervention for taxpayers will increase, even to the point where social benefits after research are negative.

This dissertation addresses the estimation of a supply function consistent with the interaction of public research programs and government income-support programs. By considering both type of policies as part of a single policy issue, this dissertation looks to address the issues described in the above paragraph.

What are the effects of market distortions on RORs? Oehmke provides the answer considering a special case of (2.3). First, assume that research is the only exogenous change in the model; it occurs only at time t=0 and has an immediate response. These assumptions imply that $dPS_t/dR_0=dPS_s/dR_0$ for s, t≥0, similarly for the consumers' surplus term. The following also holds true,

$dG_o/dR_o = dG_t/dR_o + 1$, for $t \geq 1$. Then (2.3) becomes:

$$\left(\frac{\partial PS_t}{\partial R_0} + \frac{\partial CS_t}{\partial R_0} - \frac{\partial G_t}{\partial R_0}\right)\left(\sum_{t=0}^{\infty} \beta^t\right) - 1 = 0 \tag{2.4}$$

when $|\beta|<1$, the second bracketed expression, equals $1/(1-\beta)$. By substituting $1/(1+r)$ for β the ROR is given by:

$$r = \frac{\frac{\partial PS}{\partial R_0} + \frac{\partial CS}{\partial R_0} - \frac{\partial G}{\partial R_0}}{1 - \left(\frac{\partial PS}{\partial R_0} + \frac{\partial CS}{\partial R_0} - \frac{\partial G}{\partial R_0}\right)} \tag{2.5}$$

for

$$\left[1 - \left(\frac{\partial PS}{\partial R_0} + \frac{\partial CS}{\partial R_0} - \frac{\partial G}{\partial R_0}\right)\right] \rangle 0$$

From (2.5) it is apparent that r is decreasing in dG/dR_o, which implies that if research costs increase, ceteris paribus, then ROR to research falls. Now consider that if research induces the supply to shift outward, then the government cost of market intervention will increase. If the cost increase of market intervention is attributed to research, then dG/dR_o increases relatively in a situation where only direct costs of research are considered. Therefore, accounting for the increase in the government cost of market intervention lowers the ROR of research and consequently, the traditional RORs reported in the literature are biased upward[6].

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[6] The interpretation of dG/dRo is independent of the assumptions used to derive (3). Oehmke (1988), pp.293-294.

The key of Oehmke's analysis is the interpretation of dG/dR_o. If dG/dR_o is underestimated, then the ROR will be overestimated. The increases in the cost due to the research-induced supply shift should be included as part of the research program's total cost in order to attempt the estimation of the true ROR.

Oehmke's study addresses the issue of interaction between public research programs and market intervention in the determination of the true cost of research. However, the study does not directly allow for the possibility that existing forms of government market intervention might play a role in the research program's success i.e., adoption of the new technology.

A different perspective is taken in a study by Oehmke and Yao (1990). As in Gardner's 1987 study, they base their work on the theory of interest groups and considered the joint analysis of public research spending and farm programs as part of the same political issue. Their objective was to estimate a policy preference function consistent with the government policy choices in the wheat sector. They found that government places an 80% premium on wheat producers' surplus relative to consumers'; and consumers' surplus is valued at 50% of the value of budget savings. These weights were found to be consistent with actual levels of government support and public research expenditures. The study also supports the view that, government provides funding for research mainly because increases consumers' economic welfare. These funds are limited by the costs of producers' support programs.

Oehmke and Chan Choe (1991) follow on the previous Oehmke and Yao (1990) research. One purpose of this study is to estimate the parameters of a government objective function to determine if agricultural policies, target price, and public research can be explained as the result of a bargaining process among producers, taxpayers and consumers. A second objective and major contribution of this paper is to relate the relative importance of each group in the goverment policy preference function, to the political environment and the characteristics of these groups.

To accomplish the second task, Oehmke and Chan Choe assumed that the relative weights of each group in the government's policy preference function are random variables generated by the political process. Analysis of Variance (ANOVA) and regression methods were used to test if in fact the policy weights of each group are likely to be drawn from the same distribution. The research tested for cross-crop, trend, and election year changes in the estimated weights. Tests results were related to each group's characteristics. The empirical evidence found did not provide strong support that changes on relative weights occur under the three above-mentioned hypotheses.

For a consistent utilization of applied welfare economics in the analysis of public research and farm programs, a policy analyst should estimate output supply and input demand functions incorporating the impacts of agricultural policy. Production parameters need to be related to policy variables. The estimation approach should account for policy variables induced market equilibrium changes through their impact of market equilibrium conditions; and policy variables induced changes in production structure through changes in available technology and in patterns of innovation.

Endogenous Technical Change

According to Chambers (1988), specific advantages, such as analytical and econometric tractability, and the fact that technical change occurs over time have motivated the widespread use of a *time* term in the production function as a measure of technical change. This measure obviously is a passive approach which attempts to quantify technical change without explaining it. This approach tends to *perpetuate the naive assumptions that (a) producers are unable to compute optimal solutions even when they know the true functional specification of nonstochastic production technologies, and (b) changes in aggregate technology remain invariant to changes in exogenous economic variables* [7]

Alternative approaches are Hick's (1963) induced innovation hypothesis and the work of Mundalk and others on endogenous technical change. Hicks premise is that technological change is a response to changes in relative factor prices. Most of the empirical studies on the induced innovation hypothesis do not specify factor prices as determinants of factor biases. Instead factor bias measures are calculated on the basis of time trends; these measures are compared then with movements in factor prices to test for induced innovation (Frisvold, 1991). Frisvold (1991) defines a model, in which the process of technical change is endogenous, to specifically test for the induced innovation hypothesis. In Frisvold's study, the factor bias is defined as a function of the government's objective function, the total research budget, current prices, and a time trend.

Recent work within the endogenous technical change framework has attempted to develop a conceptual base which could simultaneously relate the technology adoption process to production decisions and vice versa (Mundlak,1988;1988a;1984). Another set of studies has advanced the statistical methods to endogenize technical change: Bassman, Hayes, Slottje, and Molina,1987; Mundlak,1988; Swamy, Lupo, and Sneed, 1989; Fawson, Shumway, and Bassman, 1990. There is a third group of research which has applied this framework to specific policy analysis cases: Mundlak and

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[7] Fawson, Shumway, and Bassman (1990), pp. 182.

Hellinghausen, 1982 (a multicountry case study); Cavallo and Mundlak, 1982 (Argentina); Coeymans and Mundlak, 1987 (Chile); Mundlak, Cavallo, and Domenech, 1989 (Argentina); McGuirk and Mundlak, 1991 (Punjab)[8]. Most of the empirical work dealing with endogenous technology has used some type of Cobb-Douglas functional form.

The basic idea of the endogenous technical change approach is the need to account for systematic and random variations of the economic parameters when analyzing and estimating production and cost functions and technical relationships. The existence of these variations -- technical state of the art, factor prices, weather, and others -- are known to producers and, to a certain extent, endogenous to the economic maximization process of producers. Consequently, these variations influence producers' production and cost functions.

Marschak and Andrews (1944) were the first to introduce the notion of production coefficients depending on *the technical knowledge, the will, effort, and luck of a given entrepreneur in a given year, as can be summarized in the concept 'technical efficiency'*. [9] This notion led Marschak and Andrews to develop an alternative empirical model for the Cobb-Douglas production function, consistent with random production coefficients. In their model the parameters a_1 and a_2, elasticities of output with respect to inputs X_1 and X_2, are assumed to be time and firm-to-firm invariant; only the coefficient A_o is regarded as dependent on *technical efficiency*. The alternative production function model is summarized by:

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8 At the time this research was developed, the only application to the U.S. agriculture was provided by Fawson, Shumway, and Bassman (1990); and Fawson and Shumway (1991); both studies look to provide support for the endogenous technology framework. Neither can be regarded as a policy application.

9 Marshak and Andrews (1944), pp. 145 and 156.

$$Y_{of} = A_{of} + a_1X_{1f} + a_2X_{2f} \quad (2.6)$$

where Y_o, X_1 and X_2 stand for the natural log of the physical quantities of output and any two inputs, respectively. The subscript f indicates a particular firm and year. The parameters a_1 and a_2 also were assumed fixed only due to limitations on the statistical tools available[10].

Later, Mundlak and Hoch (1965) and Zellner, Kmenta and Dreze (1966) argue that in estimating parameters of a stochastic Cobb-Douglas production function, statistical methods are very sensitive to the specification of the behavior of the disturbance term. The specification of the disturbance is directly associated with two key assumptions; (i) a non-deterministic production function, and (ii) producers have full knowledge of the stochastic character of the production function[11]. The traditional Cobb-Douglas approach is based on a deterministic, profit-maximizing behavior.

The endogeneity of technology in the two studies above is associated with the transmission of the disturbances of the production function to inputs. This transmission implies that the independent variables and the disturbances are not independent. This dependency raises the issue of simultaneity, and therefore of endogeneity in the production parameters.

The most comprehensive endogenous technology conceptual framework was developed by Mundlak (1988)[12]. The starting point is the differentiation between technology (T) and implemented technology (IT). Technology is defined as the collection of possible techniques, described as:

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10 Marschak ans Andrews (1944), pp.159-160.

11 These assumptions belong to the Zellner et. al study. However can also be incorporated to the Mundlak and Hoch research.

12 The discussion of Mundlak's endogenous technology approach is based on Mundlak (1988a; 1988b) and McGurik and Mundlak (1981)

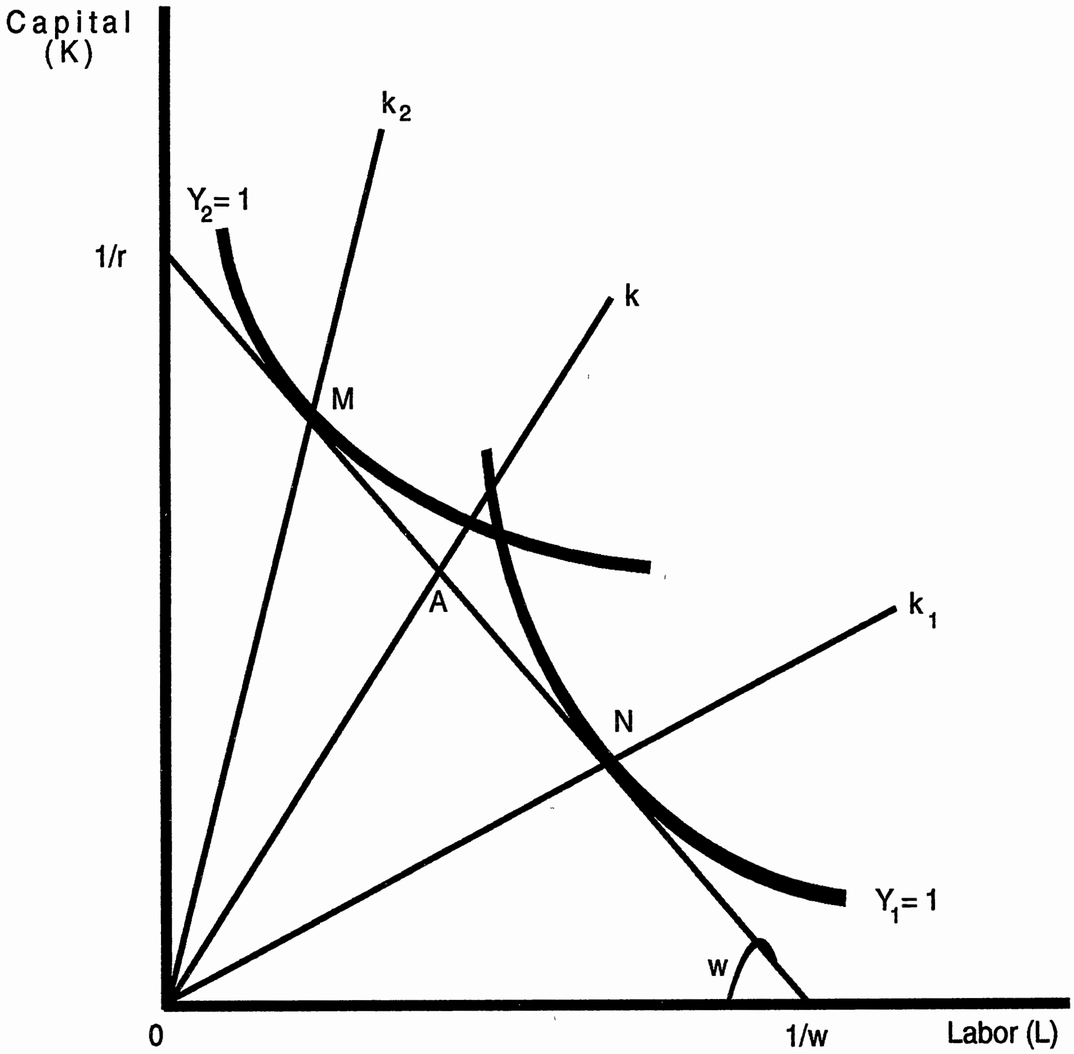
$$T = \{F_j(x)\} \tag{2.7}$$

where $F_j(x)$ is the production function associated with the j^{th} technique. A production function is a microeconomic concept which describes a specific technique. Under the regular assumptions, a production function is associated with a convex input requirement set. Therefore, T defines a convex input requirement defined by the input requirement set of the individual techniques. Within this framework, technical change is defined as a change in T.

Implemented technology is defined as the set of all techniques actually implemented. This definition implies the existence of constraints which limit the input requirement set of T, in a manner in which IT is defined as a subset of T. These concepts are illustrated in figure 5.

Assuming one output (Y) and two inputs in agriculture, capital (K) and labor (L), technology is the collection of two techniques Y_1 and Y_2, and its input requirement is bounded from below by its isoquant. In figure 5, w_o is the slope of the isocost line tangent to Y_1 and Y_2, the unit isoquants of the two technologies. Let k be the actual capital-labor ratio, and k_1 and k_2 the threshold capital-labor ratios corresponding to w_o. For $k \geq k_2$, the capital-intensive technique is used exclusively and the isoquant associated with T is identical with $Y_2=1$. For $k \leq k_1$, only the labor intensive-technique is used and the relevant isoquant is the same as $Y_1=1$. Finally, for $k_1 \leq k \geq k_2$, both techniques are used, and the input requirement set is bounded by the segment MN over the isocost line. The difference between the convex input requirement set of T and IT is then apparent, and it also is apparent that more than both techniques can coexist.

If, as shown in figure 5, several (at least two) techniques can coexist, then it is evident that an empirical production function does not necessary recognize



Source: Mundlak, Yair. 1988. "Capital Accumulation, The Choice Of Techniques, and Agricultural Output." In Agricultural Price Policy for Developing Countries. Edited by John W. Mellor and Raisuddin Ahmed. The John Hopkins University Press.

Figure 5. Choice of Technique

the existence of more than technique. Also, from the above discussion it is clear that the estimated production function will depend on the distribution of prices and resource constraints existing before and after the introduction of a new technique, therefore the identification of the constraining factor becomes key in obtaining a full description of the production process.

The choice of technique is made at the firm level. The corresponding optimization problem considers the maximization of the lagrangian:

$$L = \sum_i p_i F_i(v_i, b_i, E) - \sum_i w_i v_i + \lambda(b - \sum_i b_i) \tag{2.8}$$

such that $F_i()$ belongs to the set of available technology (T); v and b are variable and fixed inputs respectively; E represents the relevant characteristics of the economic environment in which technique i is implemented; p_i is the price of the product of technique i; w is the vector of factor prices; and b is the constraint on Σb_i.

The Khun-Tucker necessary conditions for a solution are:

$$L_{vi} = p_i F_{vi} - w_i \leq 0 \tag{2.9}$$

$$L_{bi} = p_i Fb_i - \lambda \leq 0 \tag{2.10}$$

$$\sum_i (L_{vi} v_i + L_{bi} b_i) = 0 \tag{2.11}$$

$$v_i \geq 0, \; b_i \geq 0 \tag{2.12}$$

$$L_\lambda = \sum_i b_i - b \leq 0 \qquad (2.13)$$

$$\lambda L_\lambda = 0 \qquad (2.14)$$

where L_{bi}, L_{vi}, F_{vi}, Fb_i, and L_λ are vectors of the first partial derivatives. The solution can be described as:

$$v^*_i(s),\ b^*_i(s),\ \lambda^*_i(s),$$

The problem's exogenous variables are represented by s. A most important task in this framework is the appropriate identification of the factors constraining the adoption of the implemented techniques (b). Notice that (b) not only represents constraints, but it also represents factors which might favorably induce rather than retard technology adoption. The set of "positive" and "negative" constraints will be referred as the state variables (s):

$$s=(b,p,w,E,T) \qquad (2.15)$$

The choice of techniques and the level of their use is determined jointly. The number of techniques depend on a finite number of constraints (b). Available technology (T), environment (E), constraints (b), and the product and variable inputs prices determine the techniques to be used. Meanwhile, their level of use is determined by the optimal allocation of variable inputs (v^*_i) and fixed inputs (b^*_i). Consequently equations (2.9), (2.10) and (2.11) can be rearrange as follow:

$$\sum_i (p_iF_{vi}-w_i)v_i + \sum_i (p_iF_{bi}-\lambda)b_i = 0 \qquad (2.16)$$

If equation (2.9) or equation (2.10) is negative, the marginal cost is greater than the value of the marginal product and then $v^*_i=0$ or correspondingly $b^*_i=0$.

The optimal output of technique i is $y^*_i=F_i(v^*_i,b^*_i,E)$. As presented earlier, the implemented technology (IT) is the set of all implemented techniques, and is a subset of T.

The implemented technology, IT, can be described by:

$$IT(b,p,w,E,T) = \{F_i(v_i,b_i,E) | F_i(v^*_i ,b^*_i,E) > 0, F_i e T\}. \qquad (2.17)$$

Given the usual regularity conditions for F_i and for any set of state variables, equation (2.17) describes a well-behaved technology. Consequently, a profit function can be derived:

$$\pi(s) = \Sigma p_iF_i(v^*_i(s),b^*_i(s),E) - \Sigma w_iv^*_i(s). \qquad (2.18)$$

The various theorems dealing with the duality between profit and production functions hold true though conditional on s. The frontier of IT(s) is dual to $\pi(s)$ and vice versa[13]. By Hotelling's lemma, factor demand at the technique level, $v^*_i(s)$ is given by:

$$-\frac{\partial \pi(s)}{\partial w} = v^*_i(s) \qquad (2.19)$$

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13 It is important to note that the exploitation of this property in empirical analysis is limited by the fact that s varies over the sample. Thus, strictly speaking, each point in the sample comes from a different profit function, which in turn describes a different set of implemented technology.

The aggregate input demands is given by $v^*(s)=\Sigma v^*_i(s)$. Similarly the supply of output of technique i is given by:

$$\frac{\partial \pi(s)}{\partial p_i} = y^*_i(s) \qquad (2.20)$$

If there is more than technique producing a given crop, then

$$\frac{\partial \pi(s)}{\partial p_j} = \Sigma_i y^*_{ij} = y^*_j \qquad (2.21)$$

where $y^*_{ij}$is the i^{th} technique used to produce the j^{th} crop and y^*_j is the total output of crop j. Finally, the aggregate value of supply is given by:

$$y^*(s) = \Sigma p_j y^*_j(s) \qquad (2.22)$$

A most important feature of this approach is that a change in a state variable brings about two joint and simultaneous effects. The first may lead to variations in the optimal combinations of inputs along a given production function. Next, it causes $F(x^*,s)$ to vary. For example, changes in prices generate not only variations in inputs and outputs, but a different set of implemented functions too.

Economics of Technical Change in Agriculture

There are three aspects on the economics of technical change which are of special interest to this research:

1. The process of generating new technologies.

2. The rationality of the adoption of new technologies by farmers.

3. The influence of public policy in technology adoption.

Most of the economic literature looks at the innovation process as a private, profit seeking enterprise. The theory of "induced innovation", which has been developed as a theory of the firm, argues that firms will generate innovations driven by the economy's resource endowment, the relative price of factors, changes in product demand, and the firm's research productivity and research costs (Binswanger,1974; Ruttan and Hayami,1988). Griliches (1957, 1979) argued that the decision of the technology-producing firm is influenced by the market size, marketing cost, the research and development cost, the expected rate of acceptance of the innovation, and the overall performance on the "consumer" industry. An additional element driving firm-level inventive activity is the degree to which inventing firms can enjoy the expected benefits from the innovation (Pakes and Schankerman,1984). However, according to Bosworth and Westaway (1984), although high profits increase the incentive to innovate, they also can restrict and/or delay the availability of new technology until profits from existing technologies disappear or become relatively small.

Despite the ample literature regarding the contribution of public research to agricultural output and its high rates of returns (Griliches,1958; Evenson,1967; Peterson,1967,1971; Cline,1975; Evenson, Waggoner and Ruttan,1979; Knutson and Tweeten,1979) little attention has been given to the determinants of the demand for public research. Guttman (1978) considered public agricultural research as an imperfect public good and used a model of political interest groups to explain state allocations to agricultural research in the United States. This model viewed farmers and producers of agricultural inputs as the demanders of agricultural research. He hypothesized that demand of agricultural research is a function of farmer education, the research level in bordering states, farmer sales levels, full or partial ownership of land, the number of farmers producing other commodities, the size of industry producing agro-chemical inputs, farm cooperative membership, and the overall state budget.

Huffman and Miranowski (1981), developed a model of resource allocation for state-produced research at agricultural experiment stations. This model included supply and demand equations for research, an equation for allocating state revenues to station research, and an equilibrium equation in the form of expenditure identity. To emphasize the effects of local environmental factors, and the limitations of borrowed research, Huffman and Miranowski developed the model in terms of indigenously applied agricultural research[14]. The demand is hypothesized to be a function of the size and other characteristics of the state farm output, agricultural input prices, farmer education, the use of extension services, agricultural research in other states, and the price on indigenous applied research. The influence of farm interest groups on the demand for public research is captured in a behavioral equation which allocates state government revenue to agricultural research as a function of farm size distribution, tenure status, the entrepreneurial activity of the State Agricultural Experiment Station director, amount of state government revenue, farm organization membership, and past expenditures for applied agricultural research.

Rose-Ackerman and Evenson (1985) expand that analysis to include the effects of federal grants. They studied the effects of reapportionment of state

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[14] For practical purposes indigenously applied agricultural research, is the same as the most general concept of agricultural research. It is assumed that demand and supply of agricultural research are structurally defined by indigenous elements, such as the environment and production patterns.

legislatures mandated by U.S. Supreme Court, and they considered that the overall importance of farming to a state, in terms of income and population, measures farmers' political influence and partially determines research expenditures patterns. The study explicitly differentiates between research and extension spending. While research expenditures are expected to get the support of relatively large and wealthy farmers, extension expenditures are expected to be supported by small and low-ncome producers. Which group support research or extension budgets the most is a matter of who benefits the most from each class of expenditure.

The public research studies above may have downplayed the importance of farm product consumers as beneficiaries and demanders of agricultural research. In their study, Rose-Ackerman and Evenson argue that the impact of agricultural state production on total supply is not large enough to affect prices. Therefore, state consumers have little incentive to pressure for higher research budgets. However, there are two factors which might have been overlooked: the long run expansion of supply due to interstate competition and spillover effects of state research; and the importance and implications of federal matching funds for state agricultural research budgets[15]. These two elements support the case for reconsidering consumer benefits as an additional determinant of public agricultural research, even at the state level.

The implementation of new techniques depends not only on the set of techniques available to the firm in a specific period of time, but also on the interaction of several other elements, such as variable input prices or ratio of prices; the latter is the key element in Hicks (1932) and also the focus of the induced innovation hypothesis (Ruttan and Hayami, 1988). Induced innovation

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[15] As every dollar of federal money must generally be matched by one dollar of state funding, it implies that only 20% of extension dollars are freely allocated by states over and above the required matching share (Rose-Ackerman and Evenson, pp.6).

considers that the ratio of input prices largely is determined by the factor endowment of the country or region. Therefore, the implemented techniques will reflect bias towards the relative abundant factor.

New technologies bring with them fixed investments, either in the form of capital or human assets. The developing literature considers fixed costs as one of the key factors explaining adoption patterns (Feder et al.,1985). The size of the firm budget for fixed inputs, along with the investment requirements of the new technique, will influence the implementation decision. The budget for fixed resources can be considered to be an investment budget whose size depends on the rate of capital accumulation. Mundlak (1988b) hypothesized that the rate of adoption depends on the rate of capital accumulation. The firm's investment budget, completely defined, should include not only owned resources, but credit resources available to the firm as well. Therefore, the budget constraint might shift outward to the right if the firm improves its access to borrowed funds. Consequently, the overall situation in the financial market in terms of the supply and demand of funds, as well as the corresponding interest rates, may have a significant influence in the rate of technology adoption, as is suggested by Feder,et al.(1985).

Besides the above microeconomic factors, Griliches (1957) found empirical evidence supporting the hypothesis that the rate of adoption, what Griliches called rate of acceptance, depends on the superiority of new technology over traditional technology. He used two measures for comparing corn HYV (High Yield Variety) and open pollinated varieties: the average increase in yield in bushels per acre, and the long-run average pre-hybrid yield of corn.

Regarding investments in human capital, empirical studies (Griliches, 1957,1964; Cline, 1975; Knutson and Tweeten,1979) have shown the significance of education and information in the adoption of technologies, in that education and information act as proxies for investments in human capital. Evenson (1984, 1988) reported that extension services or adult education are substitutes for formal schooling.

