ANNA LYN RICKETT
An Economic Evaluation of Cotton and Peanut Research in Southeastern United States
(Under the Direction of JEFFREY H. DORFMAN)

The purpose of this study is to utilize the economic surplus framework for evaluating the impact of investment in agricultural research. The economic impact measures used in this study are the total benefits and distribution of those benefits associated with investment in agricultural research. These results are used to calculate an internal rate of return on the investments. The focus of the research is on cotton and peanuts in the Southeast region of the United States. Two equations are estimated to determine the impacts of the money being spent on the research efforts of these two commodities.

The results reveal the positive benefits to consumers and producers exceed the investment amount in a present value sense. Total social benefits average about 201 million dollars (1982 dollars) annually for cotton research and about 191 million from peanut research. The internal rates of return were 53.58 percent for cotton and 23.87 percent for peanuts, suggesting that past research investments produced a high return to society. These results generally agree with the results of other similar studies.

INDEX WORDS: Economic surplus, Agricultural research, Return on investment, Economic impact, Benefit and costs

AN ECONOMIC EVALUATION OF COTTON AND PEANUT RESEARCH IN

SOUTHEASTERN UNITED STATES

by

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TO MICHAEL SHORE SMITH, JR.

MY BEST FRIEND AND SOULMATE

WITH LOVE

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CHAPTER 1

INTRODUCTION, OBJECTIVES, AND ORGANIZATION

Introduction

Research is a fundamental component of economic development and growth. Agricultural research has been labeled the oldest form of research in the world. There is evidence suggesting methodic attempts to apply scientific knowledge to improving agricultural production as early as the eighteenth century. Around this time, the most pressing problem in developing economies was to produce adequate amounts of food to be self-sufficient. It makes sense that individuals began to improve agriculture in order to sustain themselves. Today, agricultural research is crucial in developing and maintaining the role of developed economies in world markets as well as keeping food prices low and stable.

Agricultural research requires scarce resources like skilled labor, capital, and other inputs to continue to address these concerns and rise to new levels. These inputs are intended to combine and produce some improved technology that makes agricultural production more efficient. Agricultural research improves efficiency through developing technologies that increase output using the same inputs or decrease the costs of production. Examples of innovations from research in agriculture are new crop varieties, better pesticides and fertilizers, and improved management and storage techniques that help to stabilize food prices and supply. Technological improvements in agriculture bring about shared benefits between the producer and consumer. Creating and increasing productivity, holding all other things constant, generates new revenues for the producer by widening the margin between production cost and quantity produced. An increase in productivity can then increase supply, and depress prices, affecting producers and consumers alike.

In the United States, agricultural research has been historically funded through a heavily legislated partnership between federal and state governments. As a result, either the United States Department of Agriculture (USDA) or the State Agricultural Experiment Stations (SAES) are responsible for conducting most of the public research in the United States. Table 1 outlines the evolution of this relationship and a history of federal support for agricultural research in the United States. When the USDA was established in 1862, the majority of the nation was involved in agriculture and taxpayer support of agricultural research was popular policy. Since then, the portion of the population involved in agriculture has decreased significantly, and the support for such policy has decreased and become more complicated as a result. Public tax dollars still support agricultural research not only because the knowledge it generates has characteristics of a public good[1], but also because the returns from public investment in agricultural research have been large. Studies have shown that the past public investment in research has resulted in at least a 35 percent annual rate of return (USDA/ERS). Despite these high returns, tax dollars for research have become progressively scarcer and state research stations have increased their reliance on contributions from the private sector (USDA/ERS).

There are many changes taking place in the public and private role in supporting agricultural research. Agricultural research competes with other alternative investments

[1] Benefits produced from certain types of research are not restricted to those producing the research. This is one of the reasons that “free riders” become a problem where some firms receive some of the benefits of research without incurring any of the costs (Alston, Norton, and Pardey 1995)

Table 1: History of Federal Funding of State Agricultural Research and Extension

1862	Morrill Act	• Created land-grant colleges
1887	Hatch Act	• Authorized money to be appropriated to State Agricultural Experiment Stations every year under direction of land-grant colleges • Spending was at State's discretion
1906	Adams Act	• Mandated formal fiscal reviews of State Agricultural Experiment Stations' performance; posed a threat to extension (non-research) activities • Doubled yearly funds allocated to State Agricultural Experiment Stations
1914	Smith-Lever Act	• Provided formula funding for cooperative extension between USDA and land-grant colleges; formula based appropriations on size of State's farm sector (defined as portion of that state' share of the total US rural population) • Required federal funds be matched with State funds • Created Cooperative Extension Service
1925	Purnell Act	• Tripled level of funds allocated to State Agricultural Experiment Stations and expended the accepted areas of study.
1935	Bankhead-Jones Act	• Provided extra support to State Agricultural Experiment Stations to enhance production • Set aside 40% of funds for Special Research Fund, which established more regional research laboratories.
1938	Agricultural Adjustment Act	• Established facilities aimed at finding new industrial uses for surplus farm commodities
1946	Research and Marketing Act	• Allocated set-aside money for marketing research (was upheld in the amended Hatch Act of 1955)
1977	Food and Agriculture Act	• New grant programs, research councils, advisory boards, the National Ag Library, and projects were created. • Deleted funding set aside to marketing research in RMA of 1946.
1990	Farm Bill	• Emphasized Competitiveness, new uses sustainability and food safety and reflected new environmental concerns. • ASTRB-Agricultural Science and Technology Review Board created, stressing the issue of accountability. • NRI-National Research Initiative-increased funds going to competitive grants.

Source: Adapted from Alston & Pardey, 1996.

for a share of the federal budget. The apportionment of these funds away from agriculture may rest heavily on how current events relate to other research objectives that are more popular at the time. Public funds for agricultural research may be declining, but private funds are taking on some of that funding burden. Increased incentives for privately funded agricultural research, such as Intellectual Property Rights (IPR's) for biological inventions have further enlarged the percentage of agricultural research funded by the private sector. In 1994, the United States government spent $3 billion dollars for agricultural research, combining with $3.5 billion spent by private industry to equal $6.5 billion dollars total. Today, the private sector invests more in agricultural research and development than do the Federal and State governments combined (USDA/ERS). The trend of private sector support brings about questions about the nature of these changes. Institutional setting, scientific context and policy context are all important issues when examining the efficiency of the agricultural research system and will be addressed more thoroughly in the literature review.

The changing roles of government and private industry reflect the changing demands of producers and consumers over the past century. Some of these demands are well defined in the marketplace and have been addressed. An increase in market demand for food with easily discernable characteristics can induce more production or development of products with these characteristics and initiate investment by the private and public sector in these areas. Market response like this is more difficult when the demands are abstract and hard to define. Forces driving consumer demand have grown to include concerns about food safety and the environment. These forces are abstract and harder to measure so the market response to them is less reliable. Researching these types of issues offers small incentives to private sector because individual firms would not be able to capture the total benefits of the research.

Therefore it may be more efficient for public funds in agricultural research to be spent on research initiatives that are directed towards producing these public goods results.

There are many questions relating to how to allocate public funds to agricultural research. There are questions about which issues to tackle, how much money should be spent, and whether that money is producing results. An important aspect of this allocation process is to address the needs and wants of the consumers and producers whose tax dollars are funding it. Once the money is allocated to agriculture, decision-makers then face questions about how to spend this allocation among different agricultural research initiatives. This is the allocation of scarce resources among competing wants and is the underlying theme in all economic issues. As discussed, there is no well-defined market for supply and demand of agricultural research issues. However, in order to determine where and how much money should be spent to maximize the benefits from public agricultural expenditure, the current system must continuously be evaluated.

The broad economic problem of maximizing benefits from allocation of public funds to agriculture has several ambient factors, one of which is addressed specifically in this paper. Generally, the factors are: (a) identifying the research objectives, (b) identifying other possible choices, (c) comparing effects of these investment alternatives, and (d) deciding between the alternatives (Alston, Norton & Pardey, 1995). Like any other investment where there are many possible alternatives to choose from, there is an opportunity cost involved in forgone investments. The opportunity cost of possible foregone investments makes step (c), comparing the effects of alternatives, a subject of interest in this paper. The main focus is on measuring the economic benefits resulting from actual research expenditure on cotton and peanuts in the Southeast compared to the alternative investment of allocating that money somewhere else. State-level data can be reasonably effective because the taxpayers funding the research are often times the local consumers as well as the producers in the region. Comparing these two results will show how much is actually gained from investing in these particular commodities compared to what is gained with no investment at all.

Evaluating research priorities with formal economic analysis is complex because it is hard to account for scientific creativity and the costs of inaccurately identifying this creativity in a formal model for decision-making. Economic techniques are used to measure the benefits of research and provide estimates when used in conjunction with economic theory help to make allocation decisions. The distribution of benefits and returns on investment become especially important to those funding the research, the taxpayers. The return on investment measure is important because future funding decisions generally rely on economic, political and social pressures that to a degree depend on the successes and failures of past investment.

Agricultural research evaluation studies like this range from aggregate analysis to individual project evaluations. Analysis of aggregate returns to research justify federal appropriations to agriculture and the measurement of individual research measures the efficiency in the allocation of those appropriations. Rates of return from past research investments in various commodities in different regions could be used to evaluate whether research funds have been efficiently allocated when compared to other investment alternatives. This information could also help indicate where future research funds could be most effective per unit of agricultural research expenditure.

Objectives

For the states of Alabama, Florida, Georgia, and South Carolina, this paper addresses the returns from research in cotton and peanuts as well as the distribution of benefits among producers and consumers resulting from research dollars invested in cotton and peanuts over a thirty-three year period. Specifically, the objectives of this paper are:

i) To develop a theoretical framework for the analysis and evaluation of the social benefits of publicly funded cotton and peanut research in the Southeast as it is defined in the above paragraph.

ii) To measure the social costs and returns form public research and development funding.

iii) To asses the distribution of these benefits between producers and consumers.

Organization of the Study

A review of the literature covering the issues of measurement of agricultural research benefits and distribution is presented in Chapter 2. In Chapter 3, the theoretical framework, methodology, and variables used are presented. Chapter 4 presents the empirical results and their interpretations. Summary and conclusions of this study are presented in Chapter 5.

CHAPTER 2

LITERATURE REVIEW: ECONOMIC ISSUES IN AGRICULTURAL RESEARCH EVALUATION

Early Studies

Numerous studies have examined the benefits of agricultural research and its contribution towards many social and economic objectives. The objective of interest in this study is the efficiency of current research systems that help produce these benefits. The literature on the measurement of agricultural research systems efficiency dates back to early 1950's and consistently justifies the investment of public funds due to high rates of return. During this time, some attention was given to the idea of the Treadmill Theory that claims these returns are misleading. What follows is an overview of these studies and the economic issues in agricultural research evaluation that still exist today.

In 1953, Schultz calculated the cost savings resulting from new production and technology and compared this to costs of developing the new technology resulting in a 700 percent return on investment. Agricultural output was determined to be 32 percent higher in 1950 compared to what would have been if the research had not been conducted. Another early study evaluating the effectiveness of agricultural research investigated the rate of return on research devoted to developing hybrid corn, done by Zvi Griliches. He conducted this initial study of benefits of agricultural research in 1958 when he felt that private and public research expenditures were growing rapidly, but "we know almost nothing about the realized rate of return on these investments". Therefore his objective was to estimate the social rate of return of public and private investment in hybrid corn, a technological innovation during that period. He suggested that his result of a 37 percent internal rate of return (IROR) on investment be taken as an indication that 'research is a good thing.'

Another hypothesis introduced in 1958 was called the "treadmill theory" which was introduced as a result of farmers constantly having to adopt new technologies in order to enhance productivity. The treadmill theory postulated that despite their constant adoption of new technologies, only the initial adopters made any of the resulting profits. As more farmers adopt the technology, any profits that may be made are eventually "worn away" as increased supply and/or competition pushes prices down. The downward pressure on prices resulting from an outward shift in supply makes any increase in profits impossible at such low prices.

The treadmill effect occurs when producers begin adopting newer technology in order to stay competitive. Those who do not adopt the new technology are pushed out of the market, but those who remain must begin the process of searching and adopting newer technologies to stay current in the market place. The treadmill theory brings to light the issue of supporting farm prices while simultaneously supporting the research to develop new technology that will push prices down, only fueling the treadmill further. Since its introduction, there has been substantial evidence to support this theory's argument (Levins & Cochrane, 1996), however this theory was never empirically tested.

Research Evaluation Issues

In the past 41 years since 1958, there have been many articles debating the measurement of and benefits resulting from agricultural research. In 1995, Julian Alston, George Norton, and Philip Pardey wrote Science Under Scarcity, a book that "represents a culmination of a research agenda that extends all the way back to the late 1940's" (Ruttan foreword). The authors offer that the issues and questions surrounding resource evaluation and allocation are best answered when considered in their institutional setting, as well as scientific and policy context. These topics are a useful introduction when looking more closely at the factors affecting agricultural research benefits and measurement.

The institutional setting includes where the research is carried out and how the research is funded. Research effectiveness could be different for different places, such as a University with combined teaching, research and extension goals vs. a commodity council, which is loyal to a specific commodity or goal. Research funding and collection methods affect rates of return as they are considered to have the most positive impact when public and private resources mixed together.

The scientific context relates to whether the research is basic (i.e. fundamental) or applied[2], and is important because of the different goals of these two types of research. Linkages, technology transfers and dynamics of these transfers are also important. Specifically, barriers to adoption by farmers can result if the research was carried out in a lab where variables are more easily controlled than on the farm. The amount of time for technology to be adopted can be impacted by these barriers and can in turn impact the rate of return on investment.

The policy context relates to government policy as a method to make the market for agricultural research more efficient. Alston, Norton & Pardey (1995) suggest that government research should not crowd out private agricultural research; rather it is justified under a limited set of conditions. Social policy in agriculture is the politics involved in influencing the size and direction of research funding based on potential beneficiaries: producers, consumers, input owners, administrators, and scientists. These beneficiaries can potentially influence research objectives away from efficiency to politically driven goals. Since evaluation studies generally use methods geared to measure efficiency, this impacts the rate of return on investment their studies produce.

Between Griliches and Cochrane in 1958 and Science Under Scarcity in 1995, there has been a range of economic issues in agricultural research and many journal articles published debating these various issues. Debates pertaining to the measurement of benefits resulting from agricultural research include: the argument for government intervention, appropriate (efficient) funding mechanism, role of private research, depreciation and maintenance research, interstate spillovers of research benefits, research lags, correct model estimation, and surplus measurement methodology. What follows is an overview of the literature covering these issues.

Government Funding

The argument for government funding for agricultural research rests on the concept of market failure. Incentives for private research and development are not sufficient to meet the needs of society as a whole, meaning the market for research is inefficient and therefore a failure. This market failure occurs because information gained form agricultural research has characteristics of a public good and is therefore hard to profit from if developed in the private sector. Alston, Norton and Pardey (1995) suggest that an "output tax would alleviate market

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[2] Basic research leads to more complete knowledge in a study that does not have specific commercial objectives and applied research is conducted with hopes to gain knowledge about a specific topic that meets a specific

failure caused by producers free-riding on each other when only some carry the tax burden". Both the small and large producer can utilize the technologies that public research generates, providing the barriers to adoption are not prohibitive. It follows that an argument for supporting public agricultural research is that it keeps smaller farms competitive (Ruttan, 1982).

As for private sector support of agricultural research, it is on the rise. According to the USDA, within the total funds contributing to agricultural research, the private sector support increased from 14.3 percent in 1978 to 19.7 percent in 1994. This non-governmental share of the finding had the most rapid growth among all funding resources. Between the years of 1960 and 1992, private expenditures for food an agricultural research tripled (Klotz, Fuglie, & Pray, 1995). The growth in agricultural research in the private sector has important implications for research in the public sector. Research administrators and other public sector decision-makers must compete for their comparative advantage in conducting applied research with the private sector.

Bearing in mind the debate about the most efficient way to fund agricultural research, the literature seems to support the argument for government intervention in the market for agricultural research. Many studies indicate that the land-grant system rates of return of research are very high. The estimated rates of return on agricultural research are commonly in the thirty to sixty percent range, as in the results of the studies outlined in Table 2. However, the rate of return found by Evenson, Waggoner and Ruttan (1979) on agricultural expenditure in research was around 50 percent and is potentially a misleading figure. These results do not necessarily mean that all agricultural research is profitable as one may initially conclude. Considering the possibility that when evaluating all research in a lump study, the

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need or objective (National Science Foundation) good returns counterbalance the poor ones makes research evaluation still a very valuable practice.

Funding Mechanism

The appropriate funding mechanism is a popular topic because needs are changing along with the amount of funds available. Formula funds are unrestricted block grants allocated to state agricultural experiment stations and cooperating institutions for research on agriculture, forestry, and veterinary medicine. Funds are allocated through congressionally mandated formulas resulting from The Hatch Act, The Evans-Allen Program, McIntyre-Stennis Act, and Animal Health and Disease Research Program (Huffman, 1993). The USDA and other federal agencies also provide grant, or competitive funding on a per project basis. Changes in the funding mechanism have taken place over recent years. Between 1978 and 1994, the share of the research budget for State Agricultural Experiment Stations coming from state governments fell from 55.1% to 47%. During this time, federal support rose nearly 2% (Inv. IAR). Since the 1960's, the share of federal funds allocated as formula funds has declined over 29 percent as a result of increased use of competitive grants (USDA/ERS).

The choice of funding mechanism has ramifications on the type of research that is conducted at the state level. Funding mechanisms generally fall into two categories, formula funding or grant funding. Formula funds were more equally distributed among the states than project grants between the years of 1970 through 1994 (Frisvold & Day, 1993).

Table2: Estimated Rates of Agricultural Research for the United States

Study	Time Period	Annual Rate of Return
Griliches, 1964	1949-1959	35-45+
Lattimer, 1964	1949-1959	Not significant
Evenson, 1968	1949-1959	47
Cline, 1975	1949-1958	39-47+
	1954-1968	32-39+
	1967-1972	28-35+
Peterson and Fitzharris, 1977	1957-1962	49+
	1967-1972	34+
Evenson, Waggoner, and Ruttan, 1979	1948-1971	45+
White, Havlicek, and Otto, 1979	1942-1957	48
	1958-1977	42
Lyu, White, and Liu, 1984	1949-1981	66
Braha and Tweeten, 1986	1959-1982	47
Huffman and Evenson, 1989	1960-1982	43
Norton and Ortiz, 1992	1987	30
+ means returns to research and extension.		

Source: Norton, George W. "Benefits of US Agricultural Research"
www.warp.nal.usda.gov/pgdic/Probe/v2n2/bene.html

Formula funding often encourages recipient institutions to conduct applied or technology-oriented research (Ruttan 1982). Also, with formula funding, the scientists are less likely to be preoccupied by grant writing activities and are more apt to spend their time on their creative scientific endeavors. According to a study by Frisvold and Day (1993), more grant money is allocated toward basic research like biology and animal production compared with other types of USA funding mechanisms. Following these observations, competitive grants may favor research at institutions that conduct applied research at the expense of those who conduct more basic research. This would create a two-tiered system of the "haves and the have-nots" (Buttel 1986) within the land-grant system.

The Role of Private Sector Research

Private investment in agricultural research plays a major role in modern development of improved agricultural inputs and products. The new emphasis on agricultural research being undertaken by the private sector has redefined the standard research areas of responsibility of the public and private sector. In the 1960's, the area of emphasis in private agricultural research was either improving farm machinery or developing new products pr processing procedures. Public sector research was typically dominated by research on plant breeding or ways to increase crop and livestock yields. These roles are evolving, and in 1992 nearly sixty percent of private research was devoted to these areas previously considered public sector territory (Klotz, Fuglie, & Pray, 1995).

The new role of private research creates an overlap in the type of research advances being made by the private and public sectors. The redefinition of the roles of public and private investment in the system agricultural research in the United States partly reflects the changes in the American economy. When American consumer demand for specific products is well defined, firms can respond by developing products with the desirable characteristics. If public sector research responds to these specific demands, then the results would only meet the demands of the group consuming the specific product. For this reason, public sector research tends to be geared toward fundamental or pre-technology research areas that benefit a larger group.

In addition to market forces, increased investment in private research is driven by public policy. Since the 1960's, Congress has strengthened and expanded the scope of laws concerning intellectual property rights (IPRs). Intellectual property rights allow firms to capture a larger portion of the benefits from their new inventions. Public policy also creates the funding for fundamental research in agriculture, which advances basic scientific understanding, and lays the foundation for private sector research to capitalize on.

Depreciation and Maintenance Research

Regardless of evaluation technique, time period, or database used, high rates of return to investment in agricultural research have been steadily realized. Studies that have indicated high rates of return to agricultural investments in research (Evenson, 1967; Cline 1975) were useful in the justification for allocation of public funds to agricultural research. However, there have been studies that indicate this rate declined over time (Peterson & Hayami, 1973; Davis 1979). This indicates that the stock of knowledge increases with investment over time, but will depreciate over time as well. According to them, this is why nearly half of all research conducted is necessary for maintenance of current stock of knowledge or productivity (Adusei 1988, Adusei & Norton, 1990). They recognize that different measures are appropriate for different types of research. The type of research evaluated determines the timing and magnitude of depreciation and obsolescence. The results of applied research are more susceptible to depreciation and obsolescence than basic research because applied research is inherently more sensitive to changes in controlling factors (Alston, Norton, and Pardey, 1995). Resistance in pesticides, for example, occurs naturally when pests evolve to resist chemicals, making previous research obsolete.

Research Spillovers

Research spillovers are the consequence of results from research in one region spilling over into another region. These may include spillovers of technologies themselves or the effects of research-induced price changes. When conducting studies on the evaluation of research investments based on state level observations, interstate spillovers become an additional problem. The importance of interregional spillovers was highlighted in a study conducted by White and Havlicek (1979) when the rate of return was reduced from 70 percent to 29 percent once outside research was considered. In Evenson’s 1978 study, similar geo-climatic regions determine the impacts of interregional spillovers on a state’s productivity. In addition, the structure of the agricultural experiment station system facilitates the interstate transfer and adaptation of research information in neighboring states. Once the information has been transferred, agricultural extension efforts, farmer education, and farmer income levels all affect the rate of adoption (Otto, 1981).

Model Specification-Relating Research and Production

Bredahl and Peterson (1976) used an aggregate production function to investigate inter-commodity allocation of research expenditures. They separated output into commodity categories and estimated the marginal products of research for individual states. The returns from such aggregated studies do not deal with concepts related to evaluating research at the more individual levels.

The core model presented by Alston, Norton, and Pardey (1995) employs the typical agricultural production function with knowledge as an input, measures the size and distribution of research benefits, and addresses general equilibrium and social policy issues. They incorporate a " complicated and uncertain" conceptual tool called the research production function into the model that relates how research investments combine with the existing stock of knowledge to produce an incremental change (It) in the stock of knowledge.

$I_t = I(R_t, \ldots, R_{t-n}; K_t, Z_t)$

$_t$ = years

I_t = Incremental change in the stock of knowledge

R_{t-n} = research investment; (n is years research is lagged)

R_t = research investment in initial year (when n =0)

K_t = stock of knowledge

Z_t = influences on the increment to useful knowledge like scientific context and institutional setting.

They relate the research production function to the agricultural production function algebraically by including this incremental change in the stock of knowledge in the factors of production that in turn influence the quantity produced.

A more useful framework incorporates the lagged values of research investments as independent variables in a typical agricultural production function. They set forth a reduced form of this equation that suggests the relationship between investments in research and productivity:

$Q_t = q\ (X_t, W_t, H_t, P_t, Z_t, R_{t-r}, E_{t-e})$

$_t$ = year

X_t = conventional inputs

W_t = weather

H_t = human capital useful to utilization of knowledge

P_t = prices[3]

Z_t = infrastructure inputs

R_{t-r} = research expenditures lagged r years

E_{t-e} = extension investments lagged e years

This equation is said to "capture the essence of most the approaches used to measure the economic consequences of agricultural research" (Alston, Norton, and Pardey, 1995).

Economic Surplus Approach

Studies utilizing the economic surplus framework to measure benefits from agricultural research can be categorized in to two groups, ex post and ex ante (Norton & Davis, 1981). Ex ante procedures are used to evaluate the prospective returns of a potential project before that project is undertaken. The ex post procedures can be further categorized into two groups: (1) the economic surplus approach which is used to realize rates of return, or (2) the production function approach, which is used to estimated marginal rates of return. Ex post procedures include techniques to measure the returns on past projects to evaluate their effectiveness. In this study, the objective is to measure the ex post effectiveness of investments in past research projects in cotton and peanuts using the economic surplus approach to realize an internal rate of return.

The earliest evaluation studies (Griliches, 1958, Schultz 1953) utilized the economic surplus approach, also known as the consumer-producer surplus approach[4]. An economic surplus approach is used to evaluate the benefits from a shift in the supply curve due to a change in productivity. This productivity is theorized to be a result of technology generated form agricultural research. Investigating this relationship between research investments and improvements productivity using the economic surplus approach is shown as the most successful approach to evaluating agricultural research (Alston, Norton & Pardey, 1995). The model used in this approach is a comparative-static, partial equilibrium model of supply and demand in a commodity market. Using this model, the shift in the supply curve generated from research and technology is measured in relation to the "old" supply curve. Comparing the new and old equilibrium point is then used to calculate the size and distribution of the resulting consumer and producer surplus.

Griliches' 1958 study controlled for some of these limitations by investigating the returns from agricultural research for a specific commodity, corn. He assumed that the value for the gains in social welfare from research in corn were the losses of surplus in the absence of that research. He used only the research and extension expenditures in corn in his model and found a 743 percent rate of return. The assumption of linear supply and demand in this

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[3]prices are included based on precedent set by Fulginiti and Perrin (1992) called the "induced-innovation hypothesis" .
[4] An illustrative comparison of the models used in the early studies is presented in Figure 1(Source: Zentner R., 1982, page 202).

basic model was extended by the assumption of constant elasticity supply and demand curves (Ayer & Schuh, 1972).

The economic surplus approach is attractive for many reasons. It is flexible enough to be applied in different situations with limited data requirements. It is also an effective tool when the objectives include the measurement of welfare benefits from an induced shift in the supply curve. Then the distribution of these benefits to consumers and producers is determined without difficulty.

In summary, although the economic surplus method has its merits, it is also subject to some sensitivity as well. The size and nature of the supply shift are assumptions that should be recognized as substantially biasing the estimates. Most empirical studies have assumed a pivotal or proportional change in the supply curve as a result from new technology, however this can be dangerous. The estimate of k (size of shift in the supply curve) is particularly important in determining the size of the social benefits. Finally, the elasticity assumptions can have severe effects on the estimates of social research as well. They most significant effect is on the measurements of the distribution of benefits between producers and consumers.