The developing agriculture literature expands the analysis to account for the adoption of new technology under risk, due to output and price uncertainty. Just, Zilberman and Rausser (1980) analyzed the impact of farmer wealth, the degree of risk aversion, and the relative riskiness of new technologies with respect to traditional techniques. These factors were characterized as barriers which inhibit the adoption of new techniques. Just and Zilberman (1983) suggest that risk attitudes and the distributional characteristics of returns per unit of land under traditional and modern technologies play a key role in determining the role of farm size in technology adoption. When dealing with risk and uncertainty, Feder, Just and Zilberman (1985), found that farmer exposure to new technology plays a key role in forming their subjective probabilities, hence the importance of the availability of information and education variables for the adoption decision.

Given the logic behind the firm's adoption of new techniques, the way in which public policy can influence the rate of adoption depends on their effectiveness in influencing the variables that induce firms to chose between techniques. Specific public policy mechanisms can alter the ratio of input prices, the expectation for future output prices, and the riskiness of agricultural technologies and investments, thereby influencing the adoption decision.

The literature dealing with this topic comes mostly from research on agriculture development and is focused on the distributional effects of technology, (Feder and Gehrson,1985; Just and Zilberman,1988; Miller and Tolley,1989). Aside of Teigen's simulation work (1988), there is a lack of research analyzing the impact of U.S. agricultural polices on the rate of technology adoption.

Just and Zilberman (1985) develop a model for the U.S. which translates the difference in resource constraints and farm characteristics into markets effects, allowing the derivation of income distribution effects as measured by certainty equivalent measures. The study develops a classification of four farm regimes, according to the different constraints -- land quantity and quality, credit availability, and human characteristics -- faced by farmers. These regimes, or classes, are technologically lagging farms, highly leveraged farms, risk diversifiers, and specialized modern farms. The study hypothesizes that agricultural policies affect both the distribution of farms among classes and the response with in each class. Therefore aggregate response will depend on the predominant class or regime and on the characteristic response to a specific policy of that regime.

General Evaluation of Selected Work

The previous research documents the background for three key issues in this research: the policy analysis framework upon which this research is based , the endogenous technical approach, and the main economic issues of technical change in agriculture.

The first body of literature supports the relevance of applied classical welfare economics as a method for evaluating social effects of public policies. It also provides guidelines to overcome the shortcomings of welfare economics when dealing with equity and distributional effects and subjective interpersonal comparisons. Finally, based on Rausser's theoretical contribution, a policy preference function (PPF) is hypothesized to be an empirical, tractable representation of the relative weights assigned by policy makers to the different interests affected by the implemented public policy.

The previous studies dealing with the simultaneous analysis of public research and producers' support policies support applied welfare economics as a valid tool; but their findings are restricted by the short comings in the modeling of the supply relationship. The common constraint of previous studies is the use of supply functions and elasticities which have been estimated without allowing for interaction between public research programs and direct government intervention. This synergism is precisely the issue this dissertation intends to address.

Regarding the evolution of the endogenous technology approach, a complete model developed by Mundlak was used to illustrate the approach. In general the endogenous technology approach implies that variables besides input and output physical quantities called state variables, as well as constraints, do have a key role on production function and producer response estimation.

Finally, the main variables influencing the supply (generation) and demand (adoption) of new technologies were reviewed. From the literature reviewed, it is clear the importance of public policy in the generation and adoption of new technologies. Becauseit is difficult from private firms to approriate benefits from invention in agriculture, the role of public-supported research becomes evident. Consequently, the demand for research responds to private and public factors, the latter being the result of the political and economic bargaining process between farmers, agribusinesses, and consumers.

In the next chapter, the production economics methodological issues will be developed to provide the foundation for specifying an empirical model to estimate technology-response coefficients and supply elasticities. The single most important feature of the model will be its ability to integrate public policy effects and technological change.

CHAPTER III

PRODUCERS' RESPONSE, FUNCTIONAL FORM AND ENDOGENOUS TECHNICAL CHANGE

The purpose of this chapter is to present a production economics framework for the analysis and later estimation of producer response parameters considering the impact of technological change and of government policies. In achieving this objective two broad methods available to estimate production-response parameters, mathematical programing and econometric techniques, will be discussed. The emphasis will be to evaluate overall advantages and disadvantages, as well as theoretical support for the estimates and the most common obstacles in their empirical application.

The second section of this chapter presents the steps to specify empirical production functions. A major issue is the analysis of the implications of the characteristics of the production function and the restrictions that they imply. Another important issue is the linkage between the functional form of the production fucntion and the consistency of the corresponding response parameters.

The next section looks at the hypothesis of endogenous technical change and its relevance for producer response analysis. The most relevant research will be presented and evaluated, considering the objectives of this research.

Finally, the chapter ends by integrating the previous topics and providing a consistent theoretical framework suitable for the analysis of the effects of government policies and technological change on producer' response.

In the context of this research, the term producer' response refers primarily to the output supply elasticity. However, it also is of great interest to look at the ample set of economic parameters used to measure the change in producers behavior due to changes in exogenous and/or policy variables: production elasticities, technical change bias indicators, elasticities or marginal rate of substitution, productivity elasticities, factor demand elasticities, supply elasticity, and elasticities of output with respect to a set of variables which are called technology shifters. Each of these parameters, as well as the technology shifter variables will be defined properly as the discussion progresses.

Methodologies to Estimate Producer Response Elasticities

Given that price policies are the most frequent way in which governments intervene in agriculture, methodological and empirical issues of output supply and factor demand elasticities have always been an important part of the literature. Because of its importance, there is a large amount of research on this topic and a great diversity in the supply response estimates. This diversity mainly is due to differences in the methods employed, time periods analized, the levelof aggregation used, the explanatory variables considered, and the source and quality of the data utilized.

From all the factors mentioned above, methodological differences are at center stage. The existence of several alternative methodologies immediately suggests that each methodology has advantages and disadvantages, and the application of each one will depend of the specifics of the problem studied.

There are several published studies which have summarized the state of the arts in supply response estimation[16]. From those studies, it can be considered that there are two broad type of methodologies to estimate supply response: econometric methods estimation and mathematical programming methods. Each methodology has its own merits. This discussion will start by examining at the mathematical programming method which is the most flexible, but less popular method.

Mathematical Programming Method

The mathematical programming method also is known as RFA, or reference farm approach (Sharples,1969). RFA implies building and estimating a linear model to describe the production system of each of a number of reference farms. Each production system specifies a set of linear, additive production functions for every production outcome feasible to each firm, given the restrictions on productive resources (Colman,1983). By iteratively solving the system for several sets of prices under the condition that the objective function (e.g. profit maximization) is being optimized, supply-price relationships can be traced out for each commodity and reference farm. Although no functional relationship is obtained from maximizing the model, a function can be fitted through each of the price and output pairs estimated through the iterative solution of the model.

The most important advantage of a programing model is its flexibility to account for almost every economic and institutional factor affecting the farm

[16] For a complete review of this issue see Askari, H. and Cummings, J.T. (1976,1977); Colman, D. (1983); and Rastegary-Henneberry,S. and Tweeten, L.G. (1991).

production system. This flexibility allows for the optimal quantity to be related to all product and input prices, allowing in this way the estimation of all production "effects,"[17] a luxury not enjoyed by econometric estimation methods.

Given the flexibility of a mathematical programing model, the way in which a government intervention variable can be modeled offers far more advantages than such in modeling econometric models. Given that representative farms are the objects being modeled, it is possible to introduce a sufficiently large and explicit number of activities to account for almost any specific details involved in a farm program. Also, because there is no need for a consistent and large set of time series observations, the changing nature of farm programs is not a problem that the RFA approach can not handle. If the set of representative farms have been carefully selected an aggregate impact of government intervention can be estimated by aggregating individual impacts.

One of this approach biggest challenges comes from the fact that it is a data-intensive method and consequently its effectiveness relies first of all on data availability and quality. Although large amounts of data are needed, they can be verified with the help from field or extension agents, and by producers. The existence of large and up-to-date farm budget generators provides in most cases with a reliable source of information to this kind of models.

Together with the advantages described above come the disadvantages of a mathematical programing model. The first level of difficulties are at the modeling stage. Determining the reference farms and defining the activities and constraints are complex tasks, especially if the model is to avoid aggregation bias and consistency with economic theory at the farm and aggregate levels

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[17] As suggested by Colman(1983), the word "effects" instead of parameters. This is to account for the fact that the estimated relationships are not likely to be smooth or continuos, therefore would not be possible to summarize them in any single parameter.

(Colman,1983). When trying to account for technical change, all feasible production function points must be specified completely as alternative activities and their correspondent restrictions. New data requirements to model technical change and non-linear functions, as well as to provide continous feedback to the model after each optimal outcome and before the next iteration is computed, add additional complications to this approach. In short:

> *the demands on data and research manpower required to solve all the problems attendant in developing such a complete and complex supply model as the RFA model lead this writer to the conclusion that a short-cut solution is desirable for most problems.*[18]

This quote from Colman summarizes the potential and complexity of the mathematical programing methods. Keeping in mind this method's advantages and disadvantages, let us turn now to discuss the econometric methods to estimate supply response.

Econometric Methods

According to Colman (1983), and Rastegari-Henneberry and Tweeten (1991), there is a diversity of ways in which supply response can be estimated using econometric methods. The distinct character in econometric estimation, is the origin of the function or model to be estimated, and if the supply elasticity is being estimated directly or computed through indirectly from input demand coefficients. These issues are treated explicitly in Colman, and in Rastegari-Hennberry and Tweeten. They evaluate the different econometric specification

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[18] Colman,1983, p.216

and estimation methods on their theoretical, statistical and empirical merits to produce consistent and reliable supply parameters. That said, the following is a brief discussion of the merits of three alternative econometric approaches: direct estimation, duality, and indirect estimation.

Direct Estimation Method

The most popular method, direct estimation implies the specification of an adhoc supply model, to which data is fitted to obtain estimates for the parameters of a function and, therefore, for the supply elasticity. While output quantity, or acres, are used as the dependent variable, output and input prices are used as explanatory variables. Thi method's appeal of this method is its simplicity in terms of data requirements and estimation procedures. Whether a single equation or a simultaneous equation approach is used, this direct estimation is characterized and criticized by the weak theoretical relationship between the specified supply function and the underlying production economics theory. The theoretical support for the model to be estimated is of an ad hoc nature.

This technique is more appropriate when the objective is forecasting short run production levels instead of estimating structural parameters (Colman,1983). Another advantage of this approach is its ability to generate immediate response estimates from relatively simple resources. The weak linkage to production economics theory is by far its most serious drawback.

Duality Method.

The duality method is based upon the "dual" solution to both profit maximization and cost minimization problems, which are the indirect profit function and the indirect cost function, respectively. More precisely duality,

> *refers to the existence, under appropriate regularity conditions, of "dual functions" which embody the same essential information on ...*

technology as familiar primal functions...Dual functions describe the results of optimizing responses to input and output prices and constraints rather than global responses to input and output quantities as in the corresponding primal functions.[19]

The dual approach attractiveness comes from the well-known results of the Envelope Theorem. The first result, also known as Hotelling's Lemma, establishes that by partially differentiating the indirect profit function with respect to output and input prices, the output supply and factor demands are obtained. The second result known as Shephard's Lemma indicates that by taking the partial derivatives of the indirect cost function with respect to input prices the conditional (Hicksian) input demand functions are obtained.

There are two main advantages of duality. First is its algebraic simplicity, which allows it to handle more complex functional forms and in turn implies less restrictions on the estimated equations.

A reason for the increasing popularity of duality in applied economic analysis is that it allows greater flexibility in the specification of factor demand and output supply response equations and permits a very close relationship between economic theory and practice. [20]

Secondly, the indirect profit function allows for the simultaneous determination of supply and input demand, reduced-form equations as functions of exogenous variables. Therefore, the simultaneous equation estimation bias can be avoided (Lau and Yotopoulos, 1972). Moreover, because the input demands and output supply functions are derived from profit

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[19] Young et al,1987, p. 3
[20] Lopez, 1982, p. 353

or cost functions, the assumptions of profit maximization, cost minimization, and competitive markets are assured (Rastegari and Tweeten, 1991).

Like other methods to estimate producer responses, the dual approach has its disadvantages. Rastegari and Tweeten (1991), state this approach is best suited for microeconomic-firm level studies, and applications to aggregate level data render questionable results. From the studies discussed in Rastegari and Tweeten, the ones estimating elasticities with the dual method gave the largest short-run elasticities for the majority of the products whose elasticities were estimated by various methods.

Factor Shares or Indirect Estimation

Another method to estimate supply-response parameters is estimating cost factor shares and, from them deriving the desired parameters. Because this method implies estimating response parameters from factor shares, this is an indirect method of estimation. This method and the one previously reviewed are the most traditional approaches for estimating response parameters.

The factor shares method primarily is associated with a production function of the Cobb-Douglas form (C-D). For the C-D production function, the first-order conditions for the profit maximization problem provide production elasticities (C-D parameters) which are, under competitive equilibrium, equal to the factor shares. Therefore, as suggested by Klein (1953), the C-D production fucntion parameters can be obtained directly from expenditures and revenue data, which in general is readily available.

Given the maintained hypothesis of competitive equilibrium, and the structural characteristics of the agricultural sector the one to one correspondence between factor shares and production elasticitiies can only occur in the long run. Therefore, direct implementation of this method will imply that the estimated parameters are long-run response coefficients. To address this issue, Tyner and Tweeten (1967) introduced a methodology which allows for short-run disequilibrium of the production elasticities, consequently to differ from the actual factors shares. Estimates of supply elasticity are based on a weighted average of the input elasticity with respect to output price. The weights in this estimate are the production elasticities, defined as the elasticity of output with respect to each input (Griliches, 1959).

This method produces estimates within a background consistent with production theory. The theoretical underpinnings are as strong as the duality approach, although with more restrictive assumptions, given its relationship with the Cobb-Douglas production function. The main general disadvantage is the relationship with the Cobb-Douglas production function. Also, Rastegari and Tweeten (1991), pointed out that if prices are incorrectly defined, this method may overestimate the true supply elasticities. Furthermore, Tweeten and Quance (1969) argued that the elasticity estimates coming from this method are primarily related to increasing farm prices, because fixity of assets tend to reduce the supply elasticity applicable to falling farm prices .[21] Notice that supply elasticities are estimated based on resources adjustments (input response to output prices, and elasticities of production). Supply elasticities tend to be reduced in periods of decreasing farm prices (Tweeten and Quance, 1969). Despite of these disadvantages, it will be shown later that this method has characteristics which make it appealing under an endogenous technology approach.

A general limitation of all regression methods, is the limited number of time series observations usually available to researchers. The number of

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[21] Tweeten,L. and L. Quance (1969), p.351.

observations must be greater than the number of independent variables; the greater the difference, or degrees of freedom, the better. This issue is closely related to the limited number of cross-price effects that can be represented. Another limiting assumption is that the parameters are non-stochastic, which could be acceptable for a relatively short period of time (again putting pressure on the degrees of freedom). However, despite all of the above *"it is a technique which has shown itself capable of generating acceptable and useful results."*[22]

When technical change is considered in the econometric approaches, it usually is represented with a trend variable and by considering the intercept as a measure of disembodied technical change. When government intervention variables are considered, it is by using the policy variables defined by Houck and his collaborators. These policy variables address the issue of the relevant price for producers as a short-run response, but do not measure the effect of government policy influence on technological/investment decisions. This lack of flexibility to incorporate technical change and the interrelationship with government policy, can be overcome partiallywith appropriate modeling.

Functional Form Choice in Applied Production Economics

The choice of functional form for the production function is at the heart of applied production analysis. The choice of functional form implies a choice in the set of maintained hypothesis and restrictions that will be carried through the empirical research. Once the model has been specified, classical statistical tests are conducted only under the hypothesis that the model is true, and the

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[22] Colman, 1983, p.224

conclusions drawn are only valid within the confines of that model (Chambers, 1988, p. 159). The set of assumed maintained hypothesis and the set of restrictions implied, are very closely related to the concept of flexibility.

The plausibility of empirical results will depend on the appropriateness of the functional form to the problem being studied. This is the obvious and most important principle to keep in mind, that functional form should relate to the objectives of the analysis. Besides this obvious criterion, Fuss, McFadden and Mundlak (1978) proposed a set of criteria which may be considering when selecting a functional form:

1. Parsimony in parameters: The functional form should contain no more parameters than those needed for consistency of the maintained hypothesis. A large number of parameters usually brings about potential multicollinearity problems and implies a loss of degrees of freedom.

2. Ease of interpretation: Complex (rich in parameters) functional forms may contain unreasonable implications which are not easily detected. The more intuitive the economic interpretation of the parameters the more desirable a functional form is.

3. Computational ease: The tradeoff between the computational requirements of a linear in parameters functional form should be carefully measure weighed against the thoroughness of the empirical analysis. Current advances in computation tools allow, if needed, for the cost effective use of relationships which are non-linear in the parameters.

4. Interpolative robustness: Within the relevant sample, the functional form should show a behavior consistent with economic theory.

5. Extrapolative robustness: When the objective is to produce forecasts, the behavior of the functional form outside the range of observed data should be compatible with economic theory and with the maintained hypothesis.

To the most important issue of flexibility, consider the classification, offered by Fuss, et al. (1978) of the relevant economic effects of interest to applied production analysis. Their quantification in terms of first and second derivatives is presented in TABLE.1.

The table includes (n+1)(n+2)/2 distinct economic effects, which characterizes the usual comparative statics properties of a production function at a given point. To determine the function value at a point in terms of economic effects, those formulas can be solved for first and second partial derivatives,

$$f = y \tag{3.1}$$

$$f_i = \mu y s_i / x_i \tag{3.2}$$

$$f_{ii} = \mu y s_i \varepsilon_i / x_i^2 \tag{3.3}$$

$$f_{ij} = \left[\sigma_{ij}(s_i + s_j) + \varepsilon_i s_i + \varepsilon_j s_j\right]\mu y / 2x_i x_j \tag{3.4}$$

Consequently, *"a necessary and sufficient condition for a functional form to reproduce comparative statics effects at a point without imposing restrictions across these effects is that it have (n+1)(n+2)/2 distinct parameters.*[23] From these results it can be confirmed that the traditional linear homogeneous Cobb-Douglas only allows for n+1 distinct parameters. Consequently, it can hardly be called a flexible functional form. In contrast, and assuming non-homogeneity, the Generalized Leontief, Translog, and Quadratic functional forms allow for (n+1)(n+2)/2 distinct parameters, therefore are true flexible functional forms.[24]

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23 Fuss, McFadden, Mundlak,1982, p. 231

24 For a complete discussion on the properties of these and other functional forms refer to Chambers (1988, pp. 160-181), and Fuss, McFadden and Mundlak (1978, pp.230-240).

TABLE 1

CLASSIFICATION OF PRODUCTION ECONOMIC EFFECTS

ECONOMIC EFFECT	FORMULA	NUMBER OF DISTINCT EFFECTS
Output level	$y = f(x)$	1
Returns to scale	$\mu = \left(\sum_{i=1}^{n} x_i f_i \right) / f_i$	1
Distributive share	$s_i = x_i f_i / \sum_{j=1}^{n} x_j f_j$	n - 1
Own "price" elasticity	$\varepsilon_i = x_i f_{ii} / f_i$	n
Elasticity of Substitution	$\sigma_{ij} = \dfrac{-f_{ii} / f_i^2 + 2(f_{ij} / f_i f_j) - f_{jj} / f_j^2}{1 / x_i f_i + 1 / x_j f_j}$	$\dfrac{n(n-1)}{2}$

Source: Fuss, Melvyn, Daniel McFadden, and Yair Mundlak. 1978. "A Survey of Functional Forms in the Economic Analysis of Production." In Production Economics: A Dual Approach to Theory and Applications. Volume 1. Melvyn Fuss and Daniel McFadden editors. North Holland. p.231.

Although flexibility is a desirable characteristic of functional forms in applied economics, it does not come without caveats. First, flexibility implies few restrictions on parameters but limits the range of technologies that can be characterized. This limitation comes from the fact that flexible functional forms are algebraically too complex to be analyzed as primal, so a dual formulation almost always is used. However, *"fundamental duality results imply that any specification of a cost or profit function places some restrictions on the technology..., these (flexible) functions appear to be more limiting that originally expected."* [25] A further problem arises with generalized quadratic forms because these functions are very inflexible in representing separable technologies. Consequently, it can be concluded that flexible functional forms are preferred to traditional less flexible functions such as the original Cobb-Douglas and CES -- not because their ability to closely approximate arbitrary technologies, but because of the far fewer restrictions they place on estimation.

There is no panacea in applied production economics, as is generally the case in any other branch of applied economics. There is a set of desirable properties with known advantages and disadvantages, and the researcher must weight the tradeoffs. The analysis's objective ultimately is the researcher's guiding force in selecting the specific functional form. In summary, *"choosing a functional form is more a craft than a science."*[26]

For the estimation of supply elasticities, the literature highly values those estimation approaches in which the contribution of production economic theory is significant, e.g. duality or primal models. To maintain consistency, it should be also expected, that when estimating production functions, the functional form

[25] Chambers, 1988, p.173.
[26] Chambers, 1978, p. 159.

which adequately incorporates technology also should be consistent with producers' optimizing behavior. That is, it must provide a sound basis to estimate input demand and supply elasticities.

The above can be better illustrated with the following example. For an engineer to build a house (supply function), he must be sure that the foundation (economic theory, production function) is strong enough to support it. On the other hand, when building the foundation (estimating production function parameters) he must be sure that there is a house design (supply and input demand functions) which corresponds to it. Otherwise, the foundation will have no use, and building foundations is not an objective itself.

The economic literature has plenty of estimates of production functions which do not necessarily allow for the consistent development, estimation or computation of producers behavioral functions. This issue is of particular importance in the case of flexible forms and when employing endogenous technology approach; as it will be shown in the next section.

Endogenous Technical Change and Functional Form

For Mundlak (1988), technical change is defined as a change in the collection of all techniques available to producers. A technique can be defined as a unique input arrangement available to producers which if implemented allows for the production of one unit of a predetermined output. Each technique is represented by a production function. This definition of technique implies that there are two sets of techniques: the set of techniques available, and the set of implemented techniques. The latter is a subset of the former. The emergence of new techniques as a result of scientific and applied research activities implies a change in technology. However, producers following the relevant set of prices and technology shifter variables will determine which subset is implemented. This implemented technology is the subset for which actual evidence exists and which has concrete implications in the level of real production of agricultural goods.

The methodological objective is twofold. The first, is provide a mean to account for the set of all the techniques available. The second, is to develop a model which simultaneously accounts for the set of implemented techniques. Thinking in dynamic terms, the task is to integrate the continuos generation of new knowledge and/or techniques (technological change), with the economic process of adopting new techniques by producers.

Consider the following real-valued function to be a production fucntion satisfying all regularity conditions:

$$y = f(x;\theta) \tag{3.5}$$

where y is the maximum amount of output to be produced from any given set of inputs x and where q represents the vector of all its parameters. Also, consider that each parameter is a function of technology shifter variables γ_i :

$$\theta_i = f(\gamma_1, \gamma_2, \gamma_3, \ldots, \gamma_k) \tag{3.6}$$

Then it can be concluded that the implemented technology is endogenous to the model in the sense that it depends on the set of state variables (Mundlak, 1988). The implemented technology is determined jointly by set of all available techniques (supply of technology) and by the set of state variables. Moreover, under the induced innovation hypothesis it also can be argued that the available technology is endogenous to the extent in which the relevant prices are considered in the set of state or technology shifter variables. Moreover, Danin and Mundlak (1979) showed that capital accumulation results in the employment of capital-intensive techniques, and that the introduction of capital-intensive techniques requires capital accumulation.

Based on the model (3.5)-(3.6), define a set of parameters which will be used to extract information regarding the technical change process is defined. First, consider the elasticities of production with respect to the technology shifters ($\theta_{\gamma k}$), which provide information about the response on total output due to a change in a technology shifter:

$$\theta_{\gamma,k} = \frac{\partial y}{\partial \gamma_k} \frac{\gamma_k}{y} \tag{3.7}$$

Next consider the elasticities of the marginal rate of technical substitution ($\delta_{i,\gamma k}$) suggested by Basmann, Hayes and Slottje (1987). These parameters are defined as:

$$\delta_{n,i,\gamma k} = \frac{\gamma_k}{\frac{y_i}{y_j}} \frac{\partial \frac{\partial y_i}{\partial y_j}}{\partial \gamma_k} \tag{3.8}$$

These parameters indicate the change in the marginal rate of substitution between two inputs given a change in a technology shifter. In other words, these elasticities provide information about the pairwise input variation.

In the general case, the elasticities shown in (3.7) and (3.8), as well as the regular production elasticities would be variable and dependent on input quantities and prices.

Later in this research, it will be evident that this endogenous technical change approach, provides a powerful analytical tool for the impact of government policies on technical change. It is also useful in estimating the effects of technical change and government intervention in supply response parameters.

From the review of literature regarding endogenous technical change in the previous chapter, recall that most studies have dealt with the estimation of a production relationship to draw conclusions regarding the nature of the structure and change of technologies. Fawson, Shumway, and Bassmann (1990), distinguish themselves for the work done in estimating the "unusual" aggregate Marshallian uncompensated factor demand elasticities for the northeastern states. Although no previous empirical work on Marshallian uncompensated elasticities was found, their results in terms of cross-price effects seems to be consistent with existing research. Notice that the cross-price definitions given by this type of elasticities, can classify inputs only as gross substitutes or complements. No income (cost) effect is considered in order to classify the inputs as net complements or substitutes. No attempt to estimate the supply elasticity parameter was made.