Duncan and Tisdell (1971) first emphasized the idea that the distribution of welfare benefits from agricultural research can vary drastically depending on the shape of the supply function. This suggests there are potential problems with using producer surplus to measure the benefits of some common types of technical change. These methods may seriously underestimate the change in profit from a new technology, depending on the characteristics, which constitute the technology that shapes the supply curve and the kind of technical change (Martin & Alston, 1994). Martin and Alston concluded that the producer surplus method is troublesome even in the case of a linear supply curve and a Cobb-Douglas (quadratic) production function. They find that the profit function is a more reliable resource, provides useful results, and suggest that it be used instead of producer surplus to measure welfare benefits resulting from a shift in the supply curve. They also discuss why the type of shift in the supply curve assumed is important but impossible to prove empirically. Due to the significant difference in total welfare benefits from a parallel shift in a linear supply curve versus a pivotal shift in the same.

curve, the authors maintain that the shift used in the analysis is crucially important. Specifically, they point out that producers will lose if the shift is pivotal

Based on the argument that there is no realistic and readily available estimate for the shape of a supply curve in a given study, the realistic approach is to assume the supply shift is parallel (Rose 1980 p. 837). Under this assumption, functional form of supply and demand is insignificant and it is appropriate to use local linear approximation.

Lags

As stated in the previous chapter, the dynamics of the shift in the supply curve and the resulting change in the stock of knowledge are important when measuring the consequences of research investments. Once research produces results, the response in the supply curve is not the static snapshot that the static model represents. Alston, Norton, and Pardey addressed lags in research and adoption by separating them into three categories. The idea is that the stock of knowledge yields a stream of benefits once it is increased and continues into the future until that knowledge or technology is obsolete.

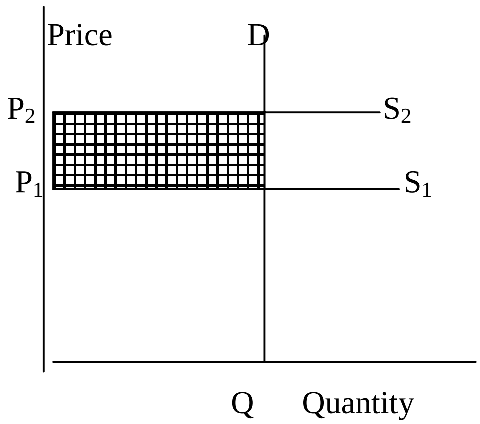


Figure 1a

Perfectly Elastic Supply
Perfectly Inelastic Demand
(Schultz, 1953)

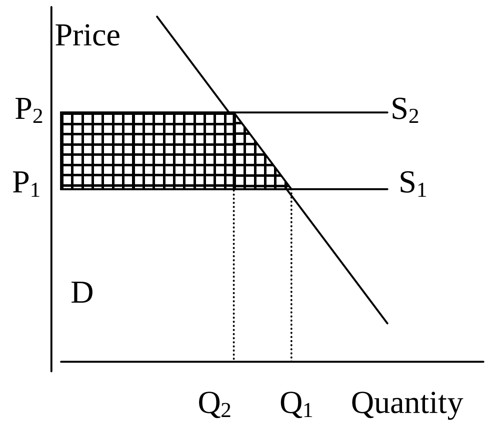


Figure 1b

Perfectly Elastic Supply
(Griliches, 1958)

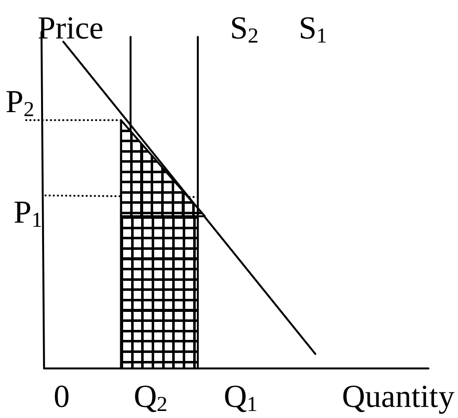


Figure 1c
Perfectly Inelastic Supply
(Griliches, 1958)

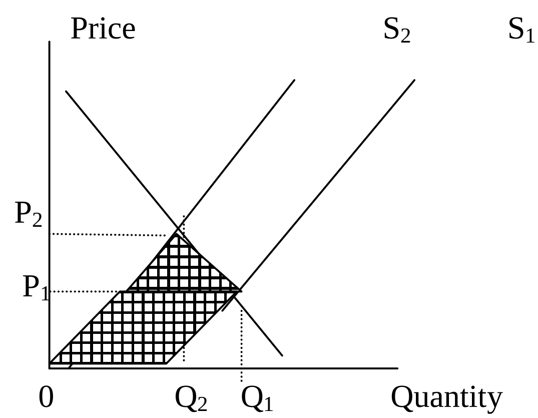


Figure 1d
Neither Perfectly Elastic
or Inelastic Supply
(Peterson, 1966)

Figure 1: Surplus Models used to Measure Welfare Benefits from Agricultural Research (Source: Zentner, 1982 p. 202.)

This happens in three stages. The first stage, the research lag, is a lag between the initial investment of the research and the results of the research. Then, the development lag is a lag between the results of the research and the development of the results into useful technology. And the third lag is called the adoption lag that is a lag in the generation of technology to its implementation in the real world. They postulate that applied research has shorter lags and basic research has longer lags.

CHAPTER 3

THEORETICAL AND METHODOLOGICAL FRAMEWORK

Introduction

Publicly funded agricultural research investments potentially contribute to agricultural productivity. Econometric approaches have been used to directly measure relationships between output and past investments in research that are not readily available from the marketplace. Economists have developed several approaches for generating information typically provided by the marketplace to help aid in supply and demand decisions in agricultural research. Most approaches attempt to determine the social value of actual or proposed research by estimating the research-induced savings in costs or gains in profit or output. The objective in this study is not to investigate the relationship between conventional inputs and output, rather to evaluate the affect that investments in research have on output.

Parametric approaches can be used to determine the nature and extent of benefits from technology resulting from past investment in research. These approaches entail many decisions including the specification of an explicit functional form that links inputs to outputs. They can be primal (production or response functions), dual (profit or cost functions), or supply equations. Additional decisions must be made about which method to use, commodity to include, level of aggregation, variables in the model, and how to specify the research variable in the model (Alston, Norton & Pardey, 1995). In the following sections, these questions are addressed based on the applicable theory in production economics as it relates to measuring benefits from research, data availability and constraints, and purpose of the analysis.

A Theoretical Model for Measuring the Magnitude and Distribution of Social Benefits from Investments in Peanuts and Cotton in the Southeast

The general theories and methods found in production economics are applied to evaluate the effects of agricultural research and development. Since the process of evaluating agricultural research and development goes beyond measuring the relationship between conventional inputs and outputs, there are problems using general models of production. The lag between investment and the impact of production are not accounted for causing the model to be mispecified and the resulting estimates to be biased (Alston, Norton & Pardey, 1995). In addition, there is the problem of specifying a variable to represent technical change. In the early 1970's, there were mostly primal models being used where quantity of output was modeled as a function of input quantities. These primal models incorporated a variable to represent technical change in a variety of ways. Some used time trends to represent technical change, or others simply distinguished between conventional inputs and other (unconventional) inputs. Griliches (1964), Evenson (1967,1968), Bredahl and Peterson (1976) and Davis (1979) used the method adopted in this study, incorporating an explicit measure of research as an input.

The majority of the literature on production economics recognizes the importance of including technological change in the specification. The problem of how to specify technical change and distinguish between economies of scale has been a popular issue in the literature as well. Most of these studies were similar to this one in that the primary goal was to estimate the impact of research. The way these studies accounted for technical change differed according the type of data being used. Studies using time-series data used a time trend to represent technical change. Alston, Norton and Pardey (1995) point out that when using panel data, “there is no natural ordering of the path of technology evolution” and it may be necessary to use a time trend and index technology cross-sectionally as well.

Traditionally, there are a few problems that are common in studies measuring effects and benefits of research. The statistical problem of simultaneity between inputs and outputs occurs commonly as a result of using annual data that are related in some way causing the error term and some included inputs to move together. In addition, a second statistical problem plaguing these models is multicollinearity. Multicollinearity occurs when all explanatory variables appear to move together and make it difficult to apportion the independent effects of each explanatory variable on the dependent variable.

Directly Estimating Supply

In choosing which parametric approach to apply in this study, consideration was given to the limitations and comparisons of primal, dual, and the direct estimation of the supply equation approach. Primal and dual approaches impose more inflexible restrictions on behavior than the supply equation approach, and are more stringent in their behavioral assumptions. They are based on competitive theory of the firm with perfect knowledge, which does not describe the situation in modeling agriculture or the effects of research investment on agricultural output. The supply equation method does a better job of handling expectations, uncertainty, and dynamic responses that are inherent in this type of estimation because it is sensitive to dynamic responses, expectation formations, and uncertainty in decision making (Alston, Norton & Pardey, 1995).

In addition to this argument, the supply equation response method is used for several reasons in this study. According to Colman (1983, p. 224),"the most significant factors in its favor are that it operates directly on the aggregate supply data which are the object of interest, and it handles dynamic adjustment in supply in ways that the other procedures do not…. Finally, it is a technique that has shown itself capable for generating acceptable and useful results". Limitations of this procedure are the problems with time-series regression analysis, which are also problems with primal and dual models. In this case, the benefits of directly estimating the supply function outweigh the costs of the limitations. There are only three studies that have actually used this method. Otto's 1981 study and Zenter's 1985 study were drawn upon heavily in organizing this study. Haque, Fox and Brinkman conducted the third study in 1989. The goal of all three studies was the evaluation of research on various specific commodities.

Drawing on the flexibility of this method in handling expectations and dynamics, this model is particularly desirable for this study because it allows supply response to price to be modeled with supply response to research. Alston, Norton, and Pardey (1995) give the general form of the equation describing the relationship between research investments and agricultural supply:

$$Q_t = q\,(P_t, W_t, \tau_t, U_t) \qquad (1)$$

Q_t = output produced

P_t = expected prices of output

W_t = conventional inputs

τ_t = a state of technology

U_t = uncontrolled variables

It should be noted that the reduced form of this equation includes indefinitely long lags in research and extension in the technology variable, as well as the stock of human capital and infrastructure.

Model Specification

The model used is an adaptation of the model presented above. The variables are aggregated across Alabama, Georgia, Florida, and South Carolina so that two separate equations will be estimated, one for cotton and one for peanuts in these four states for 33 years (1963-1995). Quantities, prices and acres are obtained from the historic database on the National Agricultural Statistics Service's (NASS) website. Prices and input costs have been deflated by the 1982 Producer Price Index for farm products (Bureau of Economic Analysis). Research expenditures are in 1984 dollars deflated by the Huffman and Evenson Index (Huffman & Evenson 1993).

For Cotton: $Q_t = q\,(P_t^*, W_t, \tau_t, U_t, A_t, t)$ (2)

Q_t = quantity produced in 1,000 pounds.

P_t^* = expected prices for year t = $P_{t-1.}$

W_t = conventional inputs-average cost of production per acre.

τ_t = state of technology- lagged research expenditures in cotton.

U_t = uncontrolled variables-rainfall weighted by acres devoted to cotton

A_t = acres harvested

T = time trend

For Peanuts: $Q_t = q\ (P_t^*, W_t, \tau_t, U_t, A_t, t)$ (3)

Q_t = quantity produced in pounds.

P_t^* = expected prices for year t = $P_{t-1.}$

W_t = conventional inputs-average cost of production per acre.

τ_t = state of technology- lagged research expenditures in peanuts.

U_t = uncontrolled variables-rainfall weighted by acres devoted to peanuts.

A_t = acres harvested

T = time trend

What follows is a brief discussion of each of the exogenous variables.

Expected prices of Cotton and peanuts

Expectations play an important role in almost any economic activity because so many decisions are made based on what is expected to happen in the future. For example, production may depend on expected sales or prices or investment may depend on expected profits. When producers make their production decisions about cotton and peanuts, they do so without complete knowledge about what levels of output there will be or the prices they will receive. They are forced to utilize available information and relative experience to formulate some expectation of the prices they will receive and level of output and then use these expectations in making their production decisions. The reasonable expectation is for production to decrease when expected price falls and increase when expected price rises.

Unfortunately, these expectations are not recorded or readily available to economists trying to estimate farm supply functions. Consequently, economists are forced to utilize some reasonable proxy to represent producer's unrecorded expectations. The literature suggests several proxies. For example, Meilke (1975) suggests using a polynomial distributed lag of past prices while Just (1974) uses a weighted lag declining over several years. Davis (1979) suggests using a polynomial distributed lag of past prices while Nerlove (1956) uses an adaptive expectation theory and assumes that expected prices are geometrically weighted average of past prices. Others postulate that a commodity's futures prices are an appropriate representation of producer's expected prices (Gardner 1976). The objective of this study is not to formulate expected price, so the assumption of a simple adaptive expectations model is chosen in the form of a one year lag of the average of prices received in Alabama, Georgia, Florida, and South Carolina.

Inputs and Costs of Production

An important question when measuring variables that affect supply is which inputs to use and more importantly how to measure them. Since fertilizer and labor are commonly major inputs in any crop production and a major determinant in affecting yields, many studies have used the prices of fertilizer and labor as a proxy for cost of production. One such study (Otto 1981) used a weighted price of fertilizer for each crop in the study.

For both cotton and peanuts, input prices are included in this model as an average yearly cost of production per acre. These costs include variable cash expenses, general farm overhead, taxes and insurance, capital replacement, operating capital, other nonland capital, and unpaid labor (Economic Research Service/USDA).

Uncontrolled Variables: Weather

Weather is a major factor affecting the yield levels of crops and can have enough of an impact in severe situations to drive the market for certain crops like cotton and peanuts. Many production studies ignore weather as an input resulting in quantity and productivity indexes that project fluctuations due to unmeasured weather influences (Alston et al 1995). Alston, Norton and Pardey (1995) conclude that omitting weather variables (thereby allocating them to the error term) will not lead to model bias or estimate problems as long as the weather variables are not correlated with other independent variables. Conversely, Otto (1981) postulated that when modeling supply response, it is necessary to consider these impacts of weather variables to prevent model bias. Some studies following Griliches (1958) method of specifying weather variables have used the Stallings (Stallings 1960) weather index, which was derived by regressing experimental yields of seven crops against a linear time trend ceteris paribus. Identifying worthwhile measures of weather variables that are effective in explaining their particular impact on particular crops is challenging especially since “different crops depend of different variables at different times within the year” (Geigel & Sundquist, 1984).

In this study, for both cotton and peanuts, averaged monthly rainfall is used as an estimate of annual rainfall in each state. The average of the monthly rainfall was computed in each of the four states weighted by the acres in that state dedicated to cotton or peanuts. The weighted average is intended to assign more importance to rainfall in the states with more acres devoted to cotton or peanuts. The disadvantage of this approach is that it allows for the possibility of late rains after harvest or in a specific geographic region that may skew the average in a falsely positive or negative direction.

Modeling Technical Change

An increase in technology is viewed as an output augmenting input in this model and incorporated directly into the supply equation. Past research evaluation studies have all chosen different means of representing the value of research investment or technical change. There are several considerations when specifying the variable for technical change.

The main issue is choosing the unit of measurement in how to specify the research variable. Griliches' (1958) measurements of research and extension were based on total number of farms times a farm average, and more recent studies used statewide totals (Peterson, 1966; Norton, 1981). The various studies in the past used proxies including research and extension man-years, salaries, and number of employees. The more common proxy is the actual money spent by the federal and state government representing the cost of research. Is this study, actual expenditures in cotton and peanuts are incorporated into separate models to measure their effects on productivity.

There are two general approaches concerning whether or not to aggregate the investment in research and extension is also an issue. The alternatives are to measure the returns to research and extension together or to measure the returns to research alone. This issue is addressed in this study by excluding extension in the technology variable. It is hypothesized in this study that research and extension have a separate effect on output. Therefore, it follows that the research-based technology variable does not include extension in its specification. Only research-based technology impacts are measured here.

When treated as a separate variable, extension can be viewed as a private good because an extension agent's expertise educating one farmer precludes his expertise from being allocated to another's education at that point in time. Other than the evaluation studies by Evenson (1978), Huffman (1976), few studies have reported impacts of investment in agricultural extension separate from the research expenditures. A justification given for this is that funding appropriations come from different sources and have independent impacts on agricultural production. Also, figures on extension spending by commodity are more difficult to compile. The impacts of extension efforts are much less likely to be a straightforward function of either spending or man-hours.

There are several alternatives in deciding how to model the lag between research expenditure and realized results from that expenditure. Three types of lags are used in the related literature: linear, polynomial and trapezoidal. Different lengths for the lags were also chosen in the related literature. Zentner (1982) utilizes several simple research lags lengths going back six, seven, then eight years. Davis (1979) compared several methods of estimating the research coefficient, testing its sensitivity to different lag structures. The specifications tested by Davis included a 6-year mean lag and a constrained second order Almon lag of 14 years, which centers the lag at 6 to 7 years (Griliches original lag in 1964 study). His results showed no significant difference in the magnitude of the research coefficient from any of these specifications when estimated in aggregate production functions.

Another question is what type of lag structure to use. There are a number of possible finite lag structures to choose from: a logistic curve (Griliches, 1958), polynomial (Cline, 1975; Davis 1979) trapezoidal (Huffman & Evenson, 1992), and inverted-V lags have all been used. A consensus in the literature points towards an inverted "V" distribution centering on a mean lag of six to seven years for aggregate research and the linearly increasing and decreasing weights on research distributing benefits over a 12-13 year period. Another option is the Pascal lag, which is presented by Alston, Norton, and Pardey (1995) "as less severe than the above approaches and more reasonably reflects our still rudimentary prior knowledge." The Pascal lag was chosen for the purposes of this study.

The Pascal lag distribution has a quite flexible shape and lag weights given by:

$$\lambda_r = (\phi + r - 1 / r) / (1 - \gamma^{\phi}) \qquad r = 0,1,\ldots, L_R$$

Where γ and ϕ are the two Pascal parameters. In keeping with common practice and previous literature on the stock of knowledge, the desired lag structure will model research expenditures so that the effect of research on production starts slowly, peaks after a lag of 3 or 4 years, and then depreciates fully by the eighth year (Evenson, 1968). Thus, the stock of knowledge is a weighted average of seven years of lagged research expenditures. The weights for the average were selected to fit on a Pascal distribution with parameters $\gamma = 0.4$ and $\phi = 0.6$. This situates the peak weights where desired and produces a distribution of weights that is skewed to the right. This calibration was checked to determine if the regression results were sensitive to the precise parameter values and the coefficient estimates were not overly sensitive; thus, the above calibration was deemed satisfactory.

An additional issue is the rate of depreciation of technological innovation once it is developed and adopted. In the past, authors have postulated that research investments add to a stock of knowledge capital, which is subject to depreciation just like any other investment over time. Also, the difference between these rates of depreciation and appreciation need to be insignificant in order for the assumption that research investment measures changes in the stock of knowledge to hold (Otto 1981). This points out that the flow from research investments is not necessarily equal to the stock of knowledge capital. Estimating the rate of research depreciation is beyond the scope of this study, and without any information about the depreciation rate, we will assume that the rate of depreciation of knowledge capital is equal to the appreciation rate as measured in annual expenditures.

Acres and Prices of Substitutes

The acres harvested are hypothesized in this study to be exogenous in influencing production of cotton and peanuts in the Southeast. The assumption is that there is no constraint on farmer's ability to acquire more land. This is also the assumption underlying the omission of prices of substitutes in the models for supply. Again, they do not have to make choices about how to allocate their acreage among cotton and peanuts based on their price expectations because they are not constrained to a fixed amount of land.

Estimation Procedure and Functional Form

In previous aggregate research evaluation studies, the databases used varied from a pool of cross-sectional data for several years (Davis, 1979; Norton, 1981), to a time series of U.S. aggregated UD production (Cline, 1975; White, Havlicek, and Otto, 1978), to a cross section of major production states over the course of one year (Griliches, 1964; Evenson, 1967; Bredahl & Peterson, 1976). For their purposes, OLS was the common means of estimation. In this study, ordinary least squares is used to estimate the supply equations for cotton and peanuts presented earlier.

The choice of functional form imposes a particular type of shift in the supply curve, parallel or pivotal, and is theorized to have a significant impact on calculations of research benefits. The procedure this study used followed the procedure used by Fox, Brinkman & Brown-Addision (1987) in which the assessment of the signs and significance of the coefficients were used to make decisions about functional form for the supply equation and simultaneously making decisions about the type of shift they induced.

Producer and Consumer Surplus Approach

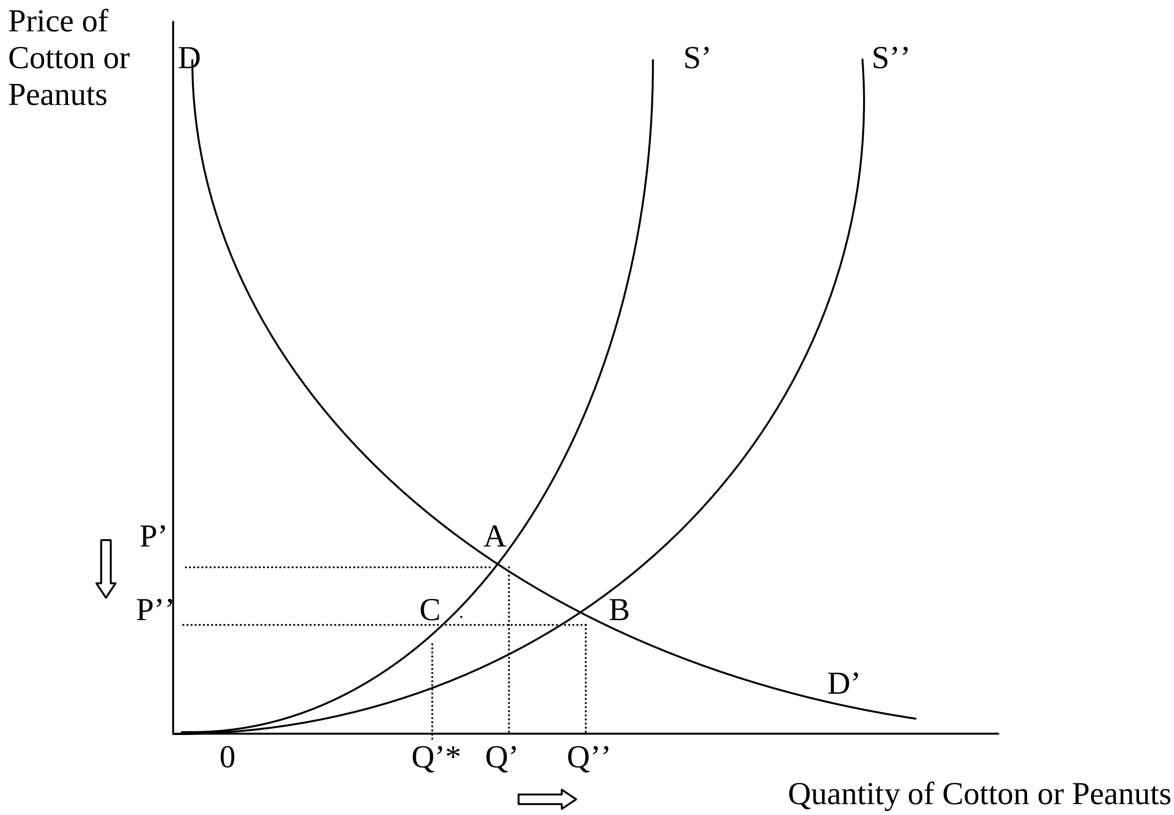
Marshall introduced the concept of economic surplus nearly a century ago in 1930 as an idea consisting of two mechanisms, consumer surplus and producer surplus. Consumer surplus is defined as the area between the price line and the Hicks compensated demand curve while producer surplus is defined as the area just below the price line and above the supply curve. For this study, the ordinary Marshallian demand curve is used instead of the theoretically correct Hicks demand curve based on past empirical studies that have justified it as acceptable if income elasticity of demand for the product is small (Ayer & Schuh, 1974).

The social benefits of agricultural research are measured in terms of changes in the consumers' and producers' surplus. These changes are the result of the outward shift in supply brought about by the adoption of some new technology derived from research. The surplus approach utilizes the area between the initial and resulting supply curve to represent surplus from a shift in supply, but this is a snapshot. For measuring the economic consequences of research, the actual shift in the supply curve occurs after the development lag and during the adoption lag producing the resulting surplus under the demand curve and between the two supply curves.

The shift in the supply curve at a point in time (snapshot) creates area between the price line and the two curves that are the consumer and producer surplus attributable to agricultural research. The consumer surplus is created as more quantities are available at lower prices and the producer surplus is created by the reduced costs of production and increased quantities. These two areas combined represent the total social benefits resulting from agricultural research. The magnitude of these benefits depends on the shape of the supply curve, and the distributions of these benefits depend on the elasticities of supply and demand. The proportion of the benefits going to consumers will be higher for low demand and high supply elasticities. The converse is also true. High demand and low supply elasticities will apportion the larger share of the benefits to producers. The constant price elasticity model engineered by Hayami and Akino (1977) will be used in this study. The constant-elasticity model has supply passing through the origin, regardless of its elasticity. Typically, this constant-elasticity model is combined with the assumption that the shift in the supply curve is proportional, not parallel.

The type of shift that the supply curve is assumed to undergo has enormous implications on the benefits realized by producer and nonproducers (consumers). If a linear supply function is chosen, total benefits from a parallel shift are twice what they would have been from a proportional shift. Given a parallel shift, producers always benefit from research unless supply is perfectly elastic or demand is perfectly inelastic. This is an important point to consider when the outcome of the research can be somewhat controlled by the choice the researcher makes about the shift in the supply curve.

To illustrate the theoretical framework of this model with constant elasticity and proportional shift in supply, consider Figure 2 where the demand for cotton or peanuts is given by the curve D’. The supply curve for cotton or peanuts is given by the curve S’’. The consumer surplus is represented by P’’BD and producer surplus by the area P’’B0. The curve S’ represents the supply of cotton or peanuts if there had been no research conducted.



<u>Figure 2</u> Theoretical Models for Measuring the Social Benefits of Cotton And Peanut Research

Consumer surplus would be area P'AD and producer surplus would be area P'A0. The change in consumer surplus resulting from the absence if technology improving research would be the area P'P''AB, is a gain to consumers as a result in the lower price of cotton or peanuts (P" to P'') and the increased quantity (Q' to Q''). The change in producer surplus would be the area 0CB minus the area P'P''AC. This represents potential gains to producers resulting from lower costs of production, increased supply, but accounts for reduced prices. Changes in consumers' and producer's surplus are then aggregated to obtain the social benefits attributed to the cotton and peanut research activities. The total social benefits from research in cotton or peanuts is then area ABC + area CB0. The mathematical formulas that provide approximations of these areas are[5]:

$$\text{Area ABC} = \tfrac{1}{2}\,(P''Q''h^2 / \varepsilon + \eta)\ \nabla\ \tfrac{1}{2}\,[P''Q''(k + k\varepsilon)^2]/ \varepsilon + \eta \qquad (4)$$

$$\text{Area CBO} = (h/1\text{-}\varepsilon)P''Q''\ \nabla\ kP''Q'' \qquad (5)$$

$$\text{Area } P''P'AC = P''Q''h/ \varepsilon + \eta\ [1\text{-}1/2(h\eta/\varepsilon + \eta)\text{-}1/2k]$$

$$= P''Q''\ k(1+\varepsilon)/\varepsilon + \eta\ [1\text{-}1/2*k(1+\varepsilon)\eta/\varepsilon + \eta - 1/2k(1+\varepsilon)] \qquad (6)$$

Where $k = (Q''\text{-}Q'/Q'')$, the rate of shift in the cotton or peanut production function,

$h = (Q''\text{-}Q'{*}/Q'')$, the rate of shift in the cotton or peanut supply function,

ε = Price elasticity of cotton or peanut supply

η = Absolute price elasticity of demand for cotton or peanuts.