Another similarity among the studies reviewed is the use of a production function of the Cobb-Douglas family. The set of studies by Mundlak and collaborators, by Basmann, Hayes, Slottje, and Molina (1987), by Swami, Lupo and Sneed (1989), by Fawson, Shumway, and Basmann (1990), and the one by Fulginiti and Perrin (1991) all use the Cobb-Douglas formulation to specify production elasticities functions. Only Frisvold (1991) uses a different functional form in the production function. Frisvold's endogenous technology model is based on a nested Constant Elasticity of Substitution (CES) function. To illustrate the above following are the production functions functions used in two of the reviewed studies.

The research by Swamy, Lupo, and Sneed (1989) proposes a Stochastic Elasticities Cobb-Douglas (SECD) function, from which the Generalized Fechner-Thurstone is a special case. The class of SECD used in that study is defined as:

$$Y(X;\Theta) = B\prod_{i=1}^{n}(A_i X_i)^{\theta i(\gamma k)} \tag{3.9}$$

$$\theta_i = \pi_i + \pi_{i0}C + \sum_{j=1}^{m}\pi_{ij}\omega_{ij} + \varepsilon_{ij} \tag{3.10}$$

where, y, is the maximum amount of output producible at time t (all subscripts t have been omitted) from any given set of vector of n inputs X; B is a lognormal variable which combines the usual intercept with a random disturbance term. A_i's are defined as each factor-augmenting function. The variables $\theta_{i}(\gamma)$ are non-negative stochastic variables representing technical methods applied and change over time, as those methods change. Each of the $\theta_{i}(\gamma)$ also represents an elasticity of output with respect to the i^{th} input. The $\theta_{i}(\gamma)$ is assumed to respond to changes in input prices, ω_j, and in scale of operations C.

A less general form called Generalized Fechner-Thurstone (GFT), is proposed in Basmann, Hayes, and Slottje (1987) and used by Fawson, Shumway, and Bassmann (1990). The GFT function is defined as

$$Y(X;\Theta) = A\prod_{i=1}^{n}X_i^{\theta i(\gamma)} \tag{3.11}$$

$$\theta_i = \beta_i C^{\sigma_{io}} \prod_{j=1}^{m} \omega_j^{\sigma_{ij}} e^{\varepsilon_i} \tag{3.12}$$

where the n-tuple Θ of positive-valued functions, $\theta_i(\gamma)$ is the parameter vector of $F(X;\Theta)$. Variables C and ω_j are defined as in (3.5). For constant γ, the GFT, as well as the SECD, satisfy the usual Cobb-Douglas properties: homogeneous of degree $\Sigma_i\theta_i$, strongly separable and homothetic in X, and constant elasticity of substitution equal to unity. Notice that if in equation (3.5), $A_i = 1$, then the SECD reduces to a GFT.

The use of a Cobb-Douglas functional form within a random coefficient framework dates from the work of Marschak and Andrews (1944). Later developments includes Ulveling and Fletcher (1970) and De Janvry (1972a, 1972b). In fact, GFT and SECD functions are special cases of the generalized power function developed by De Janvry (1972b).

The lack of research into estimating supply and input demand elasticities, based on an endogenous technology approach, is due perhaps to the relative complexity of the functional form involved and of the algebraic difficulties in solving for the primal or dual optimization problem. For example, one question is whether or not current price information should be included as a technology shifter variable. This issue is related to the phenomena of double-switching of technologies. The possibility of double-switching or reswitching technologies was first discussed by Joan Robinson, and is defined as the *"possibility that the same method of production maybe the most profitable...at more than one rate of profit...Implying that the same physical goods will have more than one value,... because a different set of relative prices will be associated with each rate of* *profit. .*"[27] Conventional economics assumes that double-switching is not possible, because if it occurs there will not be a unique relationship between input proportions and factor prices. The production functions assumed by Basmann, Hayes, Slottje, and Molina (1987), and the one assumed by Swamy, Lupo, and Sneed (1989) allow for the possibility of reswitching. This is confirmed by looking at the following ratio:

$$\left(\frac{\omega_{it}}{\omega_{kt}}\right) = \left(\frac{\theta_{it}}{\theta_{kt}}\right)\left(\frac{X_{it}}{X_{kt}}\right) \tag{3.13}$$

The expression in (3.13) is not unique, as the ratio $(\theta_{it}/\theta_{kt})$ can be nonstationary, following different distributions in different time periods, perhaps returning to some earlier distribution (Swamy, Lupo, and Sneed, 1989).

As will be shown later, the attempt to introduce endogenous technical change formulations in producer maximizing behavior could lead to mathematical expression which make no economic sense. Therefore, in order to assume functional forms as the GFT or SECD, simplifying assumptions must be made to avoid theoretical and empirical traps.

This chapter can be summarized as follows: first, econometric methods are suitable for the estimation of supply response parameters. The robustness of the estimates will depend, among other things, on the support the model has from economic theory. Secondly, representation of the technology underlying producer behaviour increases the reliability and consistency of the estimates. The specification of the empirical model of this research will consider the set of characteristics desirable on a production function and their tradeoffs.

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27 Harcourt, 1969, p.388.

Finally, the endogenous technology approach provides a consistent methodology to represent the technological structure, and the technology adoption process. Although functions of the Cobb-Douglas form are classified as non-flexible, the above discussion has shown that the introduction of the endogenous technical change hypothesis in a Cobb-Douglas environment allows for a consistent modeling structure. The endogenous technology approach brings into play potential theoretical and empirical traps that should be avoided cautiously by the researcher so as not to invalidate the overall approach.

The integration of the topics developed in this chapter provides guidelines for modeling technical change in production economics. The above will be the basis for the specification and estimation of the empirical model which is detailed in the next chapter.

CHAPTER IV

SPECIFICATION OF THE EMPIRICAL MODEL

The purpose of this chapter is to specify the empirical model, outline its theoretical implications and discuss econometric estimation of its parameters. The objective of the aggregate model described below is to provide estimates of producer-response parameters, taking into account the interdependence of government policies and technological change. To accomplish the objective, the model is built within an endogenous technical change framework and assumes producer behavior is consistent with profit maximization.

In the development of this chapter, the following issues will be addressed: the choice of functional form of the production function, the supply inducing price, specification of the government intervention variable(s), and the lag structure of the relationship between public research expenditures and agricultural output. Each of these topics is addressed within the context of an aggregate agricultural model. The aggregate nature of the model has special implications for each of these topics.

The chapter will be developed in five sections. The first deals with the choice of the functional form of the production function. On the basis of the selected production function and the assumption of profit maximization, the theoretical model is presented in the second section. The next section looks at the issues of supply inducing price and government-intervention variables. The fourth section presents an analysis of the lag structure of agricultural research expenditures and agricultural output. In section five, technology shifters in addition to research expenditures are detailed.

Functional Form of the Production Function

It is apparent from the discussion in the previous chapter that a production function of a generalized Cobb-Douglas form, in which parameters are stochastic, is well-suited for modeling endogenous technical change. It will be shown that the Cobb-Douglas family functional form has the following advantages: flexibility, ease of interpretation, parsimonious, and consistency. It also will be shown later that this kind of functional form facilitates econometric estimation, without excessive pressure on the degrees of freedom.

Consider the following case of a SECD production function for aggregate output:

$$Y(X;\theta) = A(\gamma)\prod_{i=1}^{n} X_i^{\theta_i(\gamma)} \tag{4.1}$$

$$\frac{\partial A}{\partial X_i} = 0 \tag{4.2}$$

$$\frac{\partial \theta_i}{\partial X_i} = 0 \tag{4.3}$$

Where Y is the maximum output producible from any given vector of inputs X. The n-tuple θ of positive-valued functions, $\theta_i(\gamma)$ is the parameter vector of $Y(X;\theta)$. The stochastic parameters A and θ_i, are functions of technology shifter variables z and g respectively. Changes in the stochastic parameter A and in the vector of parameters q, are independent to the change in the quantity used of each input x_i.

Consider the definition of output elasticity with respect to an input as the ratio of marginal physical product to average physical product. Then, from (4.1) it can be shown that the corresponding elasticities are no longer constants, but functions of the technology shifters γ.

$$\varepsilon_{y,x_i} = \frac{MPP}{APP} = \frac{X_i}{y}\frac{\partial y}{\partial X_i} = \theta_i(\gamma) \tag{4.4}$$

Although, given assumption (4.3) by taking first and second partial derivatives of (4.1), it can be shown that from all the effects shown in Table 3.1, this function allows only for n+1 distinct parameters, which is the same that for a traditional C-D. However, notice that:

$$\frac{\partial \theta_i}{\partial \gamma_k} \neq 0 \tag{4.5}$$

then,

$$\frac{\partial \varepsilon_{y,x_i}}{\partial \gamma_k} \neq 0 \tag{4.6}$$

and,

$$\frac{\partial MRTS}{\partial \gamma_k} \neq 0 \tag{4.7}$$

Given equations (4.6) and (4.7), the correspondent elasticities with respect to technology shifters can be computed. There are k number of elasticities of the production elasticity with respect to technology shifters. Similarly, it can be verified that the number of distinct parameters describing elasticities of marginal rate of technical substitution with respect to changes in technology shifters is kn(n-1)/2, which is the number of technology shifters (k), multiplied by the number of pairs corresponding to different marginal rates of technical substitution [n(n-1)/2].

However, if in equation (4.3) the equality sign is replaced by an inequality sign, then all the (n+2)(n+1)/2 economic effects presented in Table 3.1 would be represented distinctly. To prove this, it is necessary only to show that the elasticities of substitution are not equal to one. This proof is contained in the appendix of Swamy, Lupo and Sneed (1989).

Although ruling out assumption (4.3) implies that (4.1) becomes a fully flexible functional form, assumption (4.3) is kept. That assumption is retained because adding this flexibility imposes severe mathematical complications for the profit-maximization problem in which (4.1) will be optimized. Moreover, interpreting the concept of elasticity of substitution in the context of more than two inputs is not completely clear. Following the principle that more of a good always is preferred to less, it might be that the impossibility of distinctly identifying the elasticities of substitution could jeopardize the relevance of the model. Consequently, the choice of a SECD functional form is consistent with the objectives pursued and, the possibility to estimate elasticities of the marginal rates of substitution with respect to technology shifters compensates for not getting elasticities of substitution different from one.

As it is implied in the paragraph above, the SECD function in (4.1) is a relatively flexible form in which full flexibility has been traded for simplicity, ease of interpretation, and a parsimonious form. The same intuitive interpretation of a traditional C-D is carried by (4.1). The number of parameters to be estimated, as in any other C-D function is small, although in this case the final number of parameters to estimate will be greater and depend on the number of technology shifter variables (z,γ) that the final model will have. As it is the case in most of the studies reviewed, a common problem of an endogenous technology approach is the fact that it is parameter-intensive due to the inclusion of the technology shifters. This is one of the most important reasons for a strong preference for production functions of the Cobb-Douglas family.

The Theoretical Model

To establish the model's theoretical base consider that agricultural producers make decisions in a manner consistent with profit maximization. Also, considering the production function in (4.1), that optimization can be described as maximizing:

$$L = PA(z)\prod_{i=1}^{n} X_i^{\theta_i(\gamma)} - \sum_{i=1}^{n} w_i X_i \tag{4.8}$$

Where P and w_i, represent output and input prices respectively, and all other variables are as previously defined. The first-order conditions are represented by:

$$L_i = Py\frac{\theta_i}{X_i} = w_i \tag{4.9}$$

Rearranging the above expression, the following system of equations is obtained:

$$\theta_i = \frac{w_i X_i}{Py} \tag{4.10}$$

The above is the well-known result of the traditional Cobb-Douglas function; the elasticity of production with respect to a factor X_i is equal to its correspondent expenditure share. Appealing to Euler's theorem, the result below follows:

$$\sum_{i=1}^{n} \frac{X_i}{y} \frac{\partial y}{\partial X_i} = \sum_{i=1}^{n} \theta_i = \sum_{i=1}^{n} \frac{w_i X_i}{Py} = \Theta \tag{4.11}$$

This implies that the sum of the production elasticities (θ_i) is equal to the degree of homogeneity (Θ); likewise, the degree of homogeneity is equal to the sum of all factor shares. Furthermore, under long-run equilibrium conditions, this implies that total output is just exhausted, meaning long-run, competitive profits are zero (Henderson and Quandt,1980). Recall that one of the key assumptions of a long run competitive equilibrium is the existence of the free entry and exit of firms.

Regarding the form of the elasticities, the particular SECD function defined in (4.1) have the same characteristics as the well known traditional Cobb-Douglas (CD). As in the CD, the SECD function represents consistent profit maximizing behavior in the second stage of production, therefore $\Theta=\Sigma\theta_i<1$ or decreasing but positive marginal returns. Also, recall that the parameters θ_i are non-negative.

By simultaneously solving the system of first order conditions (4.9), the corresponding input demand equations are determined. Upon replacing them into the production function, the output supply function may be obtained.

Thereafter, the supply and input demand elasticity expressions can be obtained. Any production economics textbook[28] contains this derivation for the simple two-input case.

The own-price, cross-price, and output price input demand expressions generalized to the n input case are the following:

$$\varepsilon_{x_i,w_i} = -\frac{1-\Theta+\theta_i}{\Theta-1} \tag{4.12}$$

$$\varepsilon_{x_i,w_j} = -\frac{\theta_j}{\Theta-1} \tag{4.13}$$

$$\varepsilon_{x_i,p} = -\frac{1}{\Theta-1} \tag{4.14}$$

Given the assumptions of the values on the parameters Θ and θ_i, equations (4.12) and (4.13) are unambiguously negative, while (4.14) is unambiguously positive. These results are in agreement with production economic theory. However, equation (4.13) implies that all inputs are constrained to be complements. This imposes a serious restriction to the input demand parameters. The effects of this restriction can be overcome partially by focusing on elasticity parameters with respect to technology shifters rather than input prices alone. This alternative is totally consistent with the model's purpose and reinforces the emphasis on the methodology's technology side.

The supply elasticity parameter for this SECD case is also a generalization for the n input case of the two-input result. and is given by the following expression:

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28 See for example Beattie and Taylor (1985), pp. 125,159; and Debertin, D. (1986), pp. 219-222.

$$\varepsilon_{y,p} = \frac{\Theta}{1-\Theta} \tag{4.15}$$

The above equation defines a long-run supply elasticity, given the underlying assumption that all inputs are variable. To represent a short-run elasticity, the inputs which have to be taken into account in the definition of Θ are the ones which are variable in the short-run, within a production cycle. Movement from the short to the long-run, implies that more inputs will become variable and will be included in the correspondent definition of Θ. As can be expected, the elasticity os supply increases as producers move from the short to the long-run.[29]

Under long-run equilibrium conditions ($\Theta=1$), inputs demand and output supply elasticities become infinitely elastic or undefined. This result is associated more with the long-run equilibrium of the firm, than with a representation of aggregate behavior, as it is the case in this research.

Recall equation (4.11), which implies that under long-run equilibrium conditions the elasticity of production is equal to the corresponding factor shares, and consequently their sum is one. However, there are short-run discrepancies between the correspondent production elasticity and factor share, particularly in agriculture. This disequilibrium indicates that the process of resource adjustment in agriculture takes place over several production periods. Among the factors delaying the adjustment process are risk, uncertainty, technical constraints, institutional rigidities, and psychological resistance to change (Nerlove, 1958). This adjustment process was formalized by Tyner and Tweeten(1965, 1967) using the following partial adjustment dynamic formulation:

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[29] A more detailed explanation, and examples of this issue, can be found in the original works of Griliches (1958) and in Tyner and Tweeten (1966).

$$F_{it} - F_{i,t-1} = g(\theta_{it} - F_{i,t-1}), \qquad 0 < g < 1 \qquad (4.16)$$

Where F_{it} is defined as the expenditure share of factor X_i at time period t; $F_{i,t-1}$ as the previous period factor share corresponding to X_i; θ_{it} as the current elasticity of production or short-run equilibrium factor share; and g as the disequilibrium rate, which is constrained to be between zero and one because a tendency towards equilibrium.is assumed.

The following general model to estimate the production parameters is obtained by combining equations (4.1), (4.10), and (4.16):

$$Y(X;\theta) = A(\gamma)\prod_{i=1}^{n} X_i^{\theta_i(\gamma)} \qquad (4.17a)$$

$$F_{it} - F_{i,t-1} = g(\theta_{it}(\gamma) - F_{i,t-1}), \qquad 0 < g < 1 \qquad (4.17b)$$

Where all variables are as defined earlier.

Having defined the theoretical base of the model at its components, it is now appropriate to turn to the definition of the vector of γ variables, the technology shifters. In particular, to the definition of variables relating to government intervention, the inducing-supply price, and the lag structure of agricultural research expenditures.

Specification of Government Intervention Variables

Since government programs started in 1933, the policy instruments utilized have varied significantly. The complex combination and continuous change in the different combinations of agricultural government intervention (support prices, direct payments and supply control) make it very difficult to build a consistent time series to econometrically estimate the influence of government policies on supply and other economic parameters. Obviously, there is no question that government policies influence agriculture. The challenge is to define a variable or variables to summarize their impact on producers' behavior.

Several authors have tried different ways of dealing with the estimation of supply elasticities incorporating government market intervention mechanisms.[30] A set of studies on wheat supply response, starting with Lidman and Bawden (1974), followed by Garst, et al. (1975) and Worthington (1988), introduced each instrument of the government program individually as an independent variable. As the complexity of government programs increased, the number of variables to consider also grew, resulting in a loss of degrees of freedom. The success of this approach relies on modeling policies which have been in effect for long periods of time.

Another approach was introduced by Helmberger and is based on the hypothesis that the supply function itself may change due to government intervention. Therefore, different subsets of the sample of observations are identified, each corresponding to a particular set of policies. Studies of wheat by Morzuch, et. al (1980) and of corn by Lee, et. al (1985) used this sub-samples approach to represent government instruments as individual independent variables for each sub-sample, maintaining then the problem of loss of degrees on freedom.

Taking a different route, Houck and Ryan (1972) provided a framework in which the price and income support features of annual programs and the supply

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[30] For a review of the different methods use to specify government market intervention in agriculture, see Del Valle (1989).

control aspects are summarized in a few variables. Their approach provides for construction of the following equation:

$$PF = r\,PA \tag{4.18}$$

where, PA is the announced support price, PF is the weighted support price, r is an adjustment factor which incorporates the planting constraint associated with the announced support price. If there are no planting restrictions, then r equals unity; conversely, the larger the planting restrictions the more r approaches zero.

For years in which direct payments where offered to producers to idle land, Houck and Ryan developed the following additional expression:

$$DP = w\,PR \tag{4.19}$$

where, DP is the weighted diversion payment, PR is the announced diversion payment; and w the adjustment factor, which is equal to one in the absence of limits in the acreage eligibility for diversion payments, and approaches to zero the smaller the eligible acreage is.

Upon the methodological guidelines set by Houck and Ryan (1972), numerous studies were conducted. Houck, et al. (1976) produced a more comprehensive study which was followed by others such as Duffy (1985) for the case of corn; Duffy, et. al. (1987) for cotton; and Bailey and Womack (1985) for wheat. All these and other studies, while relying on Houck and Ryan's methodology, added new features to address specific problems and objectives.

The results obtained by using the methods described were in most cases consistent with economic theory and provided effective ways to model government market intervention. However, from the brief review presented it can be said that all studies dealt with single commodity rather than aggregate agriculture estimation. Furthermore, the commodities to which the above methodologies were applied are characterized by relatively uniform farm programs. Products such as diary and oranges, in which other forms of government intervention cannot be addressed using Houck and Ryan's methodology.

For purposes of this research, it was impractical to develop similar aggregates measures to the ones presented in equations (4.14) and (4.15). This limitation becomes more evident when considering the diversity of government intervention instruments across the agricultural sector. The literature discusses the concept of excess capacity, which is for some researchers an indication of the effect of government intervention in agriculture. Although it has not been used within a framework of producer-response estimation, the excess capacity concept has the potential of fitting into the endogenous technology approach discussed earlier. The issue of excess capacity will be examined only as a means to represent the effects of government market intervention.

The starting point is a working definition of excess capacity provided by Dvoskin (1988):

> *Economic theory...links the support of agricultural prices above market clearing to excess capacity. Thus, one could define excess capacity in agriculture as the difference between supply and demand at a given set of prices*.[31]

This definition implies that excess capacity is a function of farm prices, which are influenced by farm policy. It is apparent from this observation that

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31 Dvoskin, Dan (1988), p. 5.

there is no one-to-one relationship between the size of excess capacity and government policies. However, Tweeten (1989) argues that *"excess capacity is a creation of and exists at the will of government. ".*[32] Tweeten's conclusion is compatible with economic theory on long run equilibrium considerations. Long run excess capacity can be compatible only with economic theory in a market structure characterized by a differentiated product, many firms, free entry, and non-aggressive price competition (Chamberlain, 1939). Agriculture is far from being the case given as an "industry" with little product differentiation and with aggressive price competition.

Although the actual excess capacity cannot be calculated, a proxy measure can indeed be used and. *"it represents the difference of what farmers could have produced (at the given price levels) and the value of production that can be cleared by the commercial market (domestic and foreign demand)."*[33] A similar proxy measure has also been used in the past by Tyner and Tweeten (1964), as well as by Quance and Tweeten (1972).

A simplified representation of excess capacity consistent with the concepts used above is presented in figure 6. The line S_1 represents the actual supply function for farm output. The supply line S_2 is the hypothetical supply of farm output considering, that all land taken out of production by government programs is back on production. Line D_1 represents the presumed actual total demand for farm output; because it includes non-commercial exports the line D_2 represents the total demand for agricultural output from commercial markets.

It can be observed clearly that the difference between S_1 and S_2, represents the effects of supply-control programs, while the difference between

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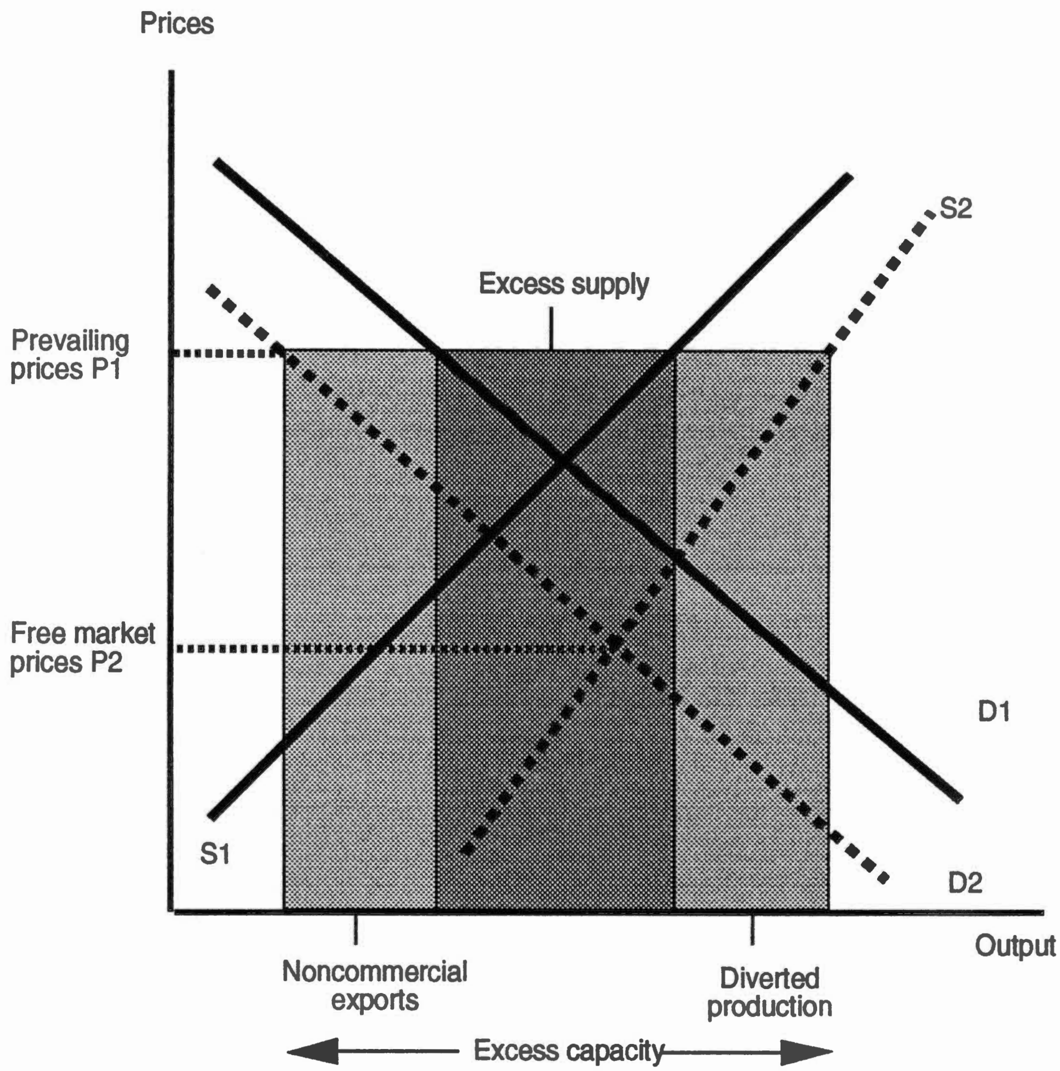
[32] Tweeten, Luther (1989), p.3.
[33] Dvoskin (1988), p.5



Source: Dvoskin, Dan. 1988. "Excess Capacity in U.S. Agriculture: An Economic Approach to Measurement." Research and Technical Division, ERS, USDA, Agricultural Economic Report No. 580.

Figure 6. Excess Capacity Representation

D_1 and D_2 indicates the effect of demand-enhancing programs. The actual disappearance of this excess implies the effect of income support policies.