The above parameters are necessary and must be specified or empirically estimated in order to estimate the annual social benefits from cotton or peanut research activities if the above theoretical model is to be used. The methodology and procedures used to obtain these parameter estimates are presented in the following sections.

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[5] These formulas are derived from Hayami and Akino (1977, pages 53-5 4).

The underlying principle used in this study is that research in agriculture generates new knowledge that contributes to some advance in technology or improvement in inputs. This new technology in turn contributes to output and generates an outward shift in supply. Research therefore generates an intermediate good, the advance in technology. Under the assumptions of perfect competition, a firm's supply function can be derived from its production function by maximizing the profit function subject to a technology constraint and solving the result for necessary parameters.

Calculating the Annual Shifts in the Supply Curve

Once the supply model is estimated, the effects of the research can be found by combining these estimates with a model of demand in order to measure the supply response and calculate changes in welfare. Although agricultural output can be increased as a result of increases in conventional or purchased inputs, we are interested in the growth consequences attributed to investment in agricultural research. The idea is to use the estimated supply function to create prices and quantities under alternative situations, with and without actual research expenditures. Then the values of the consumer and producer surpluses generated under these alternative situations can then be calculated and compared

It should be noted that choices made about expectations and specifying dynamics have implications for the use of the supply function for calculating research benefits. The choice of a static model with expected prices equal to actual lagged prices implies that a shift in supply today will have an impact on production and prices in the current period as opposed to indefinitely. However, the output from this type of model can be used comparatively faithfully in an economic surplus model of research benefits.

Calculating the annual shifts in the supply curves (k and h) requires the estimation of the coefficients of estimated supply curve. Once the coefficients are obtained, they are used to estimate quantities of cotton and peanuts with and without research expenditures in order to calculate the annual shifts in the production and supply (k and h) solely attributable to research.[6]. The supply functions with and without a research as an exogenous variable for both cotton and peanuts can be represented by equations collapsing everything that is not prices or research into one variable, α_0, so the estimated supply equation is restated as:

$$\hat{Q}_{Rt} = \hat{\alpha}_0 + \hat{\beta}_2 P_{t-1} + K_t\hat{\beta}_6 + \varepsilon_t \qquad (7)$$

Where, $\hat{Q}_{Rt}$ = output with a research variable in year t,

α_0 = constant representing all other supply shifters,

K_t = Pascal lagged public research expenditures, and

$\hat{\beta}_2$ and $\hat{\beta}_6$ = estimated coefficients on lagged prices and the research variable.

The alternative supply equation under the assumption that there are no expenditures (setting research expenditures equal to zero) is also needed to calculate h_t. This assumed equation is:

$$\hat{Q}_0 = \alpha_0 + \beta_2 P_{t-1} + \beta_6 (0) + \varepsilon_t \qquad (8)$$

Where $\hat{Q}_0$ = estimated out put without a research variable in year t.

These calculated quantities under the different research assumptions correspond to the changes in output (Q' hat and Q''hat) resulting from the shift in the supply curve illustrated

[6]Recall the consumer and producer surplus calculations require these annual shifts in the production curve (k_t)

in Figure 2. These calculations performed to obtain the annual shifts in the supply curves (h_t) attributable to peanut and cotton research in the region are:

$$h_t = \hat{Q}_{Rt} - \hat{Q}_{0t} / \hat{Q}_{Rt} \qquad (9)$$

Where $\hat{Q}_{Rt}$ = level of output of cotton or peanuts (7) that comes forth in year t as a Public research expenditures in the respective commodity (cotton or peanuts) areas, and

$\hat{Q}_{0t}$ = estimated level of output in cotton or peanuts (8) without research that would have come forth <u>ceteris paribus</u> (holding all other inputs constant).

Substituting equations (7) and (8) into equation (9):

$$h_t = (\alpha_0 + \beta_2 P_{t-1} + K_t\beta_6 + \varepsilon_t) - (\alpha_0 + \beta_2 P_{t-1} + \beta_6 (0) + \varepsilon_t) / (\alpha_0 + \beta_2 P_{t-1} + K_t\beta_6 + \varepsilon_t)$$

$$= (K_{t-l)} / (\alpha_0 + \beta_2 P_{t-1} + K_t\beta_6 + \varepsilon_t) \qquad (10)$$

Using values obtained for $h_{t,}$ the values for k_t are calculated using the following:

$$k_t = h_t / (1 + \varepsilon_{t)} \qquad (11)$$

Where k_t = rate of shift in the production function,

h_t = annual shifts in the supply curves

ε_t = the price elasticity of supply.[7]

Using these estimations for annual shifts in the cotton or peanut models due to research expenditures, substituting h_t and k_t (along with price elasticity of supply) into equations (4),

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and in related the supply curve (h_t).

(5), and (6) will produce the welfare distribution measurements. The price elasticity of supply assumed in this study is estimated from the supply function and it is assumed that this price elasticity is appropriate for the years this study covers.

Calculating Summary Economic Effects Using Internal Rate of Return (IRR)

Drawing on capital budgeting and benefit-cost analysis methods, summary statistics evaluating investment in agricultural research vary form net present value, benefit-cost rations, to internal rates of return. In order to measure the economic effects of expenditures on research, an internal rate of return is calculated using the welfare measurements obtained in the previous section. The internal rate of return is the rate of interest that enables the discounted cost of research equal to the discounted benefits from research at a given point in time. The formula for the internal rate of return is:

$$r: \quad \Sigma_{t=0 \text{ to } T} = (B_t - C_t)/(1 + r)^t = 0 \qquad (12)$$

Where, r = internal rate of interest

C_t = social costs in year t.

B_t = social benefits in year t

T = last year research produces benefits

This formula calculates average rates of return to past agricultural research investment. The research endeavor is presumed profitable if the internal rate of return is greater than the cost of the research.

[7] Hayami and Akino (1977, p. 53-54) postulate that under competitive assumptions, the relationship between (h_t) and (k_t) can be approximated by $h_t = (1+\varepsilon_t)$ kt where , is the price elasticity of supply. This equation has been solved for k_t above.

Limitations

There is a wealth of debate about the many limitations and methods in research evaluation. Therefore, it is reasonable to say that limitations are inherent in this type of research. This study is not immune to the problems they may cause. Using the naïve expectations model for expected prices could be considered one such limitation. Consider the other information farms have when making decisions about what to plant. The adaptive or rational expectations could be used. Simultaneity arises because inputs may not behaviorally or statistically be exogenous. For example, simultaneity between acres and other inputs is a limitation because past prices may in fact influence the acres planted, which would influence acres harvested.

Specification error is another potential pitfall. A major limitation in this study is the exclusion of private research and private and public extension. The social costs are likely biased downward as a result. The coefficients will be biased if a true estimate is omitted from a model, and the other variables must explain their effects or if a variable is included in the model, but is not measured correctly. A problem could exist with the chosen specification of the research variable. Zentner (1982) and Alston, Norton, and Pardey (1995) suggest that the research lag last longer than 7 years; they suggest a lag for as long as thirty years. Also, the weather variable represented by the average rainfall in each year may not accurately describe the rainfall that is most relevant to the performance of cotton and peanuts. In Zentner's model, he used an average of the two months between planting and harvesting season in each year. Cotton and peanuts are planted in April and May, and harvest begins in September. It would be more accurate to use a combination of rainfall in June, July and August to explain rainfall affecting these crops' production patterns.

Multicollinearity is inherent in research evaluation as well because research and other input variables commonly move together over time. Some options to deal with this are to perform different types of regressions (which may require a trade of variance for bias) or to acquire more data. The good news is that according to Alston, Norton and Pardey, the multicollinearity between the nonresearch inputs is not as detrimental and is less of a problem with the supply-response model used in this study.

The impact of aggregate risk variables is also suggested in the literature as important. Previous studies such as Otto (1981) indicate that a producer's attitude toward risk can influence output levels. For our purposes, this impact on production is not explicitly included, yet depending on the unobservable "real model"; this could arguably be a drawback in this study.

In the southeastern region of the United States, peanuts are a valuable and high production crop. An important caveat concerning the peanut model is how it is complicated because of government programs involving quotas and prices. Although estimating the supply curve in these conditions is dangerous, the results may be useful for the purposes of distribution of welfare benefits and returns on investment.

CHAPTER 4

DISCUSSION AND EMPIRICAL RESULTS

The following chapter is broken down step by step into three main sections: (1) empirical estimation of the supply functions, (2) economic surplus calculations, and (3) internal rates of return. The econometric techniques used in estimating the proposed cotton and peanut supply functions and their empirical results are presented in this chapter. Next, the data and mathematical processes for computing the annual rates of change in supply resulting from expenditures in research on cotton and peanuts in the region are explained and presented. Then, the consequential changes in producer and consumer surplus resulting from the annual shifts in the cotton and peanut supply are calculated and presented. Finally, internal rates of return on research expenditures are calculated and presented.

Empirical Estimation of the Cotton and Peanut Supply Functions

In general, econometrics is the application of statistical and mathematical methods to the analysis of economic data with the purpose of lending empirical content to support or refute economic theories. The theory being tested in this study is that investment in agricultural research positively contributes to agricultural production. Econometric analysis is used to estimate the parameters of a given economic model, which is a set of assumptions used to approximate the behavior of an economy using a set of observed variables (Maddala, 1992). Economic models are a simplified representation of the real world, so before a model can be estimated, some simplifying assumptions must be made. The economic model is then translated into an econometric model.

The econometric model in this study consists of supply functions for cotton and peanuts that were estimated using data derived from pooled time-series cross-sectional data for the four states of Alabama, Florida, Georgia, and South Carolina. The data were mostly published with the exception of the research expenditure variable, which was collected and provided by Wallace Huffman from Iowa State University. The prices, quantities, harvested acres, and cost of production variables for both commodities are available from the National Agricultural Statistics Service (USDA), which maintains historical agricultural statistics for many commodities. The cost of production is an average per acre cost of producing cotton and peanuts in the Southeast. Chris McIntosh of University of Idaho provided the data for the amount of rainfall in the four-state region. The expected prices and average costs of production were deflated in 1982 dollars using the Consumer Price Index (CPI) published by the Bureau of Economic Analysis. The public agricultural research expenditures are in constant 1984 prices, or real terms. The nominal or current values were deflated by the Huffman and Evenson public agricultural research price index (Huffman & Evenson, 1993). Based on the theory that research spillovers occur within similar geo-climatic regions, all the data was averaged or aggregated to create a region-wide data set for each commodity over the 33 years from 1963 through 1995.

The first step in calculating returns to research in cotton and peanuts for this study is to directly estimate the supply function of each commodity. The exact functional form of equations two (2) and three (3) from Chapter 3 are as follows:

For Cotton: $\ln Q_t = \beta_0 + \beta_1(\ln P_t^*) + \beta_2(\ln W_t) + \beta_3(\ln\tau_t) + \beta_4(\ln U_t) + \beta_5(\ln A_t)$, (13)

for t = 1 through 33

β_0 = intercept

β_i = parameters on the exogenous variables for i = 1 through 5

Q_t = quantity produced in 1,000 pounds.

P_t^* = expected prices for year t = $P_{t-1.}$

W_t = conventional inputs-average cost of production per acre.

τ_t = state of technology- Pascal lagged research expenditures in cotton.

U_t = uncontrolled variables-rainfall weighted by acres devoted to cotton

A_t = acres harvested

For Peanuts: $\ln Q_t = \beta_0 + \beta_1(\ln P_t^*) + \beta_2(\ln W_t) + \beta_3\tau_t + \beta_4(\ln U_t) + \beta_5(\ln A_t)$ (14)

for t = 1 through 33

β_0 = intercept

β_i = parameters on the exogenous variables for i = 1 through 5

Q_t = quantity produced in pounds.

P_t^* = expected prices for year t = $P_{t-1.}$

W_t = conventional inputs-average cost of production per acre.

τ_t = state of technology- Pascal lagged research expenditures in peanuts.

U_t = uncontrolled variables-rainfall weighted by acres devoted to peanuts.

A_t = acres harvested

In both of the above equations, the state of technology (τ_t) is defined as Pascal lagged research expenditures. The research expenditure variable data is lagged seven years to account for the time it takes for an investment in research to produce results[8]. In order to do this, the matrix of exogenous variables is separated into two groups, (1) the research variable

[8] The research lag assumption of seven years is reasonable based on the findings of previous empirical studies such as Evenson's 1968 study that found a mean research lag for all agricultural research in the United States was between 6 and 8 years.

and (2) all other exogenous variables. Then, the research variable will be weighted using a Pascal lag and this transformed variable will be used in the model for estimation. The research variable group is a thirty-three by seven matrix of research expenditures lagged one year in each column so that the first column is research expenditures lagged one year (1962-1994) and the second column is research expenditures lagged two years (1961-1993) until the last column is research expenditures lagged seven years (1956-1988).

The next step in performing a Pascal lag is to create a matrix of weights using the formula in chapter three. Plugging in the chosen parameters for ϕ and γ, the formula will equal seven different numbers for each number that is plugged in for the years of the lag r (r= 1,2,3….7). These seven numbers create the one by seven vector that is multiplied by the research expenditure matrix explained earlier. Multiplying these two matrices yields a column vector of weighted research expenditures that represent the stock of knowledge in the models presented in equations (13) and (14) to be estimated.

The above models were estimated using the method of ordinary least squares. The parameter estimates for research expenditures and expected price are used in the calculation of the annual shift in the supply curve, which is then used in the calculations of the consumer and producer surplus measurements. The parameter estimates for all the exogenous variables resulting from the empirical estimation procedure are shown in Table 3.