The excess capacity concept allows the identification of short term shocks and their relationship with government policies. For instance, after a sudden increase in export demand, D_2 will move to the right, free market prices will increase, and the size of the difference between P_1 and P_2 will become smaller, implying less incentive for participation. S_1 moves toward S_2, and eventually reduces government outlays. The opposite effect also can be traced intuitively. The ability of excess capacity to reflect the interaction between changes in government polices and changes in shock variables like weather and export demand is evident.

This empirical measure of excess capacity is questioned by Sutton, et al., (1989); their most important criticism is that Dvoskin's measure does not make any distinction between short and long-run based on variable and fixed inputs or resources. Therefore, they argue, Dvoskin does not provide a measure of or tendencies towards resource misallocation brought on by a policy nor the structural adjustments which could occur under domestic or trade policy reform[34]. While the base of the criticism may be correct, the alternative suggested, the concept of overinvestment, does not have the measurement advantages as excess capacity does.

Within the framework of this study, the use of excess capacity as a measure of government intervention offers three advantages. First, it provides a simply accounting for an aggregate effect of agricultural policies because it avoids the need to determine weighted average of the Houck and Ryan variables, PF (effective support price), and DP (effective diversion payment). Secondly, by singling out excess capacity as a feasible representation of

[34] Sutton, J., M. Young, and K. Alt (1989), p.28.

government intervention, the loss of degrees of freedom is reduced to a minimum. Finally, the most important advantage is that with the concept of endogenous technical change, excess capacity represents additional resources in producers' hands and therefore additional resources to implement new production techniques. Following Mundlak's hypothesis, excess capacity influences the producers' capital accumulation process and then influences the rate of implementing new techniques (Mundlak, 1988b). The latter influence implies that the excess capacity measure should be positively correlated with technical change.

As in the case of the Houch and Ryan variables, the sensitivity of the excess capacity quantification is very much in the hands of the researcher. A cautionary note in Houck, et al. (1976) referring to the quantification of the PF and DP variables, also is relevant to measuring excess capacity,

> *In analysis of this kind, much of the potential success hinges on the construction, by the researcher, of internally consistent and reasonable variables to reflect both price and policy changes. Obviously, this places an additional responsibility on the investigator as compared with more traditional econometric supply response studies. Unfortunately, there is no single method of unambiguous approach that emerge from these studies for constructing effective support price levels and related variables. The general methodology seems appropriate, but the details depend upon the commodity and the times* .[35]

The quantification method and the commodity groups included in the excess capacity variable for this research are the same as those contained in Dvoskin.[36] Because annual values were computed, a five year moving average was introduced in the final computation of the aggregate measure for

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[35] Houck et. al. (1976).

[36] For a detailed explanation of the procedure used to quantify or measure excess capacity see Dvoskin (1988), pp. 6-10. The commodities included are: wheat, corn, oats, barley, sorghum, cotton, soybeans, rye, rice, tobacco, peanuts, and dairy products.

excess capacity. This average has the purpose of averaging out short run variations and allows to use it as a proxy for long run excess capacity.

Before moving to other topics, it is necessary to state two important shortcomings of excess capacity as an indicator of government intervention. First, excess capacity is not independent from research expenditures, and therefore some degree of simultaneity is introduced. Secondly, the excess capacity measures may not reflect adequately changes in the amount of defficiency payments. For the first problem there is no immediate solution but to include it in the list of limitations and future challenges of this research. Regarding the effect of government payments, a measure of the actual payments received by producers can be introduced as means to account for changes in the amount of defficiency or diversion payments.

Lag Structure of Public Supported Agricultural Research

Agricultural research, as any other research activity, is a long term enterprise whose objective is to increase the absolute level of knowledge with productive purposes. In other words, the output from agricultural research activities increases the set of techniques available for producers. By including public research expenditures as a producers technology shifter, two objectives are being accomplished. The first is to integrate the research component of agricultural policy with the income support features of government intervention. Second, public research expenditures are a proxy for the supply of technology.

Most of the existing literature deals with the estimation of the rate of return from public research. A common method used in the literature since Griliches (1964) to account for the generation of new technology is to relate change in output productivity to the state of technology at time t. The state of technology is represented by a lag structure of public expenditures on agricultural research.

There are several identifiable lag structures in the life span of a research activity. According to Griliches (1967) in the process on generating new knowledge there are two lag structures. One is the investment period, which accounts for the time between the initial investments of funds and the appearance of first results. The second lag represents the time between the first aapearance of results and a commercial application provided to producers. Once a new technique reaches the commercial stage at time t+m, its extension begins, and farmers start to adopt it, and accrue its benefits. Then, according to Evenson (1968), the implemented technology will depreciate and after n periods, it becomes obsolete or irrelevant. The lag structure described above means that the total life of a new technique is t+m+n, which is the summation of the time spent producing it and the periods in which it was productive. Then following Evenson (1968), a total lag structure represented by a inverted V shape can be pictured. Most subsequent studies have maintained this form of the lag structure.

The length of the lag varies from one study to the other. While Griliches (1964) assumed a six-year lag, Evenson (1968) concluded that the mean lag for state-supported research was about five and a half years, while the mean lag for federally supported research was eight and a half years. Later in Cline (1975), lag lengths between eight and seventeen periods were used.

The common denominator on these studies is the specification of the number of lag periods to consider. The lag length is such that it is usually determined by its statistical fit, not by a priori knowledge. In a recent study impressive database which included observations on public research expenditures for the 1890 -1983 period, Pardey and Craig (1989) performed causality tests of alternative lag lengths. Pardey and Craig concluded that, *"the evidence indicates that long lags -- at least thirty years -- may be necessary to capture all of the impact of research on agricultural output."*[37]

Given the evidence presented above, the lag shape and its length, for purposes of this research is considered to have the inverted V shape and to be over fifteen periods. Having specified the public agricultural research lag structure to be used and previously the method to incorporate government policy effects, what follows is the specification of the remaining technology shifter variables.

Prices as Technology Shifters

The literature on technical change recognizes the importance of input prices in the innovation process. The induced innovation hypothesis is built around the idea that relative prices influence the direction of the bias of technical change. According to Ruttan and Hayami (1988), *"...it is entirely rational for competitive firms to allocate funds to develop a technology that facilitates the substitution of increasingly more expensive factors for less expensive factors."*[38] Following Binswanger (1978), the induced innovation hypothesis suggests a positive relationship between output prices and ptoductivity changes. In the context of induced innovation, there is no distinction between new technology generation and its adoption process, as both are integrated under the umbrella of technological innovation.

Mundlak (1988), also considers input as well as output prices, as technology shifters on the basis that these are the state variables which

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[37] Pardey, P.G., and Craig, B. (1989), p.18
[38] Ruttan and Hayami, 1988, p. 250.

influence producers adoption decisions. The optimal solution of the producers profit-maximization problem depends on the state (exogenous) variables, and it (the optimal solution) will determine *"... both the techniques used and the level of their use, as determined by the optimal allocation of fixed inputs...and variable inputs."*[39]

According to Mundlak (1988), data from the observation of the real world can only provide information on the techniques which have been implemented. This observation implies that the technological structure at a given point in time could be considered as the collection of the output of past decisions. Consequently, if the objective is to represent the current productive structure, the relevant prices to consider might include the observation of past input and output prices.

Different price formulations have been used in the endogenous technical change literature. For instance, Fawson, Shumway and Bassman (1990) used current price observations; and Frisvold (1991) defined two different price variables-current prices and a price variable as a moving average on observations for four periods, each period representing data in a five-years intervals. Finally, Fulginiti and Perrin (1991) used a five-year, moving average specification to formulate the relevant price expectations.

In this research, the price variables are defined in term of moving averages on past observations. Contrary to Mundlak (1988) and Frisvold (1991), current prices are not included to avoid the "reswitching" of technology and the functional intractability issues discussed early in this chapter.

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[39] Mundlak, 1988, p.319.

Additional Technology Shifters

Five other technology shifters are included in the model: nat farm income farm income, export share on gross income, total production cost, net farm income variability, and weather. From these, farm income is incorporated as a source the capital accumulation process. Producers will implement new techniques to the point that they can afford or can finance them. As Mundlak (1988b) states, modern technologies are view as capital-intensive techniques. In general, it is impossible to increase the relative importance of the modern techniques without capital accumulation. The above statements signal that the discount rate, could be introduce as a proxy variable to account for the availability of external (to the farm) financial resources.

Most technology shifters thus far have implied some long trend component. However, there are short-term elements or current events which might have a significant impact on the implementation of new techniques. One element is the level of exports. Having ruled out current output price expectations as a technology variable, there is a need to introduce variables which will transmit tothe producer short-run information about the agricultural economy's performance. The level of agricultural exports is highly associated with output prices. As export demand increases, it puts pressure on the current supply and results in an output price increase. Conversely, a reduction in export demand or an unusual increase in production will reduce the relative importance of agricultural exports, and subsequently lower prices result. The impact of these variations and price transmission, is affected only by the degree of government intervention.

The implementation of a new technique, as suggested by Mundlak (1988b), implies an investment decision. Therefore the following hypothesis is formulated: the investment decision not only depends, as implied before, on the rate of capital accumulation but also on the stability of the capital source. Given that the primary capital source is farm income, its variability is considered to be an additional technology shifter. An inverse relationship between variability and technical change is expected.

In the literature, there are several measures of variability in the literature, which have been used in the context of supply response estimation. Several existing formulations can be used indistinctly. In this research, the following income variability formulations will be considered:

A. Behrman (1968) :

$$\left[\sum_{k=1}^{n}(I_{t-k} - i_t)^2\right]^{1/2} \tag{4.20}$$

B. Ryan (1977):

$$\left[\sum_{k=1}^{n} w_k (I_{t-k} - i_t)^2\right]^{1/2} \tag{4.21}$$

C. Ryan (1977):

$$\frac{\left[\sum_{k=1}^{n} w_k (I_{t-k} - i_t)^2\right]^{1/2}}{i_t} \tag{4.22}$$

where I_t is the income level at time t; i_t represents a moving average on income observations; and n indicates the number of relevant past observations. The first two measures (A and B) are standard deviations of income measures; B is slightly different due to the introduction of different weights on each lagged period. C is a coefficient of variation measure in which weights also are introduced.

Another important variable to account for short-term variations in production parameters is weather. Much of the year-to-year differences in productivity are related to changes in performance due to weather pattern changes. Cline (1975) found empirical evidence that high variations in weather can be associated with lower rates of technology adoption.

Empirical Model

Before the empirical model is completely specified, the degree of input aggregation should be defined. The same input categories used by the United States Department of Agriculture (USDA) have been used, although they have been aggregated in four major groups. This classification has been defined according to the extent to which inputs are fixed or variable in the short and long run. These groups and their components are short term variable inputs or operating expenses[40] , machinery, labor and real estate.

That said, the full specification of the empirical model is given by the equations (4.23) to (4.27); which are presented immediatly,

$$Y = AX_1^{\theta_1}X_2^{\theta_2}X_3^{\theta_3}X_4^{\theta_4} \tag{4.23}$$

$$\theta_i = f(P_y, P_1, P_2, P_3, P_4, EC, I, EXS, R, V_l, GPF, W) \tag{4.24}$$

$$A = f(P_y, P_1, P_2, P_3, P_4, EC, I, EXS, R, V_l, GPF, W) \tag{4.25}$$

$$F_{it} - F_{i,t-1} = g(\theta_{it} - F_{i,t-1}), \tag{4.26}$$

[40] As it is presented later, the category short-run variable inputs or operating expenses includes fertilizers and chemicals; energy; feed, seed, and livestock purchases; and machinery operating expenses.

$$\Theta = \sum_{i=1}^{4} \theta_i \qquad (4.27)$$

where:

Y is the agricultural aggregate output level.

A is a parameter of disembodied technical change.

X_1, X_2, X_3, X_4 are quantity of inputs applied to production.

q_1, q_2, q_3, q_4 are production parameters and elasticities of production.

P_y is the output price.

P_1, P_2, P_3, P_4 are the corresponding input prices.

EC is a measure of the aggregate excess capacity in agriculture.

I is the net farm income.

EXS is the export share of agricultural products.

R is the amount of public research expenditures.

V_I stands for income variability.

GPF government payments share on net farm income

W is a weather index.

F_{it} is the factor share of input i at time t.

Θ measures marginal returns and homogeneity of the production function.

θ_i represents the elasticity of production respect to the ith. input.

The estimation procedures, data description and estimation results will be presented in the next chapter. In Chapter Six a policy preference function will be estimated, based on the estimates obtained and other structural foreign and domestic demand parameters taken from previous studies.

CHAPTER V

MODEL ESTIMATION AND ANALYSIS

The previous chapter ended with the presentation of the system of equations, which defines the empirical model to be used to accomplish this dissertation objectives. What follows are the details concerning the statistical procedures used to estimate the parameters of the model, and analysis of the results. Specifically, the following sections define the variables and their construction, specifiy the estimating methods, present and discuss the statistical results, and analyze the results regarding the effects of the technology shifter variables in term of elasticities of production and measurement of Hicksian technical bias.

The Model

First, recall from the previous chapter the structure of the model,

$$Y = AX_1^{\theta 1}X_2^{\theta 2}X_3^{\theta 3}X_4^{\theta 4} + u_t \tag{5.1}$$

$$\theta_i = f(P_y, P_1, P_2, P_3, P_4, EC, I, EXS, R, V_I, GPF, W) \tag{5.2}$$

$$A = f(P_y, P_1, P_2, P_3, P_4, EC, I, EXS, R, V_I, GPF, W) \tag{5.3}$$

$$F_{it} - F_{i,t-1} = g(\theta_{it} - F_{i,t-1}), \tag{5.4}$$

$$\Theta = \sum_{i=1}^{4} \theta_i \tag{5.5}$$

The variables are defined as in the previous chapter. A detailed explanation of each time series is reserved for the appendix. For now the key is to focus on the issues of: inputs classification; factor shares computations; definition of price variables; the specification of excess capacity, income, research expenditures, total cost, and weather; and the functional form for (5.2) and (5.3).

<u>Output</u>

The level of output Y is defined as the total value of agricultural production (crops and livestock). It is measured in constant dollars, computed by aggregating ERS individual commodity groups. The aggregation was performed using a Tornquist index.

<u>Input Classification</u>

The set of farm inputs was classified in four categories, based on the criteria of whether an input can be classified as relatively variable or fixed in the short run. The four categories are:

- X_1: Short-term, variable inputs. This category includes agricultural chemicals; machinery operating expenses; feed, seed, and livestock purchases (non-farm value added); operating financial expenses, and miscellaneous inputs.
- X_2: Short-term, machinery fixed costs. This category includes non-operating costs of machinery.

- X_3: Farm labor, which includes hired labor, operator labor and family unpaid labor.
- X_4: Farm real estate.

As one moves from X_1 to X_4, the inputs become less (short-term) variable. Based on ERS data, the aggregation into four categories was done using a Tornquist index, following a similar work done by Fawson and Gottret (1988).

This classification criterion was chosen based on two facts. First, the number of input categories should be reduced to minimize potential multicollinearity problems and avoid unnecessary losses of degrees of freedom, given the restricted sample size. Secondly, given the use of a Cobb-Douglas function and the fact that the corresponding supply elasticity is derived based on the production elasticities, the criterion chosen simplifies the aggregation procedure as we move from the short run (X_1), to the long run (X_4). Furthermore, as it will be confirmed later, this classification criterion facilitates the interpretation of the model results with this endogenous technical change framework.

Factor Shares

The factor shares (F_t), are nominal factor shares defined as the ratio of nominal expenditures on input X_i and the total nominal expenditures. Their construction is based on aggregating nominal ERS data on expenditures using a Tornquist index. As mentioned earlier this is based on the work of Fawson and Gottret (1988).

Input and Output Prices

Input and output prices are defined as moving averages of the previous five years of observations on the corresponding Tornquist indexes. This moving average formulation is consistent with the earlier assertion that the observed implemented technology is the result of previous producers decisions based on past prices.

In the estimation procedure, some relative input prices measures also are used. These are computed by first taking the ratio of the two Tornquist input index prices and then imposing the moving average formulation.

Excess Capacity

As defined earlier, annual observations on excess capacity were constructed using the procedure outlined by Dvoskin (1988). For the period between 1940 and 1984, the data used is the actual data presented in Dvoskin (1988). For the 1985 to 1989 period the series was updated independently using the same methodology.

The observations used in the estimation procedure are five-year, moving averages of annual observations. A similar aggregation is suggested by Dvoskin using three-and seven-year moving averages to smooth out annual changes in stocks and provide a proxy variable for long-run excess capacity[41]. A five-year, moving average proved to be more appropriate.

One of the limitations of the concept and measurement of excess capacity, is its lack of ability to reflect changes in the size of the government payments. Suppose the government decides to increase the amount of direct payments, without changing the eligibility requirements. If participation is high enough, excess capacity will not reflect the increase in government payments. To account for this limitation, a new variable defined as the government payments' share of net farm income is introduced in the empirical model.

Income

Income initially was measured as annual observations on net farm income. To account for long-term changes, a polynomial distributed lag formulation was

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[41] Dvoskin, D. (1988), p. 10

introduced. So unrestricted and restricted Almon distributed lags formulations for net income were considered as technology shifters. Given the lack of a priori knowledge, in principle the formulation for each equation needs not to be the same.

Research Expenditures

Research expenditures are defined as the sum of research resources allocated to state agricultural experiment stations and to federal agricultural agencies. A comprehensive series for the period 1890 to 1986 was taken from Pardey (1991)[42].

Based on what already has been reviewed in Chapter Four, the research variable was considered as an Almon polynomial distributed lag. The lag form was assumed to have the inverted "V" shape. Consequently, the Almon formulation was considered to have both endpoints constrained to zero. Taking into account Pardey and Craig's (1989) empirical work, the lag length was considered to be between 5 and 30 years. Although it is assumed that the inverted "V" shape is common to all equations, the lag length need not be.

Total Cost

Total cost is used as a proxy for scale of production (Fawson, Shumway, and Bassman, 1990). It is defined as total real expenditures, which were computed as the other production variables, based on a Tornquist index.

Exports

This variable is defined as a share equal to the ratio of total value of agricultural exports to farm gross income.

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42 Pardey, P.G., W.M. Eveleens, and M.L. Hallaway. "A Statistical History of U.S. Agricultural Research: 1889 to 1986." St. Paul: University of Minnesota, CIFAP, (forthcoming, 1991)

Weather

Observations on the weather variables were constructed following Stallings' (1960) empirical work. A time trend was run on yields, and the weather index is constructed based on the residuals. From the years 1939 to 1963, observations were taken as presented in Cline (1970), and for later years, the index was estimated using the methodology described in Stallings (1960) but using actual yield instead of controlled yields.

Before finishing with the presentation of the model, the issue of the functional form of equations (5.2) and (5.3) must be addressed. There is no a priori knowledge about the form of these equations, neither are constraints to any particular form, as this is a purely empirical determination. Therefore, for simplicity's sake only three alternative functional forms were tried: linear, log-linear, and logarithmic. The log-linear and the logarithmic, although being the most attractive for computing elasticities, were not selected for equation (5.2). The linear functional form showed the best fit and more consistency in the parameters. As for equation (5.3) the functional form chosen was the log-linear.

Estimation of The Model

Based on the information provided in the preceding section and in Chapter Four, the complete estimation model is given by,

$$Y = AX_1^{\theta_1}X_2^{\theta_2}X_3^{\theta_3}X_4^{\theta_4} \tag{5.6}$$

$$\theta_i = \alpha_{0i} + \sum_{k=1}^{n}\alpha_{ki}\gamma_k \tag{5.7}$$

$$LogA = \alpha_{0A} + \sum_{k=1}^{n} \alpha_{kA} \gamma_k \tag{5.8}$$

$$F_{it} - F_{i,t-1} = g(\theta_{it} - F_{i,t-1}), \tag{5.9}$$

$$\Theta = \sum_{i=1}^{4} \theta_i \tag{5.10}$$

where the γ_k represent the technology shifter variables.

To obtain the estimating equations there are two alternative procedures. First, to substitute (5.7), (5.8), and (5.9) into (5.6), one could proceed to estimate the new (5.6) by taking the natural logarithm of Y and using ordinary least squares (OLS). However, given the large number of parameters to be estimated in a single equation, it is likely that multicollinearity will be a problem. Moreover, given a sample size from of 46 years, 1944 to 1989, the number of degrees of freedom will be compromised, or it might not be possible even to use OLS if the number of parameters is greater than the total number of observations available.

An alternative estimation procedure is to substitute (5.7) into (5.9). First solve (5.9) for the factor share $F_{i,t}$

$$F_{i,t} = g\theta_{i,t} + (1-g)F_{i,t-1} \tag{5.11}$$

then,

$$F_{i,t} = g\alpha_{oi} + g\sum_{k=1}^{n} \alpha_{ki} \gamma_k + (1-g)F_{i,t-1} \tag{5.12}$$

From the estimation of the system of equations in (5.12), the estimates of θ_i can be inserted in (5.6) to obtain, as residuals, observations on LogA. With this information, it is possible to estimate LogA equation using OLS and hence complete the estimation of the production function parameters in (5.6).

To summarize, after adding the corresponding stochastic error terms, which are assumed to follow a multivariate normal distribution, the system of equations to be estimated in order to get the complete set of parameters for (5.6) is given by (5.8) and (5.12). This can be viewed as a recursive system, in which equations (5.8) need to be estimated simultaneously, in order to account for the variations across factor shares.

Bearing in mind that not all the independent variables will be included in each and everyone of the equations, that is $\alpha_{ik}=0$ for some k in i; and that the error terms across equation are contemporaneously correlated, such that the variance-covariance matrix for the system is in fact non-singular and non diagonal; then it is confirmed that (5.8) is in fact a seemingly unrelated regression equations (SURE) model. Consequently, given that by assumption the disturbances are normally distributed, using an iterative seemingly unrelated regression method will yield parameters numerically equivalent to those of the maximum likelihood estimate (ML).[43] This result and the fact that OLS is a ML estimator provides for estimates of (5.6) with all desirable asymptotic properties.

At this time, it is should be mentioned that none of the econometric software for microcomputers available for this research had the capability of estimating polynomial distributed lags (PDL) with in the framework of system estimation[44]. Therefore, the PDL variables had to be computed independently, and then inputted as independent variables. The results to be presented below

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[43] For a proof of this result , see Oberhofer and Kmenta (1974).

[44] The software available for estimation included Shazam and MicroTSP

show the coefficients and statistics for the PDL variables, which were converted later on into their correspondence coefficient with in the PDL lag structure.

Estimation Results: Statistical Analysis

The estimation procedure described above is carried out in two stages. In the first, the factor share equations (5.12) are estimated and used to estimate short run production elasticities (θ_i), which in turn are used to compute residual observations on LogA. The second stage involves the estimation of equation (5.8). This section will be developed by looking first at the statistical support for the results, with a few references to economic theory. Next, the focus will be to analyze the results based on the concepts of elasticity of production, elasticity of the marginal rate of substitution, and of supply elasticity.

The first stage estimates are presented in TABLE 2. First, looking at the aggregate model (5.12), the statistics such as the system R^2 and the corresponding Chi-square, Breusch-Pagan and likelihood ratio tests, strongly support the model formulation and estimation procedures. The Breusch-Pagan and the likelihood ratio tests support the presence of a non-diagonal, variance-covariance matrix; while the system R^2 and the Chi-square tests support the fit and the statistical significance of the model.[45]. Regarding the individual parameters, it can be observed that from fifty-four (54) parameters estimated, thirty nine (39) are significant at the 5 percent level, and forty three when the significance level is 10 percent.[46] In summary, the estimated parameters have a strong statistical support.

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[45] For a complete explanation of the properties of these tests refer to Judge et. al. (1982). For a specification of the system R^2 refer to Brendt (1991).

[46] Given that the estimator used has good asymptotic properties, the p values on the tables refer to the Wald Chi-square statistic.

TABLE 2.

FACTOR SHARE ESTIMATION RESULTS

	REAL ESTATE	LABOR	FIXED	VARIABLE
Intercept	0.17015	-0.16236	0.24685	0.27118
	0.02566 (1)	*0.17629*	*0.00003*	*0.00879*
Factor Share$_{t-1}$	0.45068	0.24958	0.47203	0.33501
	.000000	*0.01774*	*.000000*	*.000000*
Price Real. Estate	-0.23432	---(2)	---	---
	0.00852			
Price R.Estate/Var.Inp.	0.16507	---	---	-0.065746
	0.00689			*0.21598*
Price Labor	---	-0.10477	---	---
		0.40644		
Price Labor/Fix Inputs	---	-0.05956	0.038131	---
		0.57551	*0.01206*	
Price Fixed Inputs	---	---	-0.35896	---
			.000000	
Price Variable Inputs	---	---	---	-0.15621
				0.01874
Price Output	0.29772	0.19521	0.24162	0.21535
	0.00003	*0.00038*	*.000000*	*0.00186*
Excess Capacity	1.0064E-05	2.3723E-05	6.8193E-06	1.3983E-05
	0.01256	*0.00028*	*0.02074*	*0.00116*
Weather Index	-0.0014306	-0.001435	-0.0011115	-0.0014972
	0.00001	*0.00137*	*.000000*	*0.00002*
Research Expend(PDL)	3.5844E-09	-1.279E-07	-2.436E-08	-1.067E-08
	0.62057	*.000000*	*0.00166*	*0.05595*
Net Farm Inc.-NFI(PDL)	5.9557E-08	4.5372E-08(3)	6.6334E-08	3.4144E-08
	0.00005	*0.11233*	*.000000*	*0.02131*
Net Farm Income (PDL)	---	3.1317E-08(3)	---	---
		0.03114		
Export Share (PDL)	-0.0016708	0.013057	-0.0031155	0.2367(4)
	0.08351	*0.0001*	*.000000*	*0.00001*
Total Cost	3.6517E-07	2.822E-06	7.783E-07	9.0869E-07
	0.57935	*0.00256*	*0.10063*	*0.16306*
Income Variability	-0.024163	-0.040947	-0.018554	-0.013347
	0.15894	*0.07447*	*0.14843*	*0.44921*
(Gov. Pay/NFI)$_{t-1}$	-0.062673	-0.0076657	-0.069392	-0.047567
	0.00264	*0.79335*	*.000000*	*0.02678*
Farm Population Share	---	0.058438	---	
		.000000		

BREUSH-PAGAN TEST CHI SQUARE			115.04	6 D.F.
SYSTEM R^2	0.9999	**SYSTEM CHI-SQUARE**	444.90	50 D.F.