The coefficients on all the exogenous variables were statistically significant at a 5 percent significance level. The estimated coefficient on acreage in the peanut regression had a negative sign, which could at first glance indicate that as acreage harvested increased, the quantity produced decreased. This result appears to conflict with prior theoretical expectations. However, a little thought suggests that the coefficient is the result of the federal quota program for peanuts and the aggregate time series nature of these data. Because the peanut quota is in pounds, not acres, as average yields rise over time the acreage (planted and) harvested will tend to decline unless farmers choose to grow a greater amount of additional peanuts outside the quota program. Thus, we are picking up this long-run correlation in our regression results, not any causative effect of acreage that reduces production.

The cotton model indicated that the coefficient on rainfall was not statistically different from zero. The statistical insignificance of rainfall may be attributed to irrigation practices that control for the uncontrollable variance in weather variables. All of the signs on the parameters in the estimated cotton model were consistent with prior expectations based on economic theory.

For both models, the effect on output of public expenditures on cotton and peanut research in the United States was positive and statistically significant at a 5 percent significance level. These estimates suggest that for a one-dollar increase in expenditures in cotton, there was a small but positive increase in quantity produced. For peanuts, a one-dollar increase in the investment in peanut research is estimated to increase production 27 pounds. Once the postulated function was estimated, the portion of the shift in supply attributable to research was measured by calculating the annual relative shift in the supply function holding all other variables constant.

Calculating Annual Shifts in Cotton or Peanut Production Functions

Now that the supply curves have been empirically estimated for cotton and peanuts, the estimated coefficients and various exogenous variable combinations are used to calculate the

Table 3: Estimated Parameters for the Cotton and Peanut Supply Functions

VARIABLES	**COTTON**		**PEANUTS**	
	Estimated Coefficients	p-value	Estimated Coefficients	p-value
Intercept	-50.72	.004249	.54	.271035
Lagged price	1.39	.000198	.81	.000000
Rainfall	3.69	.350197	.14	.001232
Acres Harvested	.85	.000004	-.28	.000000
Input Costs	-.68	.059431	-.43	.000000
Research Expenditures	.25	.000001	.00065	.000000
R-square	.7873		.9774	
Durbin-Watson	1.69		2.21	

annual shifts in the supply curves resulting from expenditures in research. The variations in the exogenous variables involve making some simple assumptions about the values of the research expenditure variable. The explanation of the procedure for obtaining the estimates for rates of shift in the aggregate cotton or peanut production function (k_t) and in the aggregate cotton and peanut supply function (h_t) are presented in the following.

Recall the cotton and peanut supply functions were estimated including a research variable, along with other conventional and unconventional input variables. This approach was utilized to measure the social benefits of all research conducted for cotton and peanuts in Alabama, Georgia, Florida and South Carolina using the equations (4), (5), and (6) set forth in Chapter 3. It involved specification of a supply function that was flexible enough to handle unconventional inputs such as research expenditures could be included as exogenous variables. This way the contributions of cotton and peanuts research could then be measured directly by the relative shifts in the supply curve by comparing the results of a fictional situation with no research. The essence of this approach involves estimated the supply functions presented in equations (2) and (3) for cotton and peanuts respectively.

The annual shift in the supply function, h_t, for both commodities requires $\hat{Q}_{R\,t}$ and $\hat{Q}_{0t}$ representing the quantities of cotton and peanuts in each year under two different assumptions are presented in Table 4. The values obtained for $\hat{Q}_{R\,t}$ represent the quantities of the commodity with research as an exogenous variable. The values for $\hat{Q}_{0t}$ represent the quantities that would have existed without research expenditures on the commodity. These values are obtained using matrix algebra, multiplying the X matrix of exogenous variables by the coefficients from the regression, which will yield a 33 by 1 matrix of annual shifts in the supply function. The formulas for this calculation is:

$$\hat{Q}_{R\,t} = [X]*[B] \qquad (15)$$

Where X = 33 by 6 matrix of exogenous variables.

B = 6 by 1 matrix of coefficients on the exogenous variables

$$\hat{Q}_{0t} = [\tilde{X}]*[B] \qquad (16)$$

Where $\tilde{X}$ = 33 by 6 matrix of exogenous variables setting all the values for research expenditures equal to zero.

B = 6 by 1 matrix of coefficients on the exogenous variables.

These computations are substituted for the values in equation (9) that was presented in Chapter 3 to obtain the annual shifts in supply for cotton and peanuts (h_t). The calculations of producer and consumer surplus require not only annual shifts in the supply curve (h_t) for cotton and peanuts, but in the production curve (k_t) as well. The values for (k_t) are obtained using the price elasticity of supply for each commodity, which are the coefficients on expected price from the regressions. These estimates are assumed to be the appropriate price elasticities of supply for each commodity in period covered in this study, so they can be used in equation (11) to get (k_t).

Calculating Consumer and Producer Surplus

In addition to the values for (h_t) and (k_t), recall equations (3), (4), and (5) from Chapter 3 require other market related data including price elasticities of demand. In the simplest models, elasticities of demand are assumed to be zero. For the economic surplus purposes of this study, the elasticity of demand for the commodities plays an important role

Table 4: Annual Shifts in Supply and Production Curves Attributable to Research

Year	COTTON		PEANUTS	
	h_t	k_t[9]	h_t	k_t[10]
1963	1.000171	0.418306	0.999696	0.552318
1964	1.000167	0.418305	0.999651	0.552293
1965	1.000152	0.418299	0.999604	0.552268
1966	1.000084	0.418270	0.999644	0.552290
1967	1.000047	0.418255	0.999547	0.552236
1968	1.000073	0.418265	0.999558	0.552242
1969	1.000074	0.418266	0.999512	0.552216
1970	1.000077	0.418267	0.999372	0.552139
1971	1.000098	0.418276	0.999195	0.552041
1972	1.000095	0.418275	0.999081	0.551978
1973	1.000089	0.418272	0.998961	0.551912
1974	1.000156	0.418300	0.998551	0.551686
1975	1.000073	0.418266	0.998181	0.551481
1976	1.000096	0.418275	0.998316	0.551556
1977	1.000061	0.418260	0.998273	0.551532
1978	1.000054	0.418258	0.998312	0.551554
1979	1.000052	0.418257	0.998456	0.551633
1980	1.000044	0.418253	0.999169	0.552027
1981	1.000080	0.418269	0.997946	0.551351
1982	1.000085	0.418271	0.998134	0.551455
1983	1.000035	0.418250	0.998134	0.551455
1984	1.000084	0.418270	0.997163	0.550919
1985	1.000102	0.418278	0.997270	0.550978
1986	1.000056	0.418259	0.997681	0.551205
1987	1.000083	0.418270	0.997699	0.551215
1988	1.000097	0.418275	0.997551	0.551133
1989	1.000097	0.418276	0.997216	0.550948
1990	1.000103	0.418278	0.998237	0.551512
1991	1.000188	0.418314	0.996308	0.550446
1992	1.000185	0.418312	0.996842	0.550741
1993	1.000159	0.418301	0.997850	0.551298
1994	1.000311	0.418365	0.996815	0.550726
1995	1.000288	0.418355	0.997779	0.551259

[9] The price elasticity of supply used for this calculation was 1.39.
[10] The price elasticity of supply used for this calculation was .81.

in the producer and consumer surplus results. The required domestic price elasticity of supply was determined from the coefficient on prices in the directly estimated supply equation.

The price elasticity of demand entails making some additional choices. The required domestic price elasticities of demand can be obtained using previous studies published results, directly estimating the demand equations, and/or assumptions based on economic theory. Since we have no regional> estimate of price elasticity of demand for cotton and peanuts in the Southeast to match the four states modeled here, national estimates were used. It is likely that this overstates the elasticity for the region since regional elasticities tend to be smaller than national elasticities. However, given the percentage of national cotton and especially peanut production that occurs in this four-state region, regional demand elasticities may not vary much from the national values. Further, in the sensitivity analysis, the results did not drastically change under the assumption of smaller elasticities of demand indicating that using the national estimates are reasonable for the present purposes.

Two recent studies revealing cotton and peanut price elasticities of demand were relied upon for these figures in the economic surplus calculations. White and Wetzstein's 1995 study estimated an elasticity of demand for cotton that was used, and Zhang, Fletcher and Carley's (1992) study estimated an elasticity of demand for peanuts, which was also used. These estimates where used in conjunction with the annual shifts in supply and production and other variables in equations (4), (5) and (6) from Chapter 3. The annual shift calculations for supply and production of cotton and peanuts resulting from investment in cotton and peanut research are presented in Table 4.

In addition to the total social benefits to consumers and producers for cotton and peanut research, the separate changes in producer and consumer surplus were also calculated and are presented in tables 4 and 5, respectively. In tables 4 and 5, the total benefits column represents the sum of the changes in producer and consumer surplus for the period 1963 to 1995 resulting from investment in cotton and peanut research, respectively. The estimated social benefits were positive and substantial for every year in the period. The annual social benefits from investment in cotton research over the period 1963 through 1995 ranged from about 317 million dollars to 114 million dollars in 1982 terms. For peanuts, the annual social benefits ranged from $110 million to $336 million in 1982 dollars over the period.

The proportion of benefits captured by producers and consumers presented in Figures 3 and 4. The producers captured 24% and consumers captured 76% of total benefits to society resulting from investment in cotton research. The proportion of benefits captured by producers resulting from investment in peanut research was 17%, leaving 83% to be captured by consumers. Figures 3 and 4 illustrate the conclusion that the consumers in the region captured the majority of social benefits from research investment.

Calculating Summary Economic Effects Using Internal Rate of Return (IRR)

The annual social benefits represent the benefits to society, but do not consider the social costs. Annual investment in research can be combined with the results in Tables 4 and 5 to calculate an internal rate of return to compare the costs and benefits of the investments. The research expenditure variable used to directly estimate the supply equations was lagged seven years using a Pascal lag and deflated in 1984 dollars. Two changes were made to the research variable in order to utilize it in equation (12) for the IRR calculations. The actual

Table 5: Economic Surplus Measures for Cotton 1963-1995

Year	area ABC	area CBO	P1P2AC	TOTAL BENEFITS	Δ PS	ΔCS
1963	121887689.9	98707222.4	46725623.0	$ 220,594,912.37	$51,981,599.50	$168,613,312.90
1964	133223458.9	107887394.1	51071677.7	$ 241,110,853.05	$56,815,716.40	$184,295,136.60
1965	114583668.1	92793277.7	43927800.1	$ 207,376,945.77	$48,865,477.60	$158,511,468.20
1966	110855103.0	89777233.0	42505853.0	$ 200,632,336.02	$47,271,380.10	$153,360,955.90
1967	85073742.5	68899342.2	32623434.0	$ 153,973,084.70	$36,275,908.20	$117,697,176.50
1968	104042094.4	84260176.4	39894651.8	$ 188,302,270.88	$44,365,524.60	$143,936,746.30
1969	88779782.4	71899673.3	34042204.6	$ 160,679,455.72	$37,857,468.80	$122,821,987.00
1970	78037461.3	63199744.9	29922906.7	$ 141,237,206.22	$33,276,838.30	$107,960,367.90
1971	80930488.1	65541911.9	31030507.4	$ 146,472,400.04	$34,511,404.50	$111,960,995.50
1972	93816870.1	75978148.7	35971736.2	$ 169,795,018.79	$40,006,412.40	$129,788,606.40
1973	63310234.8	51272353.7	24275127.2	$ 114,582,588.47	$26,997,226.50	$87,585,362.00
1974	101507829.8	82203861.1	38914474.2	$ 183,711,690.91	$43,289,386.90	$140,422,304.00
1975	75297995.9	60981283.0	28872765.3	$ 136,279,278.85	$32,108,517.60	$104,170,761.20
1976	93767442.3	75938082.0	35952704.0	$ 169,705,524.30	$39,985,378.00	$129,720,146.30
1977	116725489.3	94532682.2	44759473.9	$ 211,258,171.50	$49,773,208.30	$161,484,963.20
1978	100048658.4	81026893.0	38365248.5	$ 181,075,551.35	$42,661,644.40	$138,413,906.90
1979	128220363.3	103842588.9	49168439.9	$ 232,062,952.28	$54,674,149.10	$177,388,803.20
1980	110381890.6	89396022.7	42328780.5	$ 199,777,913.28	$47,067,242.20	$152,710,671.10
1981	132009768.2	106909794.8	50617794.9	$ 238,919,562.99	$56,291,999.80	$182,627,563.20
1982	102545615.7	83047640.6	39319561.0	$ 185,593,256.35	$43,728,079.60	$141,865,176.80
1983	105557516.6	85489281.5	40479656.9	$ 191,046,798.13	$45,009,624.60	$146,037,173.60
1984	133042802.5	107746197.8	51013441.6	$ 240,789,000.36	$56,732,756.20	$184,056,244.10
1985	125715669.0	101811194.2	48201701.0	$ 227,526,863.21	$53,609,493.20	$173,917,370.00
1986	117946417.8	95521702.4	45228135.5	$ 213,468,120.24	$50,293,567.00	$163,174,553.30
1987	104817196.6	84887408.8	40190790.3	$ 189,704,605.42	$44,696,618.50	$145,007,986.90
1988	134785795.9	109156982.8	51680046.4	$ 243,942,778.71	$57,476,936.50	$186,465,842.30
1989	116066094.0	93996689.1	44502374.8	$ 210,062,783.10	$49,494,314.40	$160,568,468.80
1990	140486731.1	113773495.7	53865013.6	$ 254,260,226.75	$59,908,482.10	$194,351,744.60
1991	151193143.9	122438178.9	57957232.5	$ 273,631,322.74	$64,480,946.40	$209,150,376.40
1992	130772772.1	105901710.7	50129906.6	$ 236,674,482.80	$55,771,804.10	$180,902,678.70
1993	126483853.5	102430007.6	48489105.1	$ 228,913,861.06	$53,940,902.50	$174,972,958.60
1994	126241961.7	102225259.6	48377247.1	$ 228,467,221.32	$53,848,012.50	$174,619,208.80
1995	175484472.2	142101598.9	67251580.9	$ 317,586,071.10	$74,850,018.00	$242,736,053.10