(1) Values in italics are p-values on the Wald Chi-Square statistic.
(2) Indicates that variable does not belong to that equation.
(3) PDL variables with restriction in farther end point only.
(4) Current value of export share

The p-values for input prices on the labor share equation indicate that this coefficients are not significantly different from zero. The same is true for the own price coefficient on the real estate share equation. The outptut price variable is highly significant across equations.

For the case of the government intervention shifters, research expenditures is significant in all but the share of labor equation; excess capacity is highly siginificant across equations; and the government payments share of net farm income is highly significant in all but the labor share equation.

The low significance of some key coefficients in the labor share equation -- input prices, research expenditures, government payments share -- might be due to the measurement definition of labor expenditures. According to a USDA-ERS report, farm labor includes the estimated total hours of hired and unpaid operator and family labor used in agricultural production.[47] This definition of labor does not provide information about the existence of excess labor in the form of family labor. Consequently, due to the low significance of these coeffcients, caution must be taken when analyzing the implications of these variables.

Despite the fact that there is not a theory of factor shares, it can be argued from what has been discussed in previous chapters that the parameter signs are as expected, with a few exceptions. In the real estate and variable input equations, the signs of the ratio of prices have the reversed signs. This could be due to two factors: the first due to input aggregation, and the second, as suggested by Frisvold (1991), due to the limited short-run substitution possibilities between this two input groups.

Other variables which might appear to have the reversed signs in all input equations are income, exports, and the government payments share of net

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47 USDA, ERS, "Major Statistical Series of the U.S. Department of Agriculture. Agricultural Production and efficiency." Agricultural Handbook No. 671, Volume 2. October 1989. p.9.

income. All of these variables are related to capital accumulation. The discussion of these issues will be developed immediately after the estimates for θ_i are presented, specifically when analyzing the elasticities of production with respect to the technology shifters. In this way, the analysis will become more apparent as it is related to the productivity issue.

On TABLE 3, the results for the complete model and consequently for the production function in (5.6) are presented. It includes the four equations which encompass the parameters of the Cobb-Douglas and the equation corresponding to the intercept. The system statistics, for the four short-run, input elasticity of production equations, are carried out, given that the parameters for the q_i have been computed directly from TABLE 2. According to the formulation in (5.11) and (5.12), the parameters of θ_i are obtained by multiplying the parameters on $F_{i,t}$, by the inverse of the rate of adjustment, which is defined as one minus the coefficient for the lagged dependent variable.

Estimation Results: Economic Analysis

As in the case of the original estimates, TABLE 3's *p-values* are provided for each of the coefficients in the five equations. From the sixty four (64) coefficients, forty eight (48) are significant at the 5 percent level; the number increases to fifty two (52) if the level of significance is 10 percent. The equation for LogA was estimated assuming a second-degree order of auto-correlated disturbances, and the corresponding statistics also are presented. As in the case of the first stage results, most signs appear to have the right theoretical sign, except for the cases already identified.

TABLE 3.

ESTIMATED PRODUCTION FUNCTION PARAMETERS

	REAL ESTATE	LABOR	FIXED	VARIABLE	INTERCEPT(2)
Intercept	0.3097466	-0.2163588	0.4675455	0.40779561	-1.8613
	.02325	*.19709*	*.00006*	*.00851*	*.21251*
Price Real Estate	-0.4265638				6.6154
	.01599				*.00000*
Price R.Est./Var.Inp.	0.3004988			-0.0988677	
	.01553			*.20600*	
Price Labor		-0.1396151			1.5618
		.41016			*.10181*
Price Labor/FiX.Inp.		-0.0793689	0.07222191		
		.57365	*.00937*		
Price Fixed Inputs			-0.6798871		9.4994
			.00000		*.01081*
Price Variable Inputs				-0.2349058	-3.3121
				.01505	*.08417*
Price Output	0.54197917	0.26013432	0.45763964	0.32383946	-16.052
	.00034	*.00014*	*.00000*	*.00128*	*.00000*
Excess Capacity	1.8321E-05	3.1613E-05	1.2916E-05	2.1027E-05	-0.0007296
	.00920	*.00205*	*.01726*	*.00067*	*.00000*
Weather Index	-0.0026043	-0.0019123	-0.0021052	-0.0022515	0.093652
	.00022	*.00751*	*.00004*	*.00014*	*.00000*
Research Exp. (1)	-3.236E-05	0.00084537	0.00022888	7.9615E-05	-0.0109254
	.62086	*.00000*	*.00157*	*.04784*	*.00000*
Net Farm Income(1)	-1.301E-05	-4.872E-06	-1.508E-05	-6.161E-06	0.0003921
	.00054		*.00000*	*.01907*	*.00000*
Export Share(1)	0.36498944	-2.0879507	0.70810842	0.3559452	7.71516
	.09008	*.00000*	*.00000*	*.00001*	*.03688*
Total Cost	6.6477E-07	3.7606E-06	1.4741E-06	1.3665E-06	-6.911E-05
	.57953	*.00914*	*.09012*	*.15535*	*.00000*
Income Variability	-0.0439871	-0.0545654	-0.0351421	-0.020071	1.3079
	.15798	*.07025*	*.13854*	*.44473*	*.00000*
$(Gov.Pay./NFI)_{t-1}$	-0.114092	-0.0102152	-0.1314317	-0.0715304	3.5976
	.01020	*.79259*	*.00009*	*.03186*	*.00000*
Farm Pop. Share		0.07787372			
		.00000			

(1) Coefficients shown correspond to the sum of PDL lagged coefficients.

(2) In the estimation of equation LogA, the following statistics were obatined: R^2=.9850, RHO1= .83269 (6.0141); RHO2=-.34377 (-2.48287). Number in parenthesis are t-values.

The next table, TABLE 4, presents the values of the elasticity of production with respect to changes in the technology shifters; these parameters also are called elasticity of productivity. The input price coefficients indicate that increases in the prices of real estate and machinery (short-run fixed costs), lead to productivity increases, while an increase in the price of variable inputs (fertilizers, energy, seed, feed and livestock) leads to a downward shift in the production function. The elasticity with respect to the price of labor, although negative, is almost zero. The direction of production shifts due to changes in real estate and variable inputs is consistent with the induced innovation hypothesis. The contrary is concluded from the direction of the shift due to a change in the price of machinery.

The sign of the elasticity with respect to output price is in contradiction with the induced innovation hypothesis. However, from the results of TABLE 3, it can be observed that the output price effect shows a consistent behavior; it is the large influence from the intercept equation which changes the direction of the total effect. The following is a strict interpretation of these signs: an increase in output price shifts the production function upward by increasing the intensity of input use and downward by deinvesting in disembodied technical change.

An alternative hypothesis to explain the sign of the production elasticy with respect to output price might be that as output price decreases, the incentives for innovation increases due to the fact that producer survival is threatened. The source of this hypothesis is Hicks (1935) and Leibenstein (1973) and paradoxically was developed for the case of increased competition in monopolistic markets.

A hypothesis closer to agriculture is Cochrane's (1958) treadmill theory, which states as new technology is adopted, supply shifts to the right at a higher pace than demand driving farm prices down. Late adopters have either to adopt

TABLE 4.

ELASTICITIES OF PRODUCTION WITH RESPECT TO TECHNOLOGY SHIFTERS

TECHNOLOGY SHIFTER	ELASTICITY OF PRODUCTION
Quantity of Real Estate	0.27179952
Quantity of Labor	0.27288087
Quantity of Fixed Inputs	0.17016959
Quantity of Variable Inputs	0.28506927
Price of Real Estate	3.81651132
Price of Labor	-2.302E-05
Price of Fixed Inputs	2.58610774
Price of Variable Inputs	-7.9897437
Price of Output	-0.3624875
Excess Capacity	0.36139947
Weather Index	0.52373376
Research Expenditures	0.18285915
Net Farm Income	0.15563773
Export Share	0.09386995
Total Cost	0.303396
Income Variability	-0.277837
$(\text{Gov. Payments/NFI})_{t-1}$	0.05074036

or go out of business. Thus generalized adoption occurs in a context of falling farm output prices.

All three government intervention variables, excess capacity, research expenditures and the share of government payments on net farm income show a positive effect on productivity. This supports the hypothesis that government programs have had a positive impact on the process of technology adoption. The estimate of elasticity of production with respect to research is relatively high compared to similar estimates. Cline (1970) estimated an elasticity of .037 for the agricultural sector, and Norton (1981) obtained values of public research production elasticities of .105 for cash grain production, .056 for dairy, .022 for poultry and .153 for the case of livestock. However, neither of these studies accounted for the effects of public policies other than research. Hence, the relatively high production elasticity obtained .182, could be the result of accounting for any positive contribution of government programs to technology adoption in agriculture.

The effect of net farm income and export share appears to be consistent with Mundlak's capital accumulation framework described early in Chapter Two. The effect of total expenditures, a proxy for scale, also is positive and consistent with Fawson,Shumway, and Bassman (1990). The sign of the coefficient of variability is as expected, while the effect of weather is not; observe that weather has the expected negative sign in the input equations, as shown in TABLE 3, while a large positive value on the intercept equation dominates the total effect.

The elasticities of the marginal rates of substitution with respect to the technology shifters are presented in TABLE 5. Although the direct and intuitive interpretation of the MRTS in a world with more than two inputs is not straight foreward, it can be confirmed that research expenditures impact all marginal rates. Excess capacity and the government payments variables also have a

TABLE 5.

ELASTICITIES OF MARGINAL RATES OF TECHNICAL SUBSTITUTION (MRTS)

TECHNOLOGY SHIFTER	MRTS R.E.x Labor	MRTS R.E.xFixed	MRTS RExVariable	MRTS LaborxFixed	MRTS LaborxVar.	MRTS FixedxVar.
Price of Real Est.	-0.50805	-0.50805	-0.12130	0.00000	0.38675	0.38675
Price of Labor	0.63918	-0.06374	0.00000	-0.70292	-0.63918	0.06374
Price of Fix. Inp.	-0.25670	2.99699	0.00000	3.25368	0.25670	-2.99699
Price of Var. Inp.	-0.93578	-0.93578	-0.31042	0.00000	0.62536	0.62536
Price of Output	1.29042	-0.86206	1.06387	-2.15248	-0.22654	1.92594
Excess Capacity	-0.15631	-0.02741	-0.02051	0.12890	0.13580	0.00690
Weather Index	-0.26242	0.28440	-0.17166	0.54683	0.09076	-0.45607
Research Exp.	-1.53353	-0.69791	-0.18989	0.83562	1.34363	0.50802
Net Farm Income	-0.89834	1.20722	-0.77813	2.10556	0.12022	-1.98534
Export Share	1.91302	-0.16118	0.13932	-2.07419	-1.77370	0.30049
Total Cost	-0.89824	-0.49265	-0.18604	0.40559	0.71220	0.30662
Inc. Variability	0.04571	0.05357	-0.10962	0.00786	-0.15533	-0.16319
$(Gov.Pay./NFI)_{t-1}$	-0.05340	0.04925	-0.02358	0.10265	0.02982	-0.07283
Farm Pop. Share	-0.98208	0.00000	0.00000	0.98208	0.98208	0.00000

significant impact on the substitution of labor and machinery and between labor and variable inputs. The scale variable, represented by total cost also has a significant impact across input combinations. While the impact of output price is strong across input combinations, the impact of input prices is constrained by the model to the input's own price and the price of its closest substitute.

A more direct way to gauge the elasticity of marginal rates of substitution with respect to the technology shifters is through the measure of technical bias suggested by Antle (1988) and Antle and Capalbo (1988) and that used by Fawson, Shumway, and Bassman (1990).[48] They define a primal measure of Hicksian bias for input i with respect to technology shifter h at given input levels as the following:

$$B_{i,h}(X,\gamma_k) = \sum_j S_j \partial \ln(f_i / f_j) / \partial \ln \gamma_k \tag{5.13}$$

where S_j is the jth input's cost share, f_i is the elasticity of production with respect to the ith input q_i, and γ_k the kth technology shifter. The sign of the parameter B_i indicates the direction of the technical change bias. It would be neutral, factor saving or factor-using if B_i is equal, less or greater than zero. The estimated average values for these measures of bias are presented in TABLE 6.

The direction of the parameters on TABLE 6 show that the bias effect due to research expenditures is against real estate and variable inputs and toward labor and machinery. For the case of labor and variable inputs, this result contradicts the dominant literature, which indicates that technical change is labor-saving and fertilizer using. Here, it is necesary to bear in mind that the definition of research expenditures used is based on an aggregate basis without

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[48] The definition of this measurement of bias can be found in Antle (1988), p.357, and Antle and Capalbo (1988), pp.38-39. This measure was estimated by Fawson, Shumway and Bassman (1990), pp.195-195, for the case of the northeastern region.

TABLE 6

AVERAGE SHARE-WEIGHTED SUMMARY MEASURES
OF HICKSIAN BIAS

TECHNOLOGY SHIFTER	REAL ESTATE	LABOR	FIXED INPUTS	VARIABLE INPUTS
Price of Real Est.	-0.2593329	0.24716858	0.24716858	-0.1384008
Price of Labor	0.16442316	-0.4728019	0.22796832	0.16442316
Price of Fix. Inputs	0.43538922	0.6913013	-2.5524369	0.43538922
Price of Var. Inputs	-0.5023027	0.43061689	0.43061689	-0.1928276
Price of Output	0.50951017	-0.776963	1.36893972	-0.5511105
Excess Capacity	-0.0532757	0.10255896	-0.0259469	-0.0328272
Weather Index	-0.072549	0.18907377	-0.3560847	0.09858846
Research Exp.	-0.591848	0.9369903	0.10392782	-0.402535
Net Farm Income	-0.2628784	0.63271986	-1.466406	0.51286883
Export Share	0.53656068	-1.3706106	0.69724342	0.39766711
Total Cost	-0.3820075	0.51348818	0.10914145	-0.1965376
Inc. Variability	-0.0094812	-0.0550515	-0.062883	0.09980558
$(Gov.Pay./NFI)_{t-1}$	-0.0130047	0.04023434	-0.0621026	0.0105064
Farm Pop. Share	-0.269157	0.70991746	-0.269157	-0.269157

distinguishing the purpose of the research. Hence, it might not be surprising that the direction of the bias due to research does not agree with the literature.

Notice that all three government intervention variables indicate a labor using technical change. This can be interpreted as if government policies have made feasible a slower adjustment in farm labor. The effect of exports is showed to be labor-saving and toward the other inputs; this could be a reflection that when an export expansion occurs, farmers put more acreage in production, using more machinery services, and increasing the use variable inputs. On the other hand, the relative importance of labor decreases because its application does not have to relatively increase as much, due to the possible existence of "excess" labor.

Thus far, the results have been analyzed, emphasizing the effects of government intervention on technological change. It is apparent from the analysis that there is strong evidence to support the hypothesis that policy mechanisms have consistently supported the technological process in the agricultural sector. In the remainder of this chapter, the attention will be focused on the producers response coefficients.

Recall that for a Cobb-Douglas production function in which the production parameters are constant, or are not a function of contemporaneous output price, the short-run supply is given by the expression in (4.15).[49] For these elasticities to have practical value, they must be related to the length of time required by an input to be varied. The total output elasticity Θ is defined as $\Sigma\theta_i$. The range on the summation operator i, indicates the time frame of the supply elasticity. If i includes all inputs, it means that all are assumed variable, hence a long-run supply elasticity. On the contrary, if i is equal to one (variable inputs), it would represent a short-run parameter. It must be taken into account that the Cobb-

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[49] The expression in (4.15) was defined as

Douglas derived-supply elasticities are the maximum potential response and overestimate the true response, but the proportion of increase in intermediate and succeeding lengths of run may not be significantly affected.[50] The latter summarizes one of the chief empirical shortcomings when estimating supply response from a Cobb-Douglas production function. However, keep in mind that the relative changes are significant.

That said, the analysis that follows focused on the short and intermediate terms; that is, when only "variable" inputs are variable (short-run), and when in addition machinery is also variable (intermediate-run). The short-run is considered to last between one and two productive periods, and the intermediate run will imply between three and five years. The implications of longer term variations are of lesser importance due to the fact that, because of changes in short-run variables, the changes implied are unlikely to occur (Tyner and Tweeten, 1967).

If the supply elasticity is defined as (4.15), then the following concept of elasticity of the supply elasticity with respect to technology shifters, can be easily derived:

$$E\varepsilon_{y,p},\gamma_k = \left(\frac{1}{\Sigma\theta_i(1-\Sigma\theta_i)} \Sigma \frac{\partial\theta_i}{\partial\gamma_k} \right) \gamma_k \qquad (5.14)$$

where in the short-run case i equals one (VR), and for the intermediate term i is equal to two (VR and FX).

The expression in (5.14) now represents a function of supply elasticity. Therefore, (5.14) indicates the sensibility of the elasticity function with respect to technology shifter parameters. This is in fact one of the peculiarities of the

50 Tyner and Tweeten (1966), p. 628.

endogenous technology approach, the elasticity is function of the structure of technology represented by the technology shifter variables in TABLE 7.

Looking at the direction and relative size of the coefficients, the agricultural supply elasticity appears to be strongly positively (more elastic) influenced by changes in output prices (long-term tendency), changes in the share of exports, and in the total cost. On the other hand, changes in income (long term tendency) and in weather have a strong negative (more inelastic) effect. The change in excess capacity and in government payments show an opposite effect. While the effect of research expenditures is as expected, small for short periods and towards a more elastic supply.

Regarding the supply elasticity, the short run average was estimated to be .40 while the intermediate term .87. The value of the short-run parameter, although relatively high, is consistent with similar studies using a Cobb-Douglas; Griliches (1959) estimated .28 for the short run, and Tyner and Tweeten (1966) estimates were .45 and .84 for the short and intermediate run respectively. These research supply elasticities also are consistent with more recent studies which emphasize on technology issues. In Weaver (1983) the estimated supply elasticities were between .4 and .73; Shumway (1983) produced estimates ranging from .25 to .72; finally Antle (1984) estimated a coefficient for the supply elasticity equal to .427. None of the last three studies employed a Cobb-Douglas production function. The size of the coefficients and supply elasticities on TABLE 7 are relatively large, which might indicate that the use of a Cobb-Douglas function within an endogenous technology still needs more improvement in its producers response estimation.

TABLE 7

ELASTICITIES OF THE SUPPLY RESPONSE FUNCTION

TECHNOLOGY SHIFTER	SHORT RUN	INTERMEDIATE
Price of Output	4.94097	3.90711
Excess Capacity	0.83492	0.44164
Weather Index	-2.82456	-1.79102
Research Exp.	0.01731	0.02571
Net Farm Income	-1.66095	-0.64309
Export Share	1.56541	0.62904
Total Cost	1.33249	0.90768
Inc. Variability	-0.29613	-0.26694
$(Gov.Pay./NFI)_{t-1}$	-0.12294	-0.11431
TOTAL OWN-PRICE.		
MEAN	0.40275	0.86981
STD DEV.	0.07542	0.25758

CHAPTER VI

A POLICY PREFERENCE FUNCTION FOR U.S. AGRICULTURE

The objective of this chapter is to estimate the relative weights of the economic agents in the agricultural sector; namely farm producers, consumers and the taxpayers. Beyond estimating relative weights, this chapter will examine at the changes of those weights across time. This chapter is based upon the work of Oehmke and Yao (1990) and of Oehmke and Choe (1991). These two studies were presented in Chapter Two of the dissertation. This chapter is an extension of Oehmke's analysis regarding the time path of the changes in the weights, and the level of aggregation. The previously referenced works estimated policy-preferences weights for the cases of wheat, and wheat and corn, respectively.

The Policy Preference Function

The dominant methodology to assess the economic consequences of government market intervention is applied welfare economics. As presented in Chapter Two, it involves the measurement and comparison of changes in consumers' and producers' surpluses and in taxpayers costs, as well as the identification and measurement of any losses in social economic efficiency. There are two traditional assumptions. First, one dollar for consumers is equivalent to one dollar for producers or taxpayers. Secondly, there are no preference among the competing economic interests of three groups: consumers, producers, and taxpayers. The former assumptions underline the concept that public policy is neutral in term of preferences and that no economic interest exercises influence over government policies.

The policy preference function approach is based on Peltzman and Becker views on interest-group competition for political influence and in Buchanan's and Tullock's Public Choice line of thought. Government policy is viewed as the result of a bargaining process between interest groups, and government policies are introduced to transfer wealth from one group in society to another. The government, in this view, is seen purely as a mechanism to transfer wealth, not as an autonomous neutral entity. Powerful interest groups seeking their own benefit manipulate public policies in their behalf. Hence, the policy process becomes a competition among interest groups to dictate the design and implementation of government policies.

Two different approaches to define a policy preference function can be identified, one in which all economic interests are arguments of the objective function but corresponding to each group a different weight. The function then is maximized in an unconstrained fashion.

On the other hand, one can conceptualize a policy preference function which represents the objectives of the dominant or triumphant interest group. This function then could be maximized in a constrained framework, in which the interests of competing groups will represent the constraints in the maximization process. Regardless of the specification of the preference function, both approaches depart from the traditional idea that the government is an independent autonomous entity.

In summary, the government's policy preference function is a representation of the different interest groups involved in the bargaining or competitive process referred above. Previous empirical studies developed in the agricultural economics literature by Rausser and Freebairn (1974) and by Oehmke and collaborators can be considered as following closer the ideas of Becker and Peltzman. The function arguments are indicators of each group's objectives, and specifically in Oehmke's studies, the arguments are consumer surplus, producer surplus and government costs, all of which represent the interests of farm producers, consumers and taxpayers respectively. The specific representation is given by the following function:

$$V(PS,CS,GE) = \sum_{t=0}^{\infty} v(\omega_{1t}\Delta PS_t, \omega_{2t}\Delta CS_t, \omega_{1t}\Delta GE_t) \qquad (6.1)$$

where ΔPS represents change in producers' surplus, ΔCS change in consumers' surplus and ΔGE denotes change in government costs. Each of the ω_{it} parameters represent the weight each interest group's objectives have in the government policy preference function. From the first order conditions of the maximization of (6.1) with respect to the choice of policy instrument will provide enough information to estimate the relative weights of each of the three interest groups.

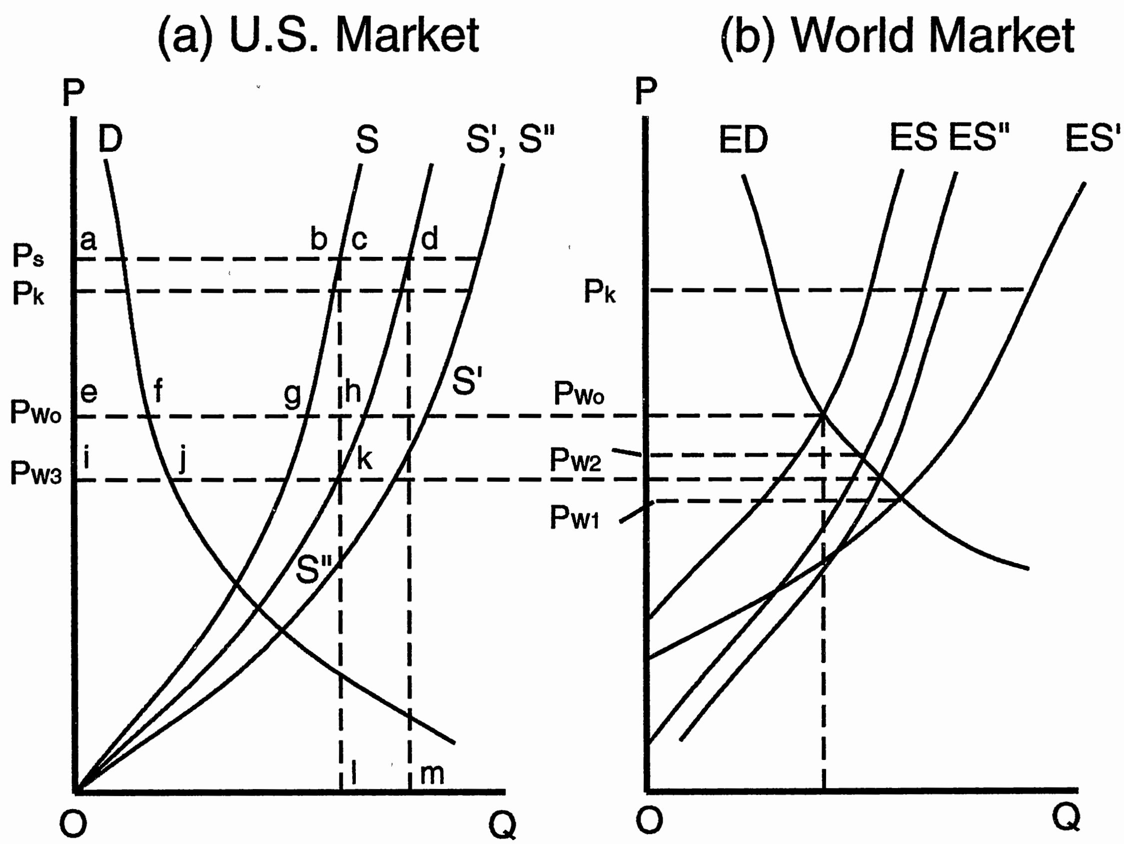
Model Specification

The objective is to estimate the evolution of the implicit relative policy weights on the policy preference function for government intervention in the U.S. agricultural sector, for the period 1945 to 1989. In order to obtain some consistency in the policies implemented for such a period, the following set of simplifying assumptions are made. There are only two kind of policy instruments, public research expenditures which shift the supply function to the right and a support policy which increases the price producers receive. Producers must comply with acreage reduction requirements in order to receive the support price. Then, the impact of these price support programs is to shift the supply inwards. It is assumed that the government holds no inventories, or that the cost of its inventories is small (in this case the cost is assumed to be zero). Also, it is assumed that government policies do not affect the demand or the effects showed are net of demand changes.

The effects of these policy instruments within the context of an open economy can be viewed in Figure 7, where D represents the domestic demand, S the supply curve in the pre-intervention period, and ED and ES the excess demand and excess supply in the pre-intervention period. When the research policy is implemented, the supply shifts to S', causing a similar shift in ES to ES' and consequently a drop in the market price from P_O to P_1. Then, the support price is implemented and, due to acreage restrictions, shifts the supply backwards from S' to S". Consequently, ES' shifts to ES", and the price increases from P_1 to P_3. At a price level P_{NP} below the support price P_s, producers might be indifferent to participate in the support program. Therefore, a kink occurs in the supply curve ES". To evaluate the welfare changes, the situations pre-intervention and post-intervention are compared, and this implies supply curves S and S".

To keep the analysis simple, assume that the agricultural sector can be represented by a set of three constant elasticity functions:

$$S = aP_s^{\sigma} \qquad (6.2)$$



Source: Oehmke, James F. and Xianbin Yao. 1990. "Apolicy Preference Function for Government Intervention in the U.S. Wheat Market." American Journal of Agricultural Economics. 72:631-640.

Figure 7. The Effects of Government Intervention on Agricultural Markets

$$D = dP^{-\delta} \tag{6.3}$$

$$ED = kP^{-\varepsilon} \tag{6.4}$$

also,

$$a = bR^{\rho} \tag{6.5}$$

The supply function is given by (6.2), where a is the supply shifter and σ is the supply eslaticity. In turn, the supply shifter is defined by equation (6.5) as a function of research expenditures (R), and the elasticity of supply with respect to research (ρ). Expressions (6.3) and (6.4), are the domestic and excess demand functions respectively. Variables d and k are function shifters, and δ and ε are the corresponding elasticities of demand. The market equilibrium condition is given by:

$$bR^{\rho}P_s^{\sigma} - dP^{-\delta} = kP^{-\varepsilon} \tag{6.6}$$

Given the above expressions and the information provided in figure 7, the following changes in welfare can be defined:

$$\Delta CS = \int_{P_3}^{P_o} dP^{-\delta}\partial P \quad \text{or area } efji \tag{6.7}$$

$$\Delta PS = \int_{P_o}^{P_s} bP^{\sigma}\partial P + \int_{0}^{P_s}[bR^{\rho}P^{\sigma} - bP^{\sigma}]\partial P \quad \text{or areas } abg'P_3 + c0d \tag{6.8}$$

$$\Delta GE = \int_{P_3}^{P_s} bR^{\rho}P^{\sigma}\partial P + \int_{S(P_3)}^{S(P_s)} \frac{S^{1/\sigma}}{b^{1/\sigma}R^{\rho\sigma}}\partial S \quad \text{or areas } abki + bdml \tag{6.9}$$

The actual evaluation of the above expressions will give an approximate measure of the welfare changes for each interest groups. But they will not provide information about the relative weight of each group within the agricultural policy formulated in the last fifty years, which is this chapter's goal.

The three expressions above (6.7 through 6.9) represent each valid criteria to account for the particular interests of each group. Therefore, if the policy preference function in (6.1) is assumed to be linear, and the measurement of changes in welfare are valid representations of the objectives of each group, then the following policy preference function can be specified:

$$V_t = \omega_{1t}\Delta CS_t + \omega_{2t}\Delta PS_t - \omega_{3t}\Delta GE_t \qquad (6.10)$$

where ω_{1t}, ω_{2t} and ω_{3t}, represent the relative weights of each interest group within the government's objective function in the period t. The maximization of (6.10) with respect to the policy variables price support (P_s) and public financed research (R) will provide a system of first order conditions from which the values for the ω's can be obtained by solving simultaneously the system. The solution of this system of equations is presented in Oehmke and Chan Choe (1991), and it is given by the following expressions:

$$\frac{\omega_{1t}}{\omega_{3t}} = \delta - 1 + \frac{\delta}{P_3} + \frac{k}{d}P_3^{\delta-2} \qquad (6.11)$$

$$\frac{\omega_{2t}}{\omega_{3t}} = -(\sigma + 1) - \frac{\sigma}{P_s} \qquad (6.12)$$

Where each of the variables and parameters are as defined earlier.

The expression in (6.11) gives the relative weight of consumers to taxpayers, while the next equation indicates the relative weight place on producers relative to taxpayers. Providing values for the parameters of the model of the agricultural sector given in (6.2-6.5) allow for a direct estimation (computation) of the weights by replacing the values of the parameters in equations (6.11) and (6.12).

Parameters Specification

There are four parameters which need to be specified in order to completely define the model in (6.2 - 6.5). These are the supply elasticity, the elasticity of supply with respect to research, the domestic demand elasticity and the export demand elasticity. Based on these parameters and the data on supply and utilization, the corresponding shifting parameters (a, b, d, and k) can be defined and the policy weights estimated.

The parameters for the supply elasticity (σ) and for the elasticity of supply with respect to research (ρ) will be derived from the estimates obtained in the previous chapter, while the demand elasticity parameters, domestic and foreign, will be taken from estimates presented in the literature.

From previous analysis, it is already known that the short term supply elasticity in a functional form of the Cobb-Douglas family, as the one defined in chapters four and five, is computed based on the inputs which are consider to be variable inputs in the short run. This classification conveniently corresponds to one of the four input groups defined earlier. The value of the elasticity is given by the already known expression:

$$\sigma = \frac{\theta_{VR}}{1-\theta_{VR}} \tag{6.13}$$

Given that θ_{VR}, as well as the other elasticities of production with respect to inputs, is a function and not a fixed parameter, the expression on (6.13) represents a function of the short-run elasticity for which the parameters are the technology shifters defined in the previous chapters. This elasticity function offers one key advantage and represents a big challenge. The advantage is that the elasticity of supply need not to be fixed across time. In fact, the function provides estimates for all periods in the sample. The challenge, has to do with the determination of the elasticity of supply with respect to research expenditures.

Previous studies by Oehmke wrongly have used the elasticity of production with respect to research as a an equivalent of the corresponding supply elasticity. They have not provided a true elasticity value for this variable because they had lacked the means to estimate them. In this research, a way to provide that true elasticity value exists. The problem, however, is to come up with the appropiate way to compute the true elasticity of supply with respect to research. The following paragraphs explain this in detail.

For a Cobb-Douglas function the supply function is given by:

$$S = A\Gamma(A\Gamma P)^{\frac{\Theta}{1-\Theta}} \tag{6.14}$$

where A is the intercept; $\Theta=\Sigma\theta_i$, P is the output price and Γ is defined as:

$$\Gamma = \prod_{i=1}^{n}\left(\frac{\theta_i}{w_i}\right)^{\theta_i} \tag{6.15}$$

where wi represent input prices, and the other variables are as usual. Throughout out the empirical sections of this research, the value of n has been equatted to four.

It can be directly observed that (6.14) is a function of the θ_i's, among other variables, and consequently also is a function of R. Therefore, a first alternative to calculate the elasticity of supply with respect to research expenditures is directly to derived from (6.14). However, there are some questions which may invalidate this method. If the objective is to compute the short term elasticity, should the elasticity be estimated taking into account all four input categories for the first lag coefficient in all? Should it be estimated taking into account only the variable input? After all, the objective is the short-run parameter. If only the input variable is considered, should only the first lag be included, or the full lag structure should be taken in consideration? The questions themselves are confusing, and the answers may be as well.

A second method to come up with an estimate for the short-run supply elasticity with respect to research first considers the full value of the relevant θ_i, in this case θ_{VR}. Then, consider the same qi but assume no impact of research expenditures; that is, assume α_i =0 for all R_{t-n}. Next, compare the two values as in the expression below:

$$(1+\sigma_{NR})(1+\rho) = (1+\sigma) \tag{6.16}$$

Where,σ_{NR} is the e supply elasticity (price) assuming that the coefficients on R are zero; ρ is the supply elasticity with respect to research, σ is the full supp;y price elasticity.

The short-run supply elasticity with respect to research would be the ratio between one plus the partial elasticity ($1+\sigma_{NR}$), and the impact of the total price elasticity of research ($1+\sigma$). Some of the same questions raised before apply to this formulation. This formulation has an advantage in that it deals with an already defined price elasticity of supply. Given that it is in a short-run formulation, there should be no concerns regarding the number of lags to be included in the formulation. Given this fact and the ease of computation, this formulation was selected to estimate the policy weights defined above.

Regarding the demand parameters, the literature is inconclusive about the size of the demand elasticities, although an original study by Tweeten (1967) estimated aggregate domestic and foreign demand elasticities as weighted average of commodity elasticities. He found that the short run elasticity of supply was -.25 while the export demand was above -6.0 for the long run. Later, Paul Johnson (1977) criticized Tweeten's method, but replicated his estimates. More recently, Barclay (1986) estimated domestic and export aggregate demands within the context of a macroeconomic general equilibrium model. Barclay estimated -.10 for the domestic demand and -1.10 for the export demand elasticity. Due to the lack of relevant estimates, the values of -.25 and -1.10 are chosen as those which better approximate the possible true values.

All parameters involved in the computation of the policy weights are presented in the appendix, as are the data from prices and production, and indexes resulting from an aggregation of ERS data on specific commodities. The export data is expressed in constant dollars and was extracted from various issues of Agricultural Statistics.

Results

The estimated policy weights are presented on TABLE 8 and Figure 8. The estimates show that both consumers' and producers' surpluses have weights above the taxpayers; being producers' weight larger that consumers,. While the relative weight of producers tends to be stable, it has increased in the last decade. Thus, the gap between consumer and producer weights is growing.

The significative decrease in the relative importance of consumers' surplus in the last decade, might be an indication of the reduction in the public research programs due to federal budget pressures. The decrease in consumers' relative importance in the government policy preference function may be due to two reasons. First the relatively small share of income spent on food induces consumers to reduce the priority of agriculture in their agendas. Second, the fact that due to their numbers, consumers are not able always to effectively organize. On the other hand, producers place a high priority in transfers from the government, are relatively small in number, and geographically concentrated. Therefore, with their relative high organizational ability, they are therefore able to exercise political pressure as a group.

The same weights were computed a second time time assuming alternative values for export demand and domestic demand. In neither case did a significant change occur, although it was observed that as export demand becomes less elastic, the relative weights of consumers increased. Conversely as domestic demand becomes less inelastic, consumers weight increases.

One moral from the above results is that as long as the federal budget allowed, both consumers and producers benefited from taxpayers. During times of fiscal budget pressures, producers were able to defend their relative position while consumers lost ground, perhaps due to their double role as consumers and taxpayers. Given that consumers are the primary beneficiaries from research, public research budgets might continue to get some downward pressure as long as consumers do not "feel" the need to regain their relative position in the

TABLE 8
ESTIMATED RELATIVE POLICY WEIGHTS

YEAR	-w1/w3	-w2/w3
1946	1.261203	1.4142754
1947	1.2754301	1.4434528
1948	1.2844746	1.3972367
1949	1.310525	1.5478346
1950	1.2867156	1.4766191
1951	1.2848691	1.4647356
1952	1.3292562	1.5211347
1953	1.3288524	1.529112
1954	1.3220971	1.5465167
1955	1.3179278	1.5912517
1956	1.267704	1.7808959
1957	1.3075959	1.5938565
1958	1.332538	1.4727382
1959	1.3040422	1.656276
1960	1.2932153	1.5938058
1961	1.2889254	1.6419018
1962	1.2953811	1.6900711
1963	1.2593573	1.6589173
1964	1.2554936	1.7137097
1965	1.2756882	1.6824356
1966	1.2582514	1.6849101
1967	1.2690229	1.6943837
1968	1.2964202	1.6575722
1969	1.3289263	1.6124296
1970	1.3033162	1.6505744
1971	1.2949939	1.6279728
1972	1.2971073	1.522923
1973	1.2344684	1.4521067
1974	0.946437	1.6634681
1975	1.137098	1.6610298
1976	1.1267558	1.6904279
1977	1.1066555	1.6960226
1978	1.1076933	1.6214518
1979	1.1299668	1.5176996
1980	1.0028707	1.7051259
1981	1.0471755	1.7181683
1982	1.0954313	1.7501679
1983	1.0577367	1.8834258
1984	1.1018649	1.8107851
1985	1.183855	1.8234187
1986	1.2166209	1.8068126
1987	1.1909358	1.6641409
1988	1.0474306	1.8084728
1989	1.0523168	1.7273618

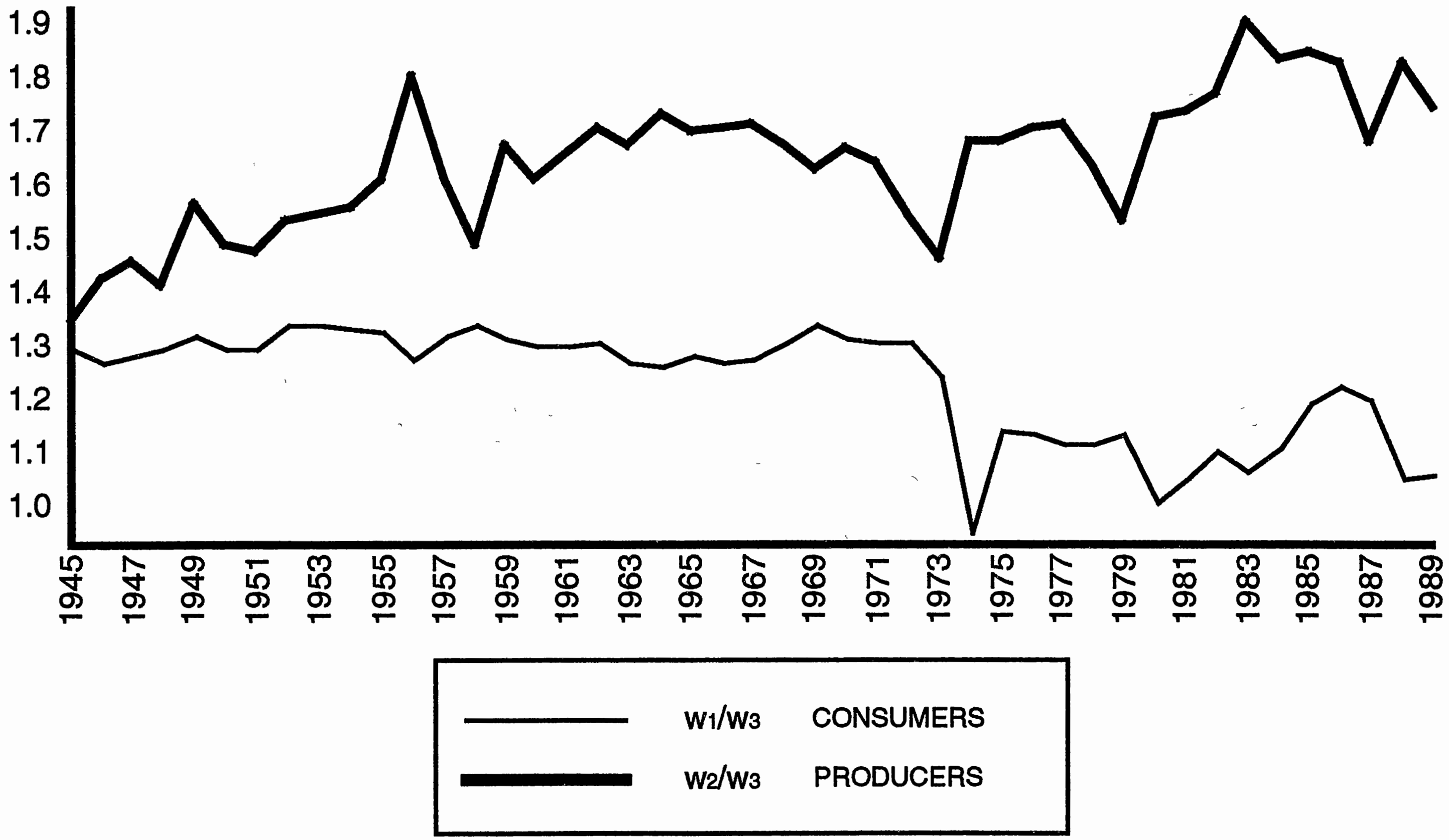


Figure 8. Changes in Consumers' and Producers' Relative Policy Weights

government agricultural policy preference function. According to Oehmke and Yao (1990), the funding for research is below its efficiency level, and because the low value placed on consumer benefits, the government will continue to underfund agricultural research. As long as fiscal pressures persists, farm producers must have to continue to be effective lobbyists in order to defend their relative and absolute position in view of the increasing need for reduced government expenditures.

CHAPTER VII

SUMMARY AND CONCLUSIONS

This research explicitly recognizes the interdependence between income support and public research policies in agriculture and, consequently, integrates those two sets of policies in the estimation of supply response parameters. The specific objectives of this study as specified in the introduction were the following:

1. To assess the relative size of net benefits to agriculture, and their distribution among farm and non-farm groups, from the policies described above.

2. To develop elasticity functions useful to describe the changes in the elasticity parameters across time, due to the adoption of new technology.

3. To determine the characteristics of the interaction between farm programs and public research policy in fostering technical change.

4. To estimate an aggregate government Policy Preference Function for the agricultural sector.

In order to address the objectives above, this study was organized in an introduction and five chapters. A brief summary of each chapter is presented below.

The literature reviewed in Chapter II documents the background for three key issues in this research: the policy analysis framework upon which this research is based, the endogenous technical approach, and the economics of technical change in agriculture.

A body of literature supports the relevance of applied classical welfare economics as a method for evaluating social effects of public policies. This literature acknowledges the limitations of welfare economics and provides guidelines to overcome these shortcomings when dealing with equity and distribution effects and subjective interpersonal comparisons. Additionally, based on Rausser's theoretical contribution, a policy preference function (PPF) is hypothesized to be an empirical, tractable representation of the relative weights assigned by policy makers to the different interests affected by the implemented public policy. The PPF recognizes the subjective character of government policy.

Previous research on the simultaneous analysis of public research and producers' support policies advocates applied welfare economics as a valid tool. But most findings are restricted by shortcomings of the supply relationship. A common problem with previous studies is the estimation of supply function and price elasticities without allowing for interaction between public research programs and direct government intervention. This synergism is precisely the issue this dissertation addresses.

Regarding the evolution of the endogenous technology approach, a complete model developed by Mundlak was used to illustrate the approach. In general the endogenous technology approach implies that other variables -- excluding input and output physical quantities -- called technology shifters have a key role on production function estimation.

Additionally, research discussing the main variables which influence the supply (generation) and demand (adoption) of new technologies was reviewed. The literature reviewed documents the importance of public policy in the generation and adoption of new technologies. Because benefits from research in agriculture are difficult for private firms to capture, the role of public-supported research is evident. Consequently, the demand for research responds to private and public factors, the latter being the result of the political-economic bargaining process among farmers, agribusinesses, and consumers.

In Chapter III, several methodological issues related to the estimation of production response parameters were addressed. Alternative approaches to producers response estimation were discussed. It was concluded that econometric methods are best suited to the estimation of supply response parameters involving an endogenous technology approach. The robustness of the estimates will depend, among other things, on the support the model has from economic theory. Also, the better the representation of the technology underlying producers behavior, the higher the reliability and consistency of the estimates will be. The specification of the empirical model of this research considered the set of characteristics desirable on a production function such as flexibility, ease of interpretation, parsimonious in parameters, and ease of computation; it also considered the tradeoffs these characteristics impose. Finally, there is ample evidence in support of the endogenous technology approach as a consistent methodology to analyze the technology adoption process in agriculture.

Although the Cobb-Douglas function initially was classified as non-flexible, recent research has shown that the introduction of the endogenous technical change hypothesis in a Cobb-Douglas environment allows a more flexible and consistent modeling structure. The endogenous technology approach brings into play potential theoretical and empirical traps which should be avoided by the researcher so as not to invalidate or make intractable the empirical analysis.

In Chapter IV, the components of the empirical model are specified. The production function is specified as a Cobb-Douglas form with varying coefficients. This functional form has the following advantages: parsimonious in parameters, facile interpretation, consistent forecasting behavior, well-founded in economic theory, and flexible in its technology shifter parameters. The corresponding shortcomings and limitations are presented later.

The discussion on the form of government intervention variable(s) to be used as a technology shifter representing policy influences in technology adoption indicated that a measure of excess capacity is preferred over more conventional variables suggested by Houck and collaborators. Excess capacity, as an indicator of the amount of resources transferred to producers, fits into Mundlak's capital accumulation requirement to speed technical adoption. The shortcomings of excess capacity also were addressed, namely the potential simultaneity problem generated by the fact that the excess capacity in itself is determined by government intervention. Another shortcoming of excess capacity is its inability to capture changes in the size of deficiency or diversion payments.

The lag structure on research expenditures was assumed to have the traditional inverted V shape. However, a 30-year lag was considered appropriate, based on statistical results and new research by Pardey (1989), which suggests the length of the lag structure is longer than conventionally thought.

In Chapter V, the empirical production function is estimated in two stages. First, factor share estimates were computed using an iterative seemingly unrelated equations estimator, which under the assumption of normal disturbances is considered a maximum likelihood estimator. As suggested by Tyner and Tweeten, a partial adjustment hypothesis was introduced to model the short-run inequality between factor shares and production elasticities. Next, the intercept equation was estimated using ordinary least squares and considering second-order, auto-correlated disturbances. Observations on the intercept were estimated as residuals of output. The estimated results showed good statistical properties.

From the statistical estimation, several measures relevant to technological change were calculated. Regarding the production elasticity, all government policy variables showed a positive sign and were highly significant, supporting the hypothesis that farm programs have positively contributed to the adoption of new technology in agriculture.

The above results suggest that to actually estimate rates of return to research, the cost side should include the cost of government programs other than public research funding. Moreover, if farm programs have supported the implementation of new technology in agriculture, the cost of those programs also should be considered as a cost in a rate of return computation.

A production elasticity of .18 was estimated for research expenditures; this estimate is significantly higher than the previous literature suggests. The size of this coefficient might be influenced by the positive impact on productivity of the government intervention variables and by the significant increase in lag length.

Other significative results include the evidence favoring the hypothesis of a positive relationship between exports and technology adoption. This result can be understood as the positive role of exports in farmer capital accumulation. Given that increases in exports usually are accompanied by higher prices and higher net farm incomes, this result is consistent with historical observations.

The estimated elasticity of production with respect to output price showed a negative sign. This result suggests a process in which producers adopt new technologies in a context of falling real output prices. Although the situation described contradicts the Induced Innovation Hypothesis, it is compatible with Cochrane's "tread-mill" hypothesis. Also, this sign is not surprising if under falling prices, the survivability of producers is threatened and therefore pressure to adopt cost-saving techniques is created. This negative sign in the production elasticity with respect to price does not imply a negative sign in the supply function.

Primal measures of Hicksian technical bias were computed. Regarding government intervention variables, the measured all were found to be labor-using. This result provides some support for the hypothesis that government policies have eased the adjustment of labor out of agriculture. The bias due to research expenditures was found to be saving for real estate and variable inputs, and using for fixed inputs and labor. These results seem to contradict previous research regarding labor bias; however, due to the low statistical significance of the corresponding parameter, this contradiction might not be a problem.

Also in Chapter V, a supply elasticity function was developed, and the corresponding response parameters were estimated. According to the empirical findings, the changes in agricultural supply elasticity are related directly to changes in excess capacity, output price, export share and total cost or scale. In the other hand, the agricultural supply elasticity is inversely related to variations in government payments, income and weather. The effect of research expenditures was found to be as expected, increasing in time and moving toward a more elastic agricultural supply.

Regarding the supply elasticity, the short-run average was estimated to be .40 while the intermediate term .87. Though the short-run parameteris high, is consistent with similar studies using a Cobb-Douglas; Griliches (1959) estimated .28 for the short run, and Tyner and Tweeten (1966) estimates were .45 and .84 for the short and intermediate run respectively. These research supply elasticities also are consistent with more recent studies which emphasize technology issues. In Weaver (1983) the estimated supply elasticities were between .4 and .73; Shumway (1983) produced estimates ranging from .25 to .72; finally Antle (1984) estimated a coefficient for the supply elasticity equal to

.427. None of the last three studies employed a Cobb-Douglas production function.

Considering the production-response parameters estimated in Chapter VI, the relative weights of a government policy preference function for agriculture were estimated as an extension of previous work by Oehmke. The results indicate that both producers and consumers have benefited consistently from government policy, relative to taxpayers. The higher relative weight for producers over consumers surplus is consistent with the advantages of producers in terms of organization and vital interests. The persistent fiscal budget problems of the last decade is likely to affect consumers the most and producers the least. By reducing real public research funding, the consumer share of benefits is negatively affected. As long as producers are able to hold on to the benefits they get from farm programs, the public policy bias towards producers will increase.

Topics for Further Research

Many questions remain unanswered, and some results remain to be re-evaluated. Here is a list of issues which need addressing.