Table 6: Economic Surplus Measures for Peanuts 1963-1995

Year	area ABC	area CBO	P1P2AC	TOTAL BENEFITS	Δ PS	ΔCS
1963	171373348.	123562380.	73091101.3	$294,935,728.42	$50,471,278.98	$244,464,449.45
1964	195263147.	140788206.	83286942.0	$336,051,353.64	$57,501,264.59	$278,550,089.04
1965	194437704.	140194044.	82941800.8	$334,631,748.45	$57,252,243.48	$277,379,504.96
1966	176290665.	127108834.	75195346.3	$303,399,499.61	$51,913,487.82	$251,486,011.78
1967	181454122.	130833730.	77411342.1	$312,287,852.30	$53,422,388.01	$258,865,464.29
1968	173161892.	124854577.	73872264.0	$298,016,469.84	$50,982,313.81	$247,034,156.03
1969	162162445.	116924503.	69185624.1	$279,086,948.01	$47,738,878.86	$231,348,069.16
1970	160006956.	115372806.	68283284.9	$275,379,762.88	$47,089,521.89	$228,290,240.99
1971	162451476.	117138602.	69348605.0	$279,590,078.97	$47,789,997.06	$231,800,081.91
1972	150545519.	108555496.	64279332.9	$259,101,016.32	$44,276,163.55	$214,824,852.77
1973	107966439.	77853971.8	46109080.8	$185,820,411.31	$31,744,890.93	$154,075,520.38
1974	103911587.	74934754.6	44410179.0	$178,846,341.84	$30,524,575.54	$148,321,766.30
1975	97991465.1	70669544.6	41908006.3	$168,661,009.69	$28,761,538.26	$139,899,471.43
1976	99812395.8	71981268.4	42676357.2	$171,793,664.17	$29,304,911.21	$142,488,752.96
1977	96634601.5	69690016.2	41320867.6	$166,324,617.63	$28,369,148.58	$137,955,469.05
1978	106811117.	77028545.8	45669049.3	$183,839,662.96	$31,359,496.45	$152,480,166.51
1979	103878857.	74912250.0	44403832.3	$178,791,107.18	$30,508,417.67	$148,282,689.52
1980	74779160.2	53921089.4	31923805.0	$128,700,249.56	$21,997,284.35	$106,702,965.21
1981	71270501.3	51400762.1	30493178.9	$122,671,263.39	$20,907,583.26	$101,763,680.13
1982	94760029.6	68339591.6	40529465.6	$163,099,621.21	$27,810,125.98	$135,289,495.23
1983	81060175.4	58459449.7	34669944.3	$139,519,625.07	$23,789,505.41	$115,730,119.65
1984	77662493.4	56017457.7	33274914.1	$133,679,951.08	$22,742,543.61	$110,937,407.47
1985	86089987.1	62095128.7	36878587.9	$148,185,115.83	$25,216,540.80	$122,968,575.03
1986	65895143.7	47525952.4	28206773.9	$113,421,096.07	$19,319,178.54	$ 94,101,917.53
1987	78277588.8	56456462.9	33506067.5	$134,734,051.71	$22,950,395.35	$111,783,656.36
1988	84262478.0	60774351.6	36077462.8	$145,036,829.50	$24,696,888.75	$120,339,940.83
1989	73118675.9	52739599.8	31325091.4	$125,858,275.69	$21,414,508.37	$104,443,767.32
1990	69806022.0	50342311.0	29850888.6	$120,148,333.00	$20,491,422.42	$ 99,656,910.59
1991	77394251.2	55831339.1	33211136.5	$133,225,590.26	$22,620,202.60	$110,605,387.66
1992	66122807.0	47696318.9	28347092.4	$113,819,125.90	$19,349,226.44	$ 94,469,899.46
1993	67864373.2	48944960.0	29040870.8	$116,809,333.20	$19,904,089.20	$ 96,905,244.01
1994	64364561.6	46428236.2	27594654.9	$110,792,797.75	$18,833,581.28	$ 91,959,216.47
1995	79028675.1	56997473.6	33822708.1	$136,026,148.69	$23,174,765.46	$112,851,383.23

Figure 3: Welfare Impacts from Investment in Peanut Research in Southeastern U.S.: 1963-1995

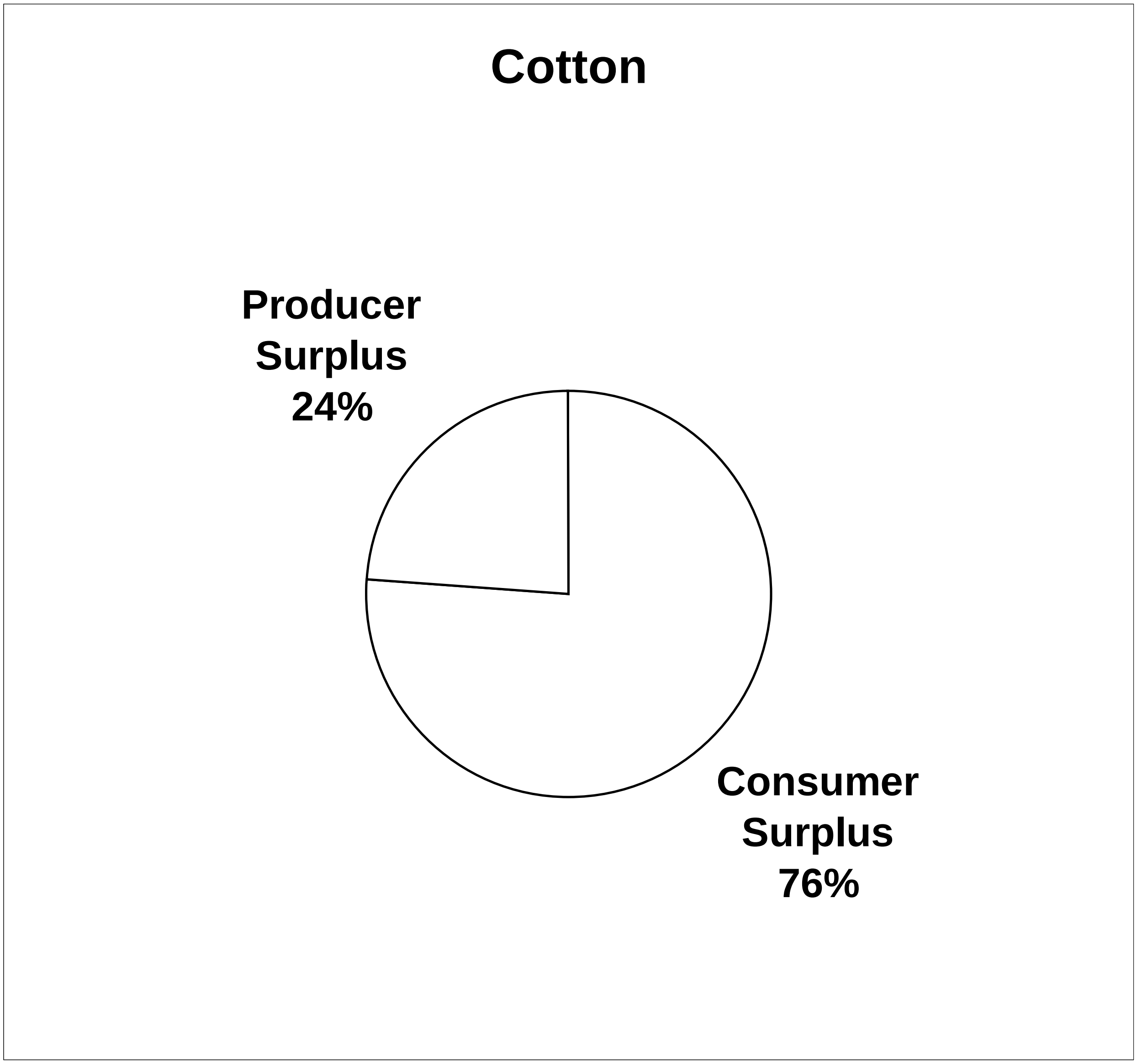
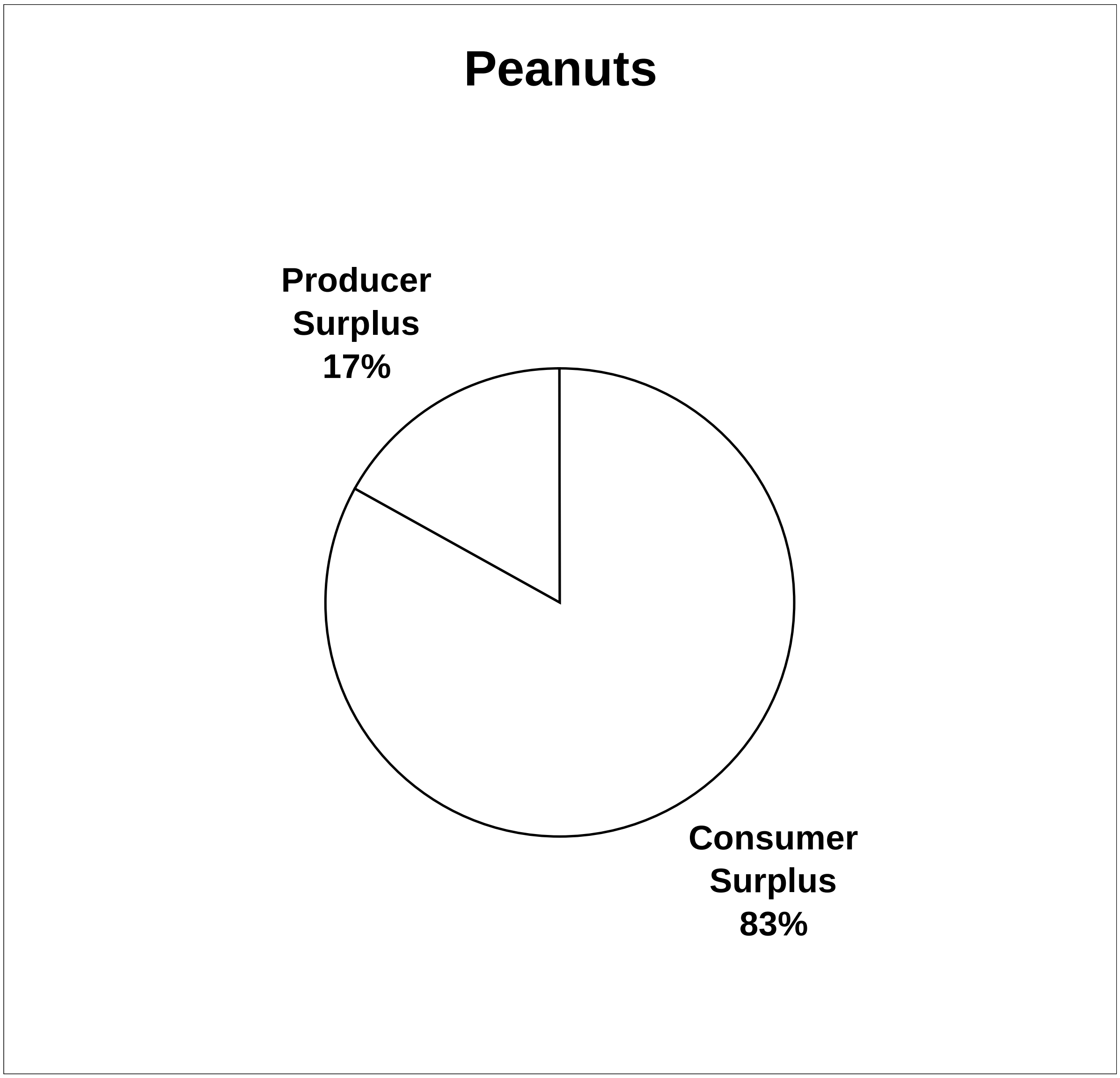


Figure 4: Welfare Impacts from Investment in Peanut Research in Southeastern U.S.: 1963-1995



expenditures from 1956 through 1995 were used in the IRR calculations instead of the Pascal lagged version (1963-1995). The extra seven years from 1956 to 1962 were necessary to establish a stream of initial investment costs for the IRR to be calculated. This variable was also deflated to represent 1982 (rather than 1984) dollars to match the base year used in measuring the social benefits. This way expenditures and benefits were in real dollars in the IRR calculations and the internal rate of return is in real terms, meaning that it is separated from any effects of inflation.

Table 7 presents the internal rate of return on investments in cotton and peanut research. In addition, the research expenditures in these two areas in 1982 dollars are presented. The internal rates of return on cotton and peanuts were calculated using the formula presented in chapter three subtracting the research expenditures presented in table 7 from the total benefits for each commodity presented in tables 5 and 6. The results convey that society has benefited considerably from public investment in cotton and peanut research. The internal rate of return for investment in cotton research was 53.58 % indicating that every dollar invested yielded, on average, $1.54 in social benefits for the period 1963-1995. The internal rate of return on investment in peanut research was 23.87 % indicating every dollar invested yielded an average $1.24 return in terms of annual social benefits.

Recall that the total benefits used in the IRR calculations utilized price elasticities of demand and supply based only on assumptions of what the true elasticities are. The price elasticities of demand were drawn from the literature and the price elasticities of supply were estimated in the regression analysis. Recognizing that these assumptions may be subject toerror, four additional analyses were performed to evaluate the sensitivity of the results to changes in these assumptions and presented in Table 8.