First, response parameters of the Cobb-Douglas production function are very sensitive to the size of the elasticities of production with respect to input use (q_i) and could considerably bias other parameters sizes. Alternative production function functional forms need to be found while maintaining some of the advantages of the Cobb-Douglas form.

Although excess capacity fits well under the endogenous technology approach used here, two limitations need to be addressed. First is the simultaneity between policy variables and excess capacity. Second, is the need to completely represent the effects of government policies.

The estimation of an elasticity function has brought new questions regarding the proper definition of the supply elasticity with respect to research expenditures. Although this is a question closely related to the functional form chosen, the differentiation in the literature between production elasticity of research and supply elasticity of research is obscure.

Regarding input and output price variables, arbitrary definitions based on past observations were used. There is a need to build price expectations closely within the framework of economic theory. Also, the relevance of including current price information should be reconsidered.

Also, as has been suggested by others in the literature, public research expenditures should not be an exogenous variable. Its endogenization could provide valuable information in designing mechanisms which assure a steady technological development process. Also, private research expenditures need to be included in the analysis to account for all sources of production technologies.

Finally, this research does not provide an estimate of the rate of return to research. Moreover, following the interest group theory as a driving force of government policy, the significance of the concept of rate of return as a mechanism to allocate public research funding has to be questioned.

REFERENCES

Alston, Julian M., Geoff W. Edwards, and John W. Freebairn. 1988. "Market Distortions And Benefits From Research." American Journal of Agricultural Economics. 70:281-288.

Antle, John E. 1984. "The Structure of US Agricultural Technology, 1910-78." American Journal of Agricultural Economics. 66:414-421.

Antle, John E. 1988. "Dynamics, Causality and Agricultural Productivity." In Agricultural Productivity Measurement and Explanation, Susan M. Capalbo and John M. Antle editors. Resources For The Future.

Antle, John E. and Susan M. Capalbo. 1988. "An Introduction to Recent Developments in Production Theory and Productivity Measurement." In Agricultural Productivity Measurement and Explanation, Susan M. Capalbo and John M. Antle editors. Resources For The Future.

Askari, Hossein and John Thomas Cummings. 1976. Agricultural Supply Response: A survey of the econometric evidence. Praeger Publishers.

Askari, Hossein and John Thomas Cummings. 1977. "Estimating Agricultural Supply Response with the Nerlove Model: A Survey."International Economic Review. 18:257-292.

Bailey, Kenneth W. and Abner W. Womack. 1985. "Wheat Acreage Response: A Regional Ecomometric Investigation." Southern Journal of Agricultural Economics. 17:171-180.

Barclay, Thomas N. 1986. "Macroeconomic Impacts on United States Agriculture: A Simulation Analysis." Unpublished PhD. dissertation, Oklahoma State University.

Basmann, R.L., K.J. Hayes and D.J. Slottje and D.J. Molina. 1987. "A New Method For Measuring Technical Change." Economic Letters. 25:329-333.

Beattie, Bruce R. and C. Robert Taylor. 1985. The Economics of Production. John Wiley & Sons.

Becker, Gary S. 1983. "A Theory of Competition Among Pressure Groups for Political Influence." The Quarterly Journal of Economics. 98:371-400.

Berndt, Ernst R. 1991. The Practice of Econometrics. Addison-Wesley Publishing Company.

Bigman, David, David Newbery, and David Zilberman. 1988. "New Approaches in Agricultural Policy Research: Discussion." American Journal of Agricultural Economics. 70:460-461.

Buccola, Steven T. 1988. "Social Welfare and Interpersonal Utility Comparisons in Applied Policy Research." American Journal of Agricultural Economics. 70:454-458.

Buchanan, James M. 1989. Essays on the Political Economy. University of Hawaii Press.

Buchanan, James M. 1990. "Public Finance and Public Choice." National Tax Journal. 28:383-394.

Cavallo, Domingo and Yair Mundlak. 1982. "Agriculture and Economic Growth: The case of Argentina." Research Report 36. International Food Policy Research Institute.

Chamberlain, Edward. 1939. The Theory of Monopolistic Competition. Harvard University Press.

Chambers, Robert G. 1988. Applied Production Analysis: A dual approach. Cambridge University Press.

Cline, Philip L. 1975. "Sources of Productivity Change in United States Agriculture." Unpublished PhD dissertation, Oklahoma State University.

Cochrane, Willard W. 1958. Farm Prices: Myth and Reality. University of Minnesota Press.

Coeymans, Juan and Yair Mundlak. 1987. "Agriculture and Economic Growth: The Case of Chile, 1960-1982". Mimeo. International Food Policy Research Institute.

Colman, David. 1983. "A Review of the Arts of Supply Response Analysis." Review of Marketing and Agricultural Economics. 51:201-230.

Currie, John M., John A. Murphy, Andrew Schmitz. 1971. "The Concept of Economic Surplus and its use in Economic Analysis." The Economic Journal. 81:741-799.

Danin, Y. and Yair Mundlak. 1979. "The Introduction of a New Technique and Capital Accumulation." Working Paper 7909. The Center for Agricultural Economics Research, Rehovat, Israel.

De Janvry, Alain. 1972a. "Optimal Levels of Fertilization Under Risk: The Potential for Corn and Wheat Fertilization Under Alternative Price Policies in Argentina." American Journal of Agricultural Economics. 54:1-10.

De Janvry, Alain. 1972b. "The Generalized Power Function." American Journal of Agricultural Economics. 54:234-237.

Debertin, David L. 1986. Agricultural Production Economics. Macmillan Publishing Company.

DeGorter, Harry and George Norton. 1989. "The Critical Appraisal of Analyzing Gains from Research with Market Distortion." Unpublished paper, Department of Agricultural Economics, Cornell University.

Del Valle, Manuel R. 1989. " A Regional Econometric Model For Policy Evaluation: The Agricultural Sector of Oklahoma." Unpublished PhD dissertation. Oklahoma State University.

Diamond, Peter. 1980. "Efficiency with Uncertain Supply." Review of Economic Studies. 47:645-651.

Duffy, Patricia A., James W. Richardson, and Michael K. Wohlgenant. 1987. "Regional Cotton Acreage Response." Southern Journal of Agricultural Economics. 19:99-109.

Dvoskin, Dan. 1988. "Excess Capacity in U.S. Agriculture: An Economic Approach to Measurement." Research and Technical Division, ERS, USDA, Agricultural Economic Report No.580.

Evenson, Robert E. 1967. "The Contribution of Agricultural Research to Production." Journal of Farm Economics. 49:1415-1425.

Evenson, Robert E. 1968. "The Contribution Of Agricultural Research And Extension To Agricultural Production." Unpublished PhD dissertation, University of Chicago.

Evenson, Robert E. 1974. "Research, Farm Scale, And Agricultural Production." Economics Growth Center, Yale University.

Evenson, Robert E. 1984. "Technical Change In U.S. Agriculture." In Government and Technical Change: A Cross Industry Analysis. Edited by R. Nelson. Pergamon Press

Evenson, Robert E. 1988. "Research, Extension, And U.S. Agricultural Productivity: A Statistical Decomposition Analysis." In Agricultural Productivity. Measurement and Explanation, Susan M. Capalbo and John M. Antle editors. Resources For The Future.

Evenson, Robert E., Paul E. Waggoner, Vernon W. Ruttan. 1979. "Economic Benefits from Research: An Example from Agriculture." Science. 205:1101-1107.

Fawson, Chris and C. Richard Shumway. 1991. "Endogenous Regional Agricultural Production Technologies." Unpublish paper.

Fawson, Chris and Pablo E. Gottret. 1988. "Regional and U.S. Agricultural Product Supplies and Input Demands: Data Documentation." Faculty Paper Series No.88-3. Department of Agricultural Economics, Texas A&M University.

Fawson, Chris, C. Richard Shumway, and Robert L. Basmann. 1990. "Agricultural Production Technologies with Systematic and Stochastic Technical Change." American Journal of Agricultural Economics. 72:182-189.

Feder, Gershon and Roger Slade. 1985. "The Role of Public Policy in the Difusion of Improved Agricultural Technology." American Journal of Agricultural Economics. 67:423-428.

Feder, Gershon, Richard E. Just, and David Zilberman. 1985. "Adoption of Agricultural Innovations in Developing Countries." Economic Development and Cultural Change. 33:255-298.

Frisvold, George B. 1990. "Endogenous Technological Change in U.S. Agriculture. A Direct Test of the Induced Innovation Hypothesis." Technical Bulletin No. 1790. ERS. USDA.

Fulginiti, Lilyan E. and Richard K. Perrin. 1991. "Prices and Productivity in Agriculture." Journal Paper No. J-14462 of the Iowa Agriculture and Home Economics Experiment Station.

Fuss, Melvyn, Daniel McFadden, and Yair Mundlak. 1978. "A Survey of Functional Forms in the Economic Analysis of Production." In Production Economics: A Dual Approach to Theory and Applications. Volume 1. Melvyn Fuss and Daniel McFadden editors. North Holland.

Gardner, Bruce L. 1983. "Efficient Re distribution Through Commodity Markets." American Journal of Agricultural Economics. 65:225-234.

Gardner, Bruce L. 1987a. The Economics of Agricultural Policies. Macmillan Publishing Company.

Gardner, Bruce L. 1987b. "Causes of U.S. Farm Commodity Programs." Journal of Political Economy. 95:290-310.

Gardner, Bruce. 1988. "Price Supports and Optimal Agricultural Research." Working Paper #88-1. Department of Agricultural and Resource Economics. University of Maryland.

Garst, Gail D., and Thomas A. Miller. 1975. "Impact of the Set-Aside Programs on the US Wheat Acreages." Agricultural Economics Research. 27:30-37.

Griliches, Zvi. 1958. "Research Cost and Social Returns: Hybrid Corn and Related Innovations." Joutnal of Political Economy. 66:419-431.

Griliches, Zvi. 1959. "The Demand for Inputs in Agriculture and a Derived Supply Elasticity." Journal of Farm Economics. 41:309-322.

Griliches, Zvi. 1963. "Estimates Of The Aggregate Agricultural Production Function From Cross-sectional Data." Journal of Farm Economics. 45:429-426.

Griliches, Zvi. 1964. "Research Expenditures, Education, and the Aggregate Agricultural Production Function." American Economic Review. 54:961-974.

Guttman, Joel M. 1978. "Interest Groups And The Demand For Agricultural Research." Journal of Political Economy. 86:467-484.

Hallam, J. Arne. 1988. "Measuring Economic Welfare: Is Theory a Cookbook?." American Journal of Agricultural Economics. 70:442-447.

Hallberg, M.C. 1989. "Resource Adjustments in American Agriculture." In Surplus Capacity and Resource Adjustment in American Agriculture: Conference Proceedings. M.C. Hallberg, Jon Brandt, Robert House, James Langley, and William Meyers editors. AERS 204, Department of Agricultural Economics and Rural Sociology, Agricultural Experiment Station. The Pennsylvania State University.

Harberger, Arnold. 1971. "Three Basic Postulates for Applied Welfare Economics: an interpretive Essay." Journal of Economic Literature. 9:785-797.

Hart, Oliver D. 1975. "On The Optimality of Equilibrium When The Market Stucture Is Incomplete." Journal of Economic Theory. 11:418-443.

Heady, Earl. 1949. "Basic Economic and Welfare Aspects of Farm Technological Advance." Journal of Farm Economics. 31:293-316.

Henderson, James M. and Richard E. Quandt. 1980. Microeconomic Theory. A Mathematical Approach. Third edition. McGraw-Hill Book Company.

Hicks, John R. 1932. The Theory Of Wages. Macmillan, London.

Hicks, John R. 1935. "Annual Survey of Economic Theory: Monopoly." Econometrica. 3:1-20.

Houck, James P. and Mary E. Ryan. 1972. "Supply Analysis for Corn in the US: The Impact of Changing Government Programs." American Journal of Agricultural Economics. 54:184-191.

Houck, James P., Maritn E. Abel, Mary E. Ryan, Paul W. Gallagher, Robert G. Hoffman, and J.B. Penn. 1976. "Analyzing the Imapct of Government Programs on Crop Acreage." Technical Bulletin No.1548, ERS, USDA.

Huffman, Wallace E. and John A. Miranowski. 1981. "An Economic Analysis Of Expenditures On Agricultural Experiment Station Research." American Journal of Agricultural Economics. 63:104-118.

Innes, Robert D. and Gordon C. Rausser. 1989. "Incomplete Markets and Government Agricultural Policy." American Journal of Agricultural Economics. 71:915-931.

Johnson, Paul. 1977. "The Elasticity of Foreign Demand for U.S. Agricultural Products." American Journal of Agricultural Economics. 59:735-736.

Judge, George G., R. Carter Hill, William E. Griffiths, Helmut Lutkepohl, and Tsoung-Chao Lee. 1985. Introduction to the Theory and Practice of Econometrics. Second edition. John Wiley & Sons.

Just, Richard E. 1988. "Making Economic Welfare Analysis Useful in the Policy Process: Implications of the Public Choice Literature." American Journal of Agricultural Economics. 70:448-453.

Just, Richard E., and David Zilberman. 1983. "Stochastic Structure, Farm Size and Technology Adoption in Developing Agriculture." Oxford Economic Papers. 35:307-328.

Just, Richard E., and David Zilberman. 1988. "The Effects of Agricultural Development Policies on Income Distribution And Technological Change in Agriculture." Journal of Development Economics. 28:193-216.

Just, Richard E., David Zilberman and Gordon C. Rausser. 1980. "A Putty-Clay Approach to the Distributional Effects of New Technology Under Risk." In Operations Research in Agriculture and Water Resources. D.Taron and C. Tapiero editors. North-Holland Publishing Company.

Klein, Lawrence R. 1953. A Textbook of Econometrics. Row, Peterson.

Knutson, Marlys and Luther G. Tweeten. 1979. "Toward an Optimal Rate of Growth in Agricultural Production Research and Extension." American Journal of Agricultural Economics. 61:70-76.

Lee, David R. and Peter G. Helmberber. 1985. "Estimating Supply Response in the Presence of Farm Programs." American Journal of Agricultural Economics. 67:193-203.

Leibenstein, H. 1973. " Competition and X-Efficiency: Reply." Journal of Political Economy. 81:765-777.

Lichtenberg, Erik and David Zilberman. 1986. "The Welfare Economics of Price Supports in U.S. Agriculture." American Economic Review. 76:1135-1141.

Lidman, Russel, Lee D. Badwen. 1974. "The Impact of Government Programs on Wheat Acreage." Land Economics. 50:327-335.

Lindner, R.K. and F.G. Jarrett. 1978. "Supply Shifts and the Size of Research Benefits." American Journal of Agricultural Economics. 60:48-58.

Little, Ian M.D. 1957. A Critique of Welfare Economics. Oxford University Press.

Marschak, Jacob and William H. Andrews, Jr. 1944. "Random Simultaneous Equations and the Theory of Production." Econometrica. 12:143-205.

McGuirk, Anya and Yair Mundlak. 1991. "Incentives and Constraints in the Transformation of Punjab Agriculture." Research Report 87. International Food Policy Research Institute.

Miller, Tracy and George Tolley. 1989. "Technology Adoption and Agricultural Price Policy." American Journal of Agricultural Economics. 71:847-857.

Morzuch, B.J., R.D. Weaver, and P.G. Helmberger. 1980. "Wheat Acreage Supply Reponse Under Changing Farm Programs." American Journal of Agricultural Economics. 62:29-37.

Mundlak, Yair and Irving Hoch. 1965. "Consequences of Alternative Specifications in Estimation of Cobb-Douglas Production Functions." Econometrica. 33:814-828.

Mundlak, Yair and Ren e Hellinghausen. 1982. "The Intercountry Agricultural Production Function: Another View." American Journal of Agricultural Economics. 64:664-672.

Mundlak, Yair, Domingo Cavallo and Roberto Domenech. 1989. "Agriculture and Economic Growth in Argentina, 1913-1984". Research Report 76. International Food Policy Research Institute.

Mundlak, Yair. 1988. "Capital Accumulation, The Choice Of Techniques, And Agricultural Output." In Agricultural Price Policy for Developing Countries. Edited by John W. Mellor and Raisuddin Ahmed. The John Hopkins University Press.

Mundlak, Yair. 1988. "Endogenous Technology and The Measurement of Productivity." In Agricultural Productivity Measurement and Explanation, Susan M. Capalbo and John M. Antle editors. Resources For The Future.

Nerlove, Marc. 1958. The Dynamics Of Supply: Estimation of Farmers' Response to Price. The John Hopkins University Press.

Norton, George W. 1981. "The Productivity and Allocation of Research: U.S. Agricultural Experiment Stations, Revisited." North Central Journal of Agricultural Economics. 3:1-10.

Oberhofer, Walter and Jan Kmenta. 1974. "A General Procedure for Obtaining Maximum Likelihood Estimates in Generalized Regression Models." Econometrica. 42:579-590.

Oehmke, James F. 1988. "The Calculation of Returns to Research in Distorted Markets." Agricultural Economics. 2:291-302.

Oehmke, James F. and Xianbin Yao. 1990. "Apolicy Preference Function for Government Intervention in the U.S. Wheat Market." American Journal of Agricultural Economics. 72:631-640.

Oehmke, James F. and Young Chan Choe. 1991. "The Political Economy of U.S. Research and Price Policy." Paper prepared for the Festschrift Symposium in Honor of D. Gale Johnson, Chicago, May 3-4, 1991.

Pardey, Philip G. and Barbara Craig. 1989. "Causal Relationship between Public Sector Agricultural Research Expenditures and Output." American Journal of Agricultural Economics. 71:9-19.

Pardey, Philip G., W.M. Eveleens, and M.L. Hallaway. 1991. "A Statistical History of U.S. Agricultural Research: 1889 to 1986." University of Minnesota, CIFAP, (forthcoming).

Peltzman, Sam. 1976. "Towards a More General Theory of Regulation." Journal of Law and Economics. 19:211-240.

Peterson, Willis L. 1967. "Return To Poultry Research In The United States." Journal of Farm Economics. 49:656-669.

Peterson, Willis L. 1971. "The Returns To Investment In Agricultural Research." In Resource Allocation In Agricultural Research. Edited by Walter L. Fishel. University of Minnesota Press

Pray, Carl E. and Catherine Neumeyer. 1989. "Impact of Technology Policy on Research in the Agricultural Input Industries." Paper presented at the AAEA Anual Meeting, Baton Rouge, Louisiana.

Quance, Leroy and Luther G. Tweeten. 1972. "Excess Capacity and Adjustment Potential in U.S. Agriculture." Agricultural Economics Research. 24:57-66.

Rastegari Henneberry, Shida and Luther G. Tweeten. 1991. "A Review of International Agricultural Supply Response." Journal of International Food and Agribusiness Marketing. 2:49-95.

Rausser, Gordon C. 1982. "Political Economic Markets: PERTs And PESTs In Food And Agriculture." American Journal of Agricultural Economics. 64:821-833.

Rausser, Gordon C. and J.W. Freebairn. 1974. "Estimation of Policy Preference Functions: An Application to U.S. Beef Import Quotas." Review of Economics and Statistics. 56:437-449.

Ray, Daryll E. and James S. Plaxico. 1988. "The Economic Structure Of Agriculture: Rhetoric Versus Reality." Unpublished paper, Department of Agricultural Economics, Oklahoma State University.

Rose-Ackerman, Susan and Robert E. Evenson. 1985. "The Political Economy Of Agricultural Research And Extension: Grants, Votes, And Reapportionment." American Journal of Agricultural Economics. 67:1-14.

Ruttan, Vernon W. and Yujiro Hayami. 1988. "Induced Technical Change In Agriculture." In Agricultural Productivity Measurement and Explanation, Susan M. Capalbo and John M. Antle editors. Resources For The Future.

Schltz, Theodore W. 1953. "The Economic Organization of Agriculture." Mc Graw Hill Book Company.

Schmitz, Andrew and David Seckler. 1970. "Mechanized Agriculture And Social Welfare: The Case Of The Tomato Harvester." Journal of Farm Economics. 52:569-578.

Sharples, J.A. 1969. "The Representative Farm Approach to Estimation of Supply Response." American Journal of Agricultural Economics. 51:353-360.

Shumway, C. Richard. 1983. "Supply, Demand, and Technology in a Multiproduct Industry: Texas Fiels Crops." American Journal of Agricultural Economics. 65:748-760.

Stallings, James L. 1960. "Weather Indexes". Journal of Farm Economics. 42:180-186.

Sutton, John, Michael Young, and Klaus Alt. 1989. "Excess Capacity or Overinvestment: Relevance for Policy Reform in U.S. Agriculture." In Surplus Capacity and Resource Adjustment in American Agriculture: Conference Proceedings, M.C. Hallberg, Jon Brandt, Robert House, James Langley, and William H. Meyers, editors. AERS204, Department of Agricultural Economics and Rural Sociology, Agricultural Experiment Station, The Pennsylvania State University.

Swamy, P.A.V.B, Leonard A. Lupo and John D. Sneed. 1989. "Coherent Methods of Estimating Technical Progress." Finance and Economics Discussion Series No.77. Federal Reseve Board, Washington, D.C.

Technical Committee of Interregional Hatch Project 6 (IR-6). 1990. "Economic Evaluation of Agricultural Research." IR-6 Information Report No.90-1. May, 1990.

Teigen, Lloyd D. 1988. "Agricultural Policy,Technology Adoption, And Farm Structure." Agricultural and Trade Analysis Division, ERS, Staff Report AGES 880810.

Tweeten, Luther G. 1967. "The Demand for united States Farm Output." Food Research Institute Study, 7:343-369.

Tweeten, Luther G. and C. Leroy Quance. 1967. "Positivistic Measures of Aggregate Supply Elasticities: Some New Approaches." American Journal Of Agricultural Economics. 51: 342-352.

Tweeten, Luther. 1979. Foundations of Farm Policy. University of Nebraska Press, Lincoln.

Tweeten, Luther. 1987. "Economics Of Major Commodity Programs." Unpublished paper, Department of Agricultural Economics, Oklahoma State University.

Tweeten, Luther. 1989. "Technological Progress, Productivity, and the Productive Capacity of American Agriculture." In Surplus Capacity and Resource Adjustment in American Agriculture: Conference Proceedings. M.C. Hallberg, Jon Brandt, Robert House, James Langley, and William Meyers editors. AERS 204, Department of Agricultural Economics and Rural Sociology, Agricultural Experiment Station. The Pennsylvania State University.

Tweeten, Luther. 1989a. Farm Policy Analysis. Westview Press.

Tyner, Fred H. and Luther G. Tweeten. 1964. "Excess Capacity in U.S. Agriculture." Agricultural Economics Research. 16:23-31.

Tyner, Fred H. and Luther G. Tweeten. 1965. "A Methodology for Estimating Production Parameters." Journal of Farm Economics. 47:1462-1467.

Tyner, Fred H. and Luther G. Tweeten. 1966. "Optimum Resource Allocation in U.S. Agriculture." Journal of Farm Economics. 48:613-631.

Ulveling, Edwin F. and Lehman B. Fletcher. 1970. "A Cobb-Douglas Production Function with Variable Returns to Scale." American Journal of Agricultural Economics. 52:322-326.

Wallace, T.D. 1962. "Measures Of Social Costs Of Agricultural Programs." Journal of Farm Economics. 44:580-594.

Weaver, R.D. 1983. "Multiple Input, Multiple Output Production Choices and Technology in the U.S. Wheat Region." American Journal of Agricultural Economics. 65:45-56.

Young, Douglas L., Ron C. Mittelhammer, Ahmad Rostamizadeh, David W. Holland. 1987. "Duality Theory And Applied Production Economics Research: A Pedagogical Treatise." EB-1473. Cooperative Extension, College of Agriculture and Home Economics, Washington State University.

Zellner, A., J. Kmenta and J. Dreze. 1966. "Specification and Estimation of Cobb-Douglas Production Function Models." Econometrica. 34:786-795.