Table 7: Internal Rates of Return and Annual Research Expenditures

COTTON: IRR = 53.58%		PEANUTS: IRR = 23.87%	
Year	Research Expenditures	Year	Research Expenditures
1956	$10,005,059.26	1956	$1,089,948.96
1957	$10,680,359.18	1957	$1,120,004.80
1958	$11,418,672.63	1958	$1,129,287.19
1959	$11,009,070.43	1959	$1,006,274.88
1960	$10,651,383.03	1960	$1,097,382.45
1961	$10,231,460.24	1961	$1,119,977.34
1962	$9,847,601.24	1962	$1,233,225.38
1963	$9,737,166.43	1963	$1,462,138.39
1964	$9,587,633.92	1964	$1,632,347.48
1965	$9,156,516.67	1965	$1,794,925.21
1966	$8,696,145.56	1966	$2,062,480.62
1967	$8,231,733.04	1967	$2,222,489.96
1968	$6,678,757.05	1968	$2,192,377.33
1969	$6,415,036.44	1969	$3,395,652.91
1970	$5,654,366.28	1970	$2,898,734.81
1971	$6,789,754.86	1971	$3,565,322.38
1972	$8,497,958.69	1972	$3,756,957.18
1973	$6,072,698.67	1973	$3,807,056.54
1974	$5,507,413.69	1974	$4,946,337.09
1975	$5,563,549.98	1975	$4,793,836.03
1976	$5,237,224.34	1976	$5,385,151.48
1977	$5,482,343.43	1977	$4,856,794.42
1978	$5,005,172.57	1978	$4,791,497.68
1979	$4,514,132.55	1979	$4,113,024.30
1980	$4,109,063.69	1980	$4,061,291.88
1981	$4,987,353.93	1981	$4,114,206.73
1982	$4,548,608.78	1982	$4,620,678.92
1983	$4,455,585.05	1983	$4,983,769.61
1984	$3,997,756.90	1984	$4,815,746.46
1985	$3,825,638.31	1985	$4,805,182.23
1986	$3,935,253.28	1986	$5,294,994.40
1987	$3,421,173.19	1987	$5,302,738.40
1988	$3,916,027.16	1988	$5,522,209.02
1989	$4,323,836.11	1989	$5,371,573.91
1990	$4,114,197.92	1990	$5,894,012.20
1991	$4,582,832.89	1991	$6,777,344.83
1992	$5,156,092.66	1992	$6,937,923.14
1993	$5,039,361.61	1993	$7,249,693.22
1994	$5,559,764.47	1994	$6,878,708.95
1995	$5,582,908.80	1995	$6,695,317.06

The results presented in table 7 are comprised of what is referred to as the base situation. All additional analyses will only change one assumption of the base situation at a time leaving all other base situation assumptions the same. This will isolate the sensitivity of the results to each change in the assumptions of the base situation. The first additional analysis will be to increase the price elasticity of supply for both commodities by one standard error. The second analysis will be to decrease the price elasticity of supply for each commodity by one standard error. The price elasticity of demand for peanuts will be changed by the standard error from the study from which it was drawn (Zhang, Fletcher & Carley, 1992), which was .03. The price elasticity of demand be increased and decreased by .10 based on the study by White and Wetzstein (1995), which partly relied on the work of Shui, Shangnan, Beghin and Wohlgenant (1993).

By increasing the price elasticity of demand, a portion of the consumer surplus area (the area ABC) is reduced and a portion of the producer surplus (area CBO) area is increased. The net reduction in the surplus area reduces the benefits associated with the same level of research investment, therefore decreasing the internal rate of return. This same mechanism increases the internal rate of return when the price elasticity of demand is decreased for both commodities. However, by increasing the price elasticity of supply, the rate of change that production function shifts resulting from investment in research is decreased. The slower the rate of change of the production function shift, the smaller the producer surplus area (area CBO) and consumer surplus area (area ABC). This reduction in the areas of consumer and producer benefits reduce the internal rate of return on investment in research on each commodity.

Table 8: Sensitivity of IRR Results for Cotton and Peanuts

COTTON		
PRICE ELASTICITY OF SUPPLY	PRICE ELASTICITY OF DEMAND	IRR
1.391	.55	53.58%
1.711	.55	53.05%
1.071	.55	54.36%
1.391	.65	52.38%
1.391	.45	54.98%
PEANUTS		
PRICE ELASTICITY OF SUPPLY	PRICE ELASTICITY OF DEMAND	IRR
.81	.10	23.87%
.86	.10	23.94%
.76	.10	23.82%
.81	.13	23.04%
.81	.07	24.75%

The internal rates of return on cotton and peanut research were not very sensitive to the assumptions about price elasticities of supply or demand. For both commodities, an increase in the price elasticity of demand resulted in very small decreases in the return on research investment in that commodity. For both commodities, decreases in the price elasticity of demand resulted in increases in the internal rate of return on investment. For cotton, an increase in the price elasticity of supply caused a slight decrease in the return on research investment. A decrease in the price elasticity of supply of cotton increased the IRR nearly 1%. An increase in the price elasticity of supply for peanuts increased the return in peanut investment by only .07%. A decrease in this elasticity decreased the IRR on peanut research by only .05%. Changes in the price elasticity of supply for peanuts had a minor effect on the return to peanut research investment.

For cotton, the maximum change in the internal rate of return on research investment resulting from small changes in assumptions about the price elasticity of demand was 2.6%. For peanuts, the maximum change in the IRR resulting form small changes in assumptions about the price elasticity of demand was 1.71%. The maximum change in the IRR on investment in research resulting from changes in the assumptions about the price elasticity of supply was 1.31% for cotton and .12% in peanuts.

Discussion

A limitation noted in the literature review in Schultz's 1953 study was the upward bias of social costs because not all agricultural research conducted intended to improve technology and productivity. This is an accurate observation because in an aggregated study like his, the fundamental and applied research are all lumped into one dollar figure for every year. Obviously, the fundamental research was not aimed at improving productivity directly, yet it was counted. To correct for this limitation in this study, the expenditures on cotton and peanuts were disaggregated and separately tested and the focus was centered on specific commodities. Research expenditures classified as directed at a specific commodity are much more likely to be immediately applicable in terms of realizing productivity gains in the field. Thus, while this bias is likely not completely eliminated, it has been minimized to the extent possible.

It should also be noted that consumer and producer surplus measures are limited in a few ways. The partial equilibrium framework ignores all second-order effects and any interpersonal utility comparisons. Some types of consumers or producers may get the majority of the benefits going to their group. The theoretical framework ignores the overlap of producers that are consumers as well, which may cause the benefits to be overestimated.

However, one of the advantages of this model and its results is that directly estimating the supply function yields results that are comparatively effortlessly and immediately usable in economic surplus model of measuring research benefits. Therefore, this method is the most practical choice for the goals of this study. Not only is this the most adaptable option, it is the option that most closely links the concept of supply and demand the statistical model of supply and demand.

The estimated internal rate of return for cotton research is considerably larger than that for peanut research. One possible factor in this differential is the greater potential spillover effects in cotton. The four-state region modeled here has the majority of US peanut production, but a much smaller percentage of national cotton production. There are also more nearby major research programs in cotton than peanuts, which could potentially be producing benefits for the four states modeled in this study. Spillover benefits will have inflated both cotton and peanut IRR estimates above what would be computed if such benefits not paid for within the four states could be excluded. While this upward bias cannot be eliminated easily, it is likely a larger factor in the cotton model than in the peanut model.

The internal rate of return presented in Table7 is an average rate of return that does not indicate how changes in research costs and benefits affected this rate over time. To investigate these changes in the internal rate of return over time, the period (1963-1995) was separated into three consecutive 11-year subperiods for each commodity. They will be for the years 1963-1973, 1974-1984, and 1985-1995. An internal rate of return was then calculated for each subperiod to compare how research investments were performing over time. An initial stream of investments was established using the seven previous years for each 11-year period. These results are presented in Table 9.

The estimates for the IRR for the subperiods are not to be taken as accurate since the period measured is too short to be meaningful. However, it should be noted that they are useful in showing the trend in the returns to research on these two commodities. The internal rate of return on cotton investment increased over the three subperiods. Investment in cotton research has decreased consistently over the thirty-three year period with a small increase from 1989-1995. During this time, total benefits for society have remained somewhat flat in comparison. Although investment in cotton research has declined steadily, the benefits have remained promising. Either the benefit of earlier research investments is being realized in later years (a longer lag between project initiation and realized results) or the money is being utilized more efficiently.

The internal rate of return for peanut research trended very differently from the returns on cotton investment. Over the thirty-three year period, the IRR steadily decreased. This results from the steady increase in expenditures for peanut research over the period. Total benefits to society over this period gradually decrease causing the internal rate of return to shrink over time. Given that investment decisions are made annually, shrinking annual benefits to society give no economic justification for continuing increases in peanut investment in research over the period. Research allocation decisions are vulnerable to political influence and the political interests of those in decision-making positions. This may be one explanation for continuing to increase the investment in peanut research despite the evidence of declining benefits to society.

Additionally, in a time when research initiatives in different commodities are competing for limited funds, the allocation of funds to peanut research could be forcing a decrease in allocations to cotton research. Although the estimated internal rate of return to research in cotton exceeds the estimate for peanuts, politics not economics may be the deciding factor in the respective trends in research funding.

Table 9: IRR Trends in Cotton and Peanut Research over Time

SUBPERIODS	COTTON	PEANUTS
1963-1973	54.37	124.03
1974-1984	58.67	83.23
1985-1995	73.80	63.65

CHAPTER 5

SUMMARY AND CONCLUSIONS

Publicly funded agricultural research contributes to growth in agricultural productivity by reducing the real cost of food production through the advancement of output enhancing technology. Improvements in output enhancing technology include improvements in usage or quality of inputs that make production more efficient. The theory is that not only does investment in research contribute to improvements in production, but also that consumers and producers benefit as a result and there is a positive return on that investment. This study makes an effort to add empirical content to the economic theory that research in agriculture contributes to agricultural production by examining the specific case of cotton and peanuts in the southeastern region of the United States for the period from 1963-1995.

Assume broad societal goals of efficiency are aimed at the well being of the economy. For the research system of cotton and peanuts, the goals are to improve the total average of well being to producers and consumers taken in the aggregate. Public investment in agricultural research on cotton and peanuts in the region contributed to the production of those quantities commodities, respectively. These increases were due to the combination of inputs used in the production process and research expenditures in the area of production. The improved efficiency can be in the form of improvements in the quality of the inputs or in the way the inputs are combined. This growth in productivity reduces the real costs of production.

Public research scientists and administrators are being held more accountable for the resources allocated to conduct public agricultural research. This creates a need for current research systems to be continuously evaluated in order to monitor investment decisions. One way to monitor current research systems is to measure the effectiveness of monies allocated to research projects using an internal rate of return. Information on the nature, extent and distribution of social benefits and costs are useful for this type of evaluation.

The purpose of this study was to utilize the economic surplus framework for evaluating the impact of investment in agricultural research. The economic impact measures used in this study were the total benefits and distribution of those benefits associated with investment in agricultural research. These results were used to calculate an internal rate of return on the investments. The focus of the research was on cotton and peanuts in the Southeast region of the United States. Two equations were estimated to determine the impacts of the money being spent on the research efforts of these two commodities.

The model in this study consists of supply functions for cotton and peanuts that were estimated using data derived from pooled time-series cross-sectional data for the four states of Alabama, Florida, Georgia, and South Carolina. The prices, quantities, harvested acres, and cost of production were considered exogenous variables in the supply models for both commodities. The cost of production is an average per acre cost of producing cotton and peanuts in the Southeast. Rainfall and research expenditures on each commodity on the area were also exogenous variables in the model. The expected prices and average costs of production were deflated in 1982 dollars. The public agricultural research expenditures are in constant 1984 prices, or real terms. Since research spillovers occur within similar geo-climatic regions, all the data was averaged or aggregated to create a region-wide data set for each commodity over the 33 years from 1963 through 1995.

The economic surplus framework used to evaluate the model described above measures the contribution of research investment to agricultural productivity by comparing two production scenarios. First, the supply equation is estimated with research expenditures as an exogenous variable. The second scenario measured in this framework is the fictional quantities that would have been produced with no investment in research. The theory is that new production technology generated from investment in the research shifts the production curve to the right and generates welfare benefits for society (the first scenario). The economic surplus framework measures producer and consumer surplus changes that result from comparing the two scenarios, as the production function shifts to the right. To evaluate the performance of the investment, these results are used in conjunction with the research investment costs to generate and internal rate of return on the investment The results revealed positive benefits to consumers and producers exceeded the investment amount in each year for both commodities in the period. The total social benefits averaged about 201 million (1982) dollars annually for cotton research. Peanut research averaged about 191 million (1982) dollars resulting form research investment. The internal rates of return were 23.87 percent for cotton and 53.58 percent for peanuts, suggesting that past research investments produced a high return to society. This result does not conflict the results of other similar studies as those mentioned in the literature review.

The positive social benefits and internal rate of return indicate that investment in cotton and peanuts in the southeastern region of the United States has been a sound investment. These results indicate that society would benefit from increased investment in these commodities in the future. These results do not guarantee that similar investment in the future will yield the same results. They may indicate that research investment is a good thing, but do not indicate whether or not money invested in cotton and peanuts was efficiently allocated. The theoretical framework utilized in this study would be a useful tool for administrators in similar studies on public investment in other agricultural commodities to determine whether sufficient progress is made in the area. This may warrant this type of evaluation study one more regular basis.

Since the commodities in this study compete for the same funds, the result from the estimated supply functions is useful for comparing the allocation decisions between the two commodities. A suggestion for further research would be to evaluate allocative efficiency between these two commodities using a marginal rate of return. Allocative efficiency could also be useful in monitoring the role of private research in biotechnology and other agricultural research areas. In particular, this model could be used to compare the efficiency of private and public investment in specific commodities.

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