APPENDIXES

APPENDIX A

DATA UTILIZED IN THE MODEL ESTIMATION

Year	Factor Share of Real Estate	Factor Share of Labor	Factor Share of Fixed Inputs	Factor Share of Variable Inputs	Price Index of Real Estate (Five Years Mov.Average)	Price Index of Labor (Five Years Mov.Average)	Price Index of Fixed Inputs (Five Years Mov Average)	Price Index of Variable Inputs (Five Years Mov.Average)	Price Index of Output (Five Years Mov Average)	Price Ratio of R Est./Var Inp (Five Years Mov.Average)	Price Ratio of Labor/Fix Inp (Five Years Mov.Average)	Excess Capacity (Five Years Mov.Average) Mill 1977 $	Weather Index	Farm Exports Share	Total Cost of Inputs $ 1977 Million $	Coefficient of Income Variability
1944	0 23850	0 44386	0 09572	0 20072	0 85255	0 48978	0 79600	1 42735	1 42627	0 59699	0 60916	499 94	101 00	0 09115	90698 90	1 34466
1945	0 23987	0 44014	0 08509	0 20185	0 88639	0 56795	0 82150	1 46127	1.58781	0 60585	0 68229	-71 72	106 80	0 11260	92290 80	1 11227
1946	0 22889	0 41747	0 06705	0 18939	0 92604	0 65888	0 83659	1 50544	1 75570	0 61438	0 78260	-188 75	100 80	0 12209	81617 30	1 01769
1947	0 23473	0 36716	0 07162	0 19741	0 94062	0 72646	0 82666	1 50213	1 85318	0 62665	0 88921	-122 59	96 50	0 10823	79023 00	1 01762
1948	0 24695	0 35862	0 08750	0 21355	0 94868	0 73031	0 79632	1 47212	1 92188	0 64638	0 92390	1209 43	118 40	0 10506	79863 60	1 09333
1949	0 27780	0 42039	0 12064	0 25022	0 94577	0 70365	0 76488	1 42791	1 88930	0 66473	0 92192	1135 14	93 90	0 09707	82663 50	1 07956
1950	0 27281	0 39812	0 12939	0 24329	0 92940	0 66855	0 73578	1 37255	1 80976	0 67926	0 90806	957 28	102 30	0 10304	82958 10	1.22653
1951	0 24941	0 33994	0 12501	0 22891	0 91009	0 62565	0 72051	1 31363	1 72756	0 69305	0 87150	689 62	100 90	0 10587	85956 40	1 25301
1952	0 26657	0 36600	0 14242	0 25348	0 92288	0 59700	0 73782	1 30606	1.70645	0 70661	0 80933	1487 88	95 80	0 07467	87899 10	1 11320
1953	0 28430	0 38941	0 15873	0 27001	0 93254	0 61866	0 75795	1 30569	1 64236	0 71417	0 81552	1520 66	95 60	0 08523	84641 30	1 07862
1954	0 29788	0 41271	0 16839	0 28130	0 93124	0 64571	0 76959	1 29081	1 58043	0.72155	0 83859	1919 37	96 10	0 09198	83820 20	1 16673
1955	0 30537	0 35658	0 17596	0 29118	0 93185	0 67272	0 77068	1 27773	1 55036	0 72961	0 87296	3008 78	104 20	0 10443	76591 70	1.16399
1956	0 30135	0 34798	0 17818	0 29345	0 92565	0 66401	0 76805	1 25013	1 48461	0.74092	0 86413	3867 16	89 40	0 13923	74497 90	1 13251
1957	0 31420	0 35585	0 18547	0 30153	0 90794	0 65150	0 76082	1 21327	1.38007	0 74901	0 85525	3744 55	103 20	0 11507	73292.50	1.12142
1958	0 27292	0 30495	0 16459	0 26968	0 88916	0 63780	0.75318	1 17014	1 28787	0 76066	0 84580	3984 32	113 80	0 09546	73377 60	1 06168
1959	0 29080	0 32182	0 17991	0 29312	0 87825	0 62700	0 75220	1 13867	1 23677	0 77210	0 83288	3834 48	96 00	0 11921	74216 30	1 11065
1960	0 28680	0 27355	0 17995	0 28502	0 86827	0 61036	0 75619	1 10614	1.18524	0 78560	0 80676	4035 56	108 20	0 12818	70296 10	1 16776
1961	0 27989	0 27159	0 17443	0 27964	0 86333	0 60867	0 76350	1 08403	1 15452	0 79683	0 79729	4433 65	102 30	0 12682	70501 20	1.18230
1962	0 27648	0 27408	0 17237	0 27777	0 86082	0 61551	0 77259	1 06806	1 13552	0 80615	0 79698	4857 07	97 40	0 11993	71031 50	1 06062
1963	0 27594	0 24825	0 17361	0 27943	0 85766	0 62058	0 78040	1 05501	1 12580	0 81307	0 79533	4488 39	105 10	0 13992	69606 50	1 04012
1964	0 28718	0 24906	0 18330	0 29479	0 85424	0 61374	0 78673	1 04152	1 10448	0 82030	0 78007	4862 97	100 73	0 14412	69164 40	1 03918
1965	0 29161	0 22863	0 17761	0 28602	0 85020	0 60940	0 79014	1 03085	1 09107	0 82492	0 77114	5024 23	103 85	0 13098	70936 80	1 12333
1966	0 28278	0 22724	0 17405	0 28301	0 85779	0 61655	0 79326	1 02391	1 08131	0 83794	0 77728	4924 14	99 65	0 13228	72609 70	1 12859
1967	0 29834	0 21529	0 18849	0 30717	0 86793	0 63142	0 79568	1 01474	1 07931	0 85551	0 79356	4727 19	101 50	0 13403	72291 00	1 16236
1968	0 28784	0 22137	0 18895	0 29222	0 87831	0 63139	0 79798	1 00559	1 05947	0 87370	0 79122	4986 22	103 29	0 12172	72028 50	1 10651
1969	0 28427	0 21787	0 18584	0 28229	0 88646	0 64689	0 79833	0 98911	1 03863	0 89711	0 81023	4902 31	103 87	0 10178	70995 00	1 14942
1970	0 29841	0 22513	0 19086	0 28852	0 89629	0 66687	0 79647	0 96706	1 02305	0 92870	0 83738	4422 94	98 82	0 11427	70846 40	1 06650
1971	0 28747	0 27545	0 18857	0 29182	0 89348	0 69665	0 79344	0 93896	1 00532	0 95369	0 87859	4378 12	106 09	0 12489	74900 80	1 06662
1972	0 25461	0 23032	0 16875	0 25817	0 88771	0 75402	0 79177	0 90958	0 96625	0 97794	0 95307	4063 62	107 70	0 11311	74740 20	1 04562
1973	0 20100	0 17149	0 12930	0 21565	0 88608	0 80929	0 79125	0 88302	0 96617	1 00456	1 02277	3329 21	106 04	0 13044	80424 80	1 17489
1974	0 23015	0 18609	0 15486	0 28435	0 90322	0 86004	0 79556	0 88278	1 04198	1 02312	1 08000	2673 10	92 82	0 21673	85499 20	1 54605
1975	0 23236	0 18414	0 17888	0 29247	0 92723	0 89939	0 80942	0 92351	1 11604	1 00810	1 11116	2666 75	99 75	0 21451	85669 50	1 36976
1976	0 23865	0 22229	0 20561	0 32883	0 95284	0 92851	0 83895	0 97542	1 15981	0 98477	1.11182	2309 37	96 23	0 21519	87495 10	1 35338
1977	0 27126	0 22042	0 21774	0 33411	0 96326	0 94297	0 87787	1 01438	1 19326	0 95671	1 07785	2210 78	100 89	0 22042	88619 10	1 31500
1978	0 24424	0 18672	0 19636	0 30836	0 98458	0 95990	0 91811	1 04395	1 19174	0 94703	1 04867	2129 79	104 41	0 21245	89376 90	1 29277
1979	0 23369	0 16996	0 18245	0 29404	0 99010	0 96157	0 95377	1 05413	1 12967	0 94184	1 00938	2456 85	110 79	0 21218	94311 00	1 11838
1980	0 26351	0 18059	0 20317	0 33747	0 99535	0 97620	0 98617	1 03521	1 08167	0 96440	0 98990	1997 31	96 68	0 27119	95292.70	1 13181
1981	0 26238	0 15845	0 20145	0 32843	1 00553	0 99183	1 00567	1 02777	1 06085	0 97967	0 98671	2783 45	109 65	0 26322	91547 70	1 45329
1982	0 27050	0 17608	0 21249	0 31291	1 02841	0 95353	1 01633	1 03168	1 03794	0 99782	0 93889	3567 20	109 11	0 23916	87129 10	1 42599
1983	0 32206	0 16958	0 25106	0 35475	1 03195	0 93547	1 02584	1 03331	1 01724	0 99972	0 91257	3384 25	92 80	0 22701	79729 80	1 30339
1984	0 27024	0 18908	0 20466	0 31995	1 02940	0 88053	1 03812	1 03321	0 98343	0 99724	0 84980	4005 18	102 57	0 22348	81683 00	1 57887
1985	0 27799	0 20083	0 20262	0 31767	1.01541	0 86524	1 04847	1 01936	0 93558	0 99757	0 82621	6268 54	108 47	0 19152	76109 60	1 58077
1986	0 30199	0 25334	0 21389	0.34251	0 98717	0.86268	1 05045	0 97961	0 87247	1 00875	0 82189	5969 47	103 50	0 16695	72590 10	1 59523
1987	0 28027	0 24507	0 18142	0 32026	0 95247	0 91315	1 04032	0 93382	0 81793	1 02055	0 88149	5335 33	108 36	0 16497	71388 10	1 04670
1988	0 28637	0 25354	0 18140	0 32444	0 87650	0 96558	1 02475	0 89472	0 78096	0 97565	0 94950	5090 32	92 21	0 20316	71293 00	1 22524
1989	0 26056	0 24069	0 16274	0 32741	0 80843	1 07467	1 01196	0 86095	0.75787	0 93389	1 06704	4669 81	102 24	0 20956	73699 00	1 20924

APPENDIX A. (CONTINUED)

Year	Share of Gov. Pay on Net Farm Income	Percentage of Population on Farms %	Output Quantity (Log) $ 1977 Million $	Real Estate Quantity (Log) $ 1977 Million $	Labor Quantity (Log) $ 1977 Million $	Fixed Inputs Quantity (Log) $ 1977 Million $	Var. Inputs Quantity (Log) $ 1977 Million $	Research Expenditures (PDL Variable) (Both ends Constrained) Million 1977 $	Net Farm Income (PDL Variable I1) (Far end Constrained) Million 1977 $	Net Farm Income (PDL Variable I2) (Far end Constrained) Million 1977 $	Net Farm Income (PDL Variable I7) (Both ends Constrained) Million 1977 $	Farm Exports Share (PDL Variable) (Both ends Constrained)
1944	0 05496	7 36994	10 79180	10 02560	10 90810	9 20669	9 39636	-847224	-1109530	-4205060	-4040313	-8 28863
1945	0 06630	7 14796	10 77450	10 04370	10 84040	9 20005	9.41238	-882410	-1166250	-4660120	-4547012	-8 95995
1946	0 06027	7 28430	10 80580	10 06640	10 79840	9 09497	9 46167	-918518	-1346350	-4897520	-5113812	-9 96016
1947	0 05123	7 21721	10.75230	10 07560	10 98500	9 16862	9 53662	-955906	-1568410	-4826270	-5572415	-11 01344
1948	0 02045	7 09413	10 84410	10 08030	10 94780	9 30569	9 58461	-994902	-1694280	-4786950	-5909998	-12 03757
1949	0 01455	6 70241	10 84420	10 09080	10 94180	9 44066	9 63810	-1036398	-1608860	-4417130	-5960545	-12 51430
1950	0 01455	6 52604	10 83470	10 09800	10 86240	9 54037	9 62828	-1080174	-1585430	-4115610	-5796396	-12 77350
1951	0 02073	6 15684	10 87140	10 09690	10 80920	9.61361	9 69357	-1125270	-1565530	-3985860	-5572888	-12 80575
1952	0 01795	5 79618	10 90360	10 09490	10 75280	9 66348	9 73181	-1171344	-1448810	-3858570	-5340866	-12 53511
1953	0 01838	5 57644	10 90400	10 09330	10 68120	9 68807	9 74251	-1217792	-1474930	-3632410	-5071719	-12 01824
1954	0 01641	5 35714	10 90340	10 09060	10 64960	9 70022	9 74065	-1264508	-1194360	-3459740	-4797351	-11 53545
1955	0 02077	5 08167	10 94240	10 08940	10 66920	9 70946	9 76423	-1312370	-1181200	-3183750	-4525414	-11 32253
1956	0 02026	4 69679	10 94810	10 07140	10 62370	9 70378	9 78134	-1361668	-1217590	-2905030	-4241210	-11 55450
1957	0 04923	4 43666	10 93880	10 06670	10.53490	9 68161	9 78947	-1413746	-1127690	-2685250	-4009963	-11 94446
1958	0 09157	4 30787	11 02050	10 05660	10.45980	9 67371	9 81965	-1469442	-1027310	-2659700	-3777052	-12 23561
1959	0 08263	4 10343	11 03620	10 06690	10 46730	9 68468	9.86883	-1529508	-966648	-2530340	-3525350	-12 68090
1960	0 06366	3 92699	11 06220	10 06450	10 42830	9 69311	9 85220	-1593676	-888163	-2459000	-3332795	-13 34801
1961	0 06270	3 75612	11 06320	10 06400	10 37020	9 67482	9 85849	-1663282	-868236	-2437080	-3214613	-13 86945
1962	0 12486	3 59057	11 07710	10 06890	10 34490	9 66926	9 88030	-1737666	-842381	-2416130	-3137876	-14 19138
1963	0 14473	3.43370	11 10850	10 07020	10 29120	9 66943	9 90211	-1816540	-911095	-2367830	-3090468	-14 47188
1964	0 14410	3 17874	11 09960	10 07680	10 24420	9 68035	9 92484	-1900248	-784351	-2290260	-3026027	-14 77321
1965	0 20768	2.88066	11 14090	10 06610	10 21630	9 68861	9 91766	-1988326	-803842	-2309960	-2981152	-15 25879
1966	0 19094	2.64496	11.11630	10 06310	10 12340	9 70382	9 96168	-2080968	-839982	-2358450	-2954480	-15 71394
1967	0 23474	2.46479	11 17010	10 07330	10 09130	9 73192	10 01400	-2178386	-825565	-2325300	-2955926	-15 92212
1968	0 24946	2.34180	11 18770	10 06470	10 05670	9 75091	10 03030	-2279400	-795932	-2272880	-2928623	-15 94531
1969	0 28103	2.26936	11 19730	10 05860	10 00920	9 75461	10 04640	-2382546	-743925	-2278530	-2900400	-15 70853
1970	0 26537	2.19405	11 18750	10 08450	9 95961	9 75939	10 05470	-2488490	-813169	-2229150	-2876307	-15 35091
1971	0 25874	2.11844	11 26410	10 06710	9 92110	9.74969	10 10600	-2596119	-828672	-2188990	-2856344	-14 91361
1972	0 20950	2.09624	11 26080	10 05880	9 93422	9 75932	10 11990	-2704947	-787561	-2318210	-2879129	-14 49238
1973	0 20363	2.02926	11 28090	10 04640	9 92110	9 77763	10 16030	-2814177	-880611	-2907270	-3055788	-14 32157
1974	0 07588	2.05704	11 20400	10 03280	9 92093	9 79988	10 16060	-2922177	-944792	-3133210	-3276213	-14 98739
1975	0 01944	1 99074	11 30880	10 01030	9 89341	9 83278	10 12060	-3029493	-914450	-3176660	-3495478	-16 31366
1976	0 03159	2.01835	11 31840	10 02570	9 83733	9 81830	10 22270	-3136303	-856663	-2948220	-3612360	-18 15879
1977	0 03638	1 90736	11 34950	10.04480	9 83729	9 82503	10 25320	-3243712	-894033	-2586420	-3605655	-20 27923
1978	0 09144	1 79695	11 38400	10 05340	9 83730	9 83910	10 30490	-3352698	-1194300	-2286170	-3530240	-22 21440
1979	0 12020	1 68814	11 44580	10 09200	9 82291	9 86057	10 35370	-3464042	-954637	-2173110	-3375647	-23 86562
1980	0 05023	1 62423	11 38780	10 08970	9 79335	9 86288	10 29990	-3577973	-809869	-1880170	-3050514	-25 61537
1981	0 08086	1 56454	11 51670	10 09550	9 79269	9 83628	10 29420	-3694339	-670356	-1826300	-2682999	-26 98954
1982	0 07219	1 46237	11 49340	10 07850	9 76141	9 80828	10 23360	-3811589	-619016	-1692070	-2445790	-27 66876
1983	0 15337	1 36286	11 31070	10 06900	9 80744	9 75157	10 17180	-3926767	-629258	-1376650	-2214357	-28 20123
1984	0 77003	1 30802	11 46320	10 05200	9 75488	9 67072	10 25440	-4038928	-646502	-1409390	-2082449	-28 51599
1985	0 27390	1 21187	11 50670	10 04710	9 67355	9.61130	10 19970	-4146958	-467426	-1506500	-1989099	-28 34623
1986	0 25251	1 11755	11 44720	10 02960	9 61410	9.55776	10.18850	-4250490	-597900	-1561700	-1919902	-27 59502
1987	0 38786	1.10701	11 44890	10 32680	9.58441	9.47309	10 21810	-4352175	-568683	-1794180	-1961013	-26.27382
1988	0 40345	1 13775	11.37320	10 30850	9 55584	9 42514	10 20690	-4453333	-462890	-2001990	-2107721	-24 78024
1989	0 34435	1.16606	11.48080	10 30460	9 56883	9 38708	10 28060	-4554673	-690680	-2140520	-2264192	-23 77365

APPENDIX B

ORIGINAL DATA

Year	Gross Farm income (million $) (1),(4)	Net farm income Billion $ (1)	Direct Government Payments Billion $ (1)	Excess Capacity (million $) (2)	Agricultural Exports (million $) (3)	GNP Deflator 1982 (5)	Real Estate Price Index (6)	Labor Price Index (6)	Fixed Inputs Price Index (6)	Variable Inputs Price Index (6)	Agricultural Output Price Index (6)
1940	11340	4.5	0.72	233.50	350	13.00	0.156	0.073	0.146	0.265	0.213
1941	14271	6.5	0.54	43.80	1032	13.80	0.168	0.091	0.152	0.280	0.278
1942	19893	9.9	0.65	66.50	1497	14.70	0.190	0.121	0.183	0.320	0.352
1943	23344	11.7	0.65	-324.90	2305	15.10	0.212	0.157	0.195	0.345	0.443
1944	24038	11.7	0.78	504.90	2191	15.30	0.225	0.173	0.205	0.355	0.439
1945	25374	12.3	0.74	-384.80	2857	15.70	0.235	0.194	0.194	0.372	0.472
1946	29568	15.1	0.77	-107.10	3610	19.40	0.257	0.225	0.199	0.389	0.536
1947	32386	15.4	0.31	208.60	3505	22.10	0.299	0.188	0.226	0.431	0.648
1948	36454	17.7	0.26	1827.70	3830	23.60	0.326	0.199	0.250	0.462	0.614
1949	30762	12.8	0.19	645.80	2986	23.50	0.317	0.205	0.264	0.449	0.538
1950	33103	13.6	0.28	-901.60	3411	23.90	0.324	0.220	0.268	0.462	0.568
1951	38282	15.9	0.29	-637.70	4053	25.10	0.356	0.238	0.290	0.490	0.659
1952	37751	15.0	0.28	1753.00	2819	25.50	0.364	0.259	0.299	0.497	0.607
1953	34447	13.0	0.21	2068.90	2936	25.90	0.355	0.270	0.297	0.478	0.555
1954	34181	12.4	0.26	1501.80	3144	26.30	0.356	0.282	0.298	0.477	0.531
1955	33476	11.3	0.23	1175.40	3496	27.20	0.356	0.233	0.300	0.470	0.496
1956	33959	11.3	0.55	1078.10	4728	28.10	0.362	0.241	0.309	0.471	0.500
1957	34788	11.1	1.02	1735.40	4003	29.10	0.374	0.265	0.325	0.474	0.498
1958	38958	13.2	1.09	2901.50	3719	29.70	0.383	0.286	0.338	0.479	0.535
1959	37890	10.7	0.68	1397.50	4517	30.40	0.389	0.289	0.353	0.478	0.508
1960	38587	11.2	0.70	1796.90	4946	30.90	0.393	0.260	0.357	0.483	0.505
1961	40547	12.0	1.49	2119.80	5142	31.20	0.396	0.283	0.364	0.486	0.521
1962	42343	12.1	1.75	2905.90	5078	31.90	0.403	0.303	0.374	0.489	0.531
1963	43368	11.8	1.70	2277.80	6068	32.40	0.409	0.295	0.384	0.490	0.525
1964	42304	10.5	2.18	2428.00	6097	32.90	0.411	0.302	0.390	0.492	0.515
1965	46549	12.9	2.46	2370.50	6097	33.80	0.449	0.303	0.399	0.511	0.525
1966	50468	14.0	3.28	2117.70	6676	35.00	0.471	0.356	0.415	0.521	0.581
1967	50520	12.3	3.08	2745.00	6771	35.90	0.481	0.341	0.427	0.525	0.538
1968	51847	12.3	3.46	3375.90	6311	37.70	0.499	0.387	0.448	0.524	0.564
1969	56408	14.3	3.79	2689.10	5741	39.80	0.527	0.424	0.467	0.529	0.593
1970	58818	14.4	3.72	1449.80	6721	42.00	0.549	0.469	0.486	0.547	0.610
1971	62119	15.0	3.15	2538.60	7758	44.40	0.578	0.641	0.521	0.564	0.607
1972	71145	19.5	3.96	2469.00	8047	46.50	0.617	0.632	0.552	0.589	0.729
1973	98910	34.4	2.61	1731.70	12902	49.50	0.718	0.695	0.605	0.688	1.040
1974	98247	27.3	0.53	1016.30	21293	54.00	0.811	0.733	0.689	0.882	1.092
1975	100590	25.5	0.81	2019.00	21578	59.30	0.888	0.791	0.816	1.001	1.043
1976	102917	20.2	0.73	1932.40	22147	63.10	0.870	0.979	0.923	0.985	1.001
1977	108765	19.9	1.82	3080.50	23974	67.30	1.000	1.000	1.000	1.000	1.000
1978	128447	25.2	3.03	2091.40	27289	72.20	1.077	1.022	1.073	1.058	1.166
1979	150720	27.4	1.38	3389.10	31979	78.60	1.211	1.153	1.192	1.173	1.338
1980	149274	16.1	1.29	-8.00	40481	85.70	1.348	1.242	1.304	1.399	1.397
1981	166323	26.9	1.93	8368.80	43780	94.00	1.456	1.190	1.449	1.494	1.340
1982	163474	23.5	3.49	10400.10	39097	100.00	1.512	1.352	1.556	1.498	1.358
1983	153160	15.3	9.30	1597.40	34769	103.90	1.531	1.047	1.639	1.521	1.373
1984	170159	26.3	8.43	9612.20	38027	107.70	1.547	1.457	1.716	1.496	1.396
1985	162912	31.0	7.71	18638.00	31201	110.90	1.511	1.586	1.703	1.483	1.263
1986	156524	31.0	11.81	7603.00	26132	113.80	1.470	1.868	1.668	1.422	1.179
1987	168973	41.3	16.75	6678.70	27876	117.40	1.113	2.044	1.691	1.418	1.293
1988	173838	41.8	14.48	-343.05	35316	121.30	1.173	2.205	1.798	1.472	1.413
1989	189219	46.7	10.89	7326.41	39652	126.30	1.217	2.346	1.903	1.566	1.441

SOURCES

(1) Johnson, Cheryl D "A Historical Look at Farm Income" B#807 ERS USDA May,1990

(2) Dvoskin, Dan. "Excess Capacity in US Agriculture An Economic Approach to Measurement" AGECON Report#580 ERS USDA February, 1988 Data for 1985-89 was estimated using USDA sources

(3) Agricultural Statistics, various issues.

(4) For 1980-89 the source is ECIFS, National Financial Summary,1989

(5) "Economic Report to the President" 1991

(6) Aggregated from ERS data.

APPENDIX B. (CONTINUED)

Year	Research Expenditures SAES & USDA $	Agricultural Research Deflator	Year	Research Expenditures SAES & USDA $	Agricultural Research Deflator
1890	1203386	6 826	1940	40860472	12 396
1891	1178065	6 749	1941	41261687	12 613
1892	1253475	6 425	1942	42390744	12 829
1893	1315528	6 526	1943	43453178	13 382
1894	1360765	6 198	1944	46215934	14 371
1895	1397128	6 330	1945	48107365	14 478
1896	1520416	6 257	1946	53024382	15 505
1897	1531991	6 336	1947	66096770	16 995
1898	1643664	6 501	1948	80391010	18 747
1899	1662877	6 704	1949	94333076	19 362
1900	1837557	6 901	1950	102676412	20 468
1901	2048583	6 874	1951	107067850	22 032
1902	2281594	7 006	1952	112472534	23 333
1903	2495866	7 043	1953	117082152	24 416
1904	2613086	7 134	1954	124577712	25 431
1905	2724802	7 235	1955	141314077	26 038
1906	3401860	7 322	1956	155646244	27 033
1907	4091321	7 542	1957	182076407	28 427
1908	5162263	7 416	1958	205835037	29 650
1909	6195384	7 738	1959	228630872	30 885
1910	6700749	7 886	1960	243032555	33 025
1911	6636676	7 792	1961	273466192	34 202
1912	8160143	7 680	1962	281597196	35 586
1913	8285391	8 013	1963	303461288	37 180
1914	9090937	8 009	1964	348041935	38 708
1915	11034683	8 114	1965	385586620	40 438
1916	10366331	8 719	1966	419996692	42 261
1917	10849949	9 912	1967	452372053	44 425
1918	11778303	10.717	1968	468906072	46 767
1919	13208146	11 938	1969	483929236	50 547
1920	14722104	13 026	1970	530900992	54 301
1921	14921547	11 754	1971	574170952	57 561
1922	15734901	12 257	1972	615692496	60 064
1923	17107068	12 537	1973	659639490	63 796
1924	17922738	12 538	1974	700039887	68 541
1925	19056330	12 835	1975	800893000	73 298
1926	21257788	12 833	1976	888052000	77 991
1927	22771802	12 806	1977	996626000	81 115
1928	25329858	12 927	1978	1100662000	86 082
1929	28607064	12 849	1979	1224005000	92 312
1930	31334402	12 725	1980	1333885000	100 000
1931	33671585	12 747	1981	1491757000	109 019
1932	33113454	12 638	1982	1625271000	117 855
1933	28610162	12 281	1983	1700257000	128 618
1934	24885341	12 091	1984	1784769000	133 003
1935	25771850	11 642	1985	1888346000	140 660
1936	29941224	11 743	1986	1981692911	149 258
1937	33226558	12 215	1987	2127685601	146 407
1938	36956846	12.179	1988	2267562900	151 468
1939	43138831	12 262	1989	2410366898	157 949

SOURCES:
1890-1986 Pardey, P G , W M Eveleens, and M L. Hallaway. "A Statistical History of U S Agricultural Research 1889 to 1986" St.Paul. University of Minnesota, CIFAP, forthcoming, 1991
1987-1989. Collected from USDA, "Current Research Information System, CRIS" Agricultural research deflator estimated based on GNP deflator

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