July 2001

An Economic Analysis of the Cotton Research and Promotion Program

Draft Report

Prepared for

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Memphis, TN

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1 Introduction

In the 1960s, as cotton began losing many of its traditional markets to synthetic fibers, U.S. upland cotton producers responded by developing a research and promotion program for cotton that could potentially offset the growth of synthetics and reestablish cotton as a dominant fiber. This effort has evolved today into the Cotton Research and Promotion Program. The program is funded by a per-bale assessment on cotton. The revenues are collected and managed by The Cotton Board, a quasi-governmental, nonprofit entity that administers the program.

The goal of the Cotton Research and Promotion Program is to expand the demand for upland cotton and to increase the profitability of both cotton growers and importers of cotton products. The underlying premise is that factors that expand the demand for cotton or reduce the cost of production improve the welfare of the producers and importers paying assessments. Demand expansion can occur through promotional and advertising programs. Such initiatives aim to develop consumer preferences for products made from cotton over those made from other fibers. In addition, textile research can expand the demand for cotton by finding new uses for the fiber and improving quality. Agricultural research can reduce the cost of production by developing new cultivation and processing methods.

The economic value of the Program to producers and importers depends not only on whether promotion and research have been effective in increasing sales or lowering the cost of cotton production, but also on the cost-effectiveness of these activities. It is very unlikely that Program promotion and research activities would not have at least some positive impacts on sales and production costs. The question is whether the costs of the Program are justified by its benefits. To address this question, a team of economists from Research Triangle Institute (RTI) and North Carolina State University (NCSU) performed an economic analysis of the cotton program. The results of that analysis are reported in this document.

1.1 STUDY OBJECTIVES

The purpose of this study is to assess how well the Cotton Research and Promotion Program's goals are being met. Toward that end, the Cotton Board has directed that the study must answer the following key questions:

1. What are the effects of the research and promotion activities on the three key areas of the Program?
   - ➤ demand for upland cotton
   - ➤ return-on-investment (ROI) to cotton producers funding the Program
   - ➤ net value to companies who import cotton products and raw cotton
2. What is the overall rate-of-return associated with the Program?
3. What are the qualitative benefits and returns associated with the Program?

Redundant. Another relevant question is: What is the distribution of benefits among industry segments & are benefits consistent with assessments?

The primary objective of this study is to evaluate the economic impacts of the activities funded by the Program. The most important questions addressed by this study include whether Program expenditures have led to an increase in demand for cotton and cotton products and whether industry revenues have increased sufficiently to cover the costs of the Program for both domestic producers and importers.

To provide answers to these questions we developed and applied econometric models of the market for U.S. upland cotton. Using these models we can obtain empirical evidence of the Program's effectiveness in enhancing the demand for—and in the case of agricultural research, the supply of—U.S. cotton. For instance, these models can tell us whether the Program has had a statistically significant effect on the demand for cotton, while controlling for factors that are economically important but outside the sphere of the Program's influence (e.g., national income, the price of synthetic substitutes).

Rigorous econometric analysis can be an effective tool for evaluating a program's effectiveness. But some aspects of the Cotton Program are not easy to quantify precisely. Therefore, sole reliance on econometric modeling would likely not provide a complete characterization of the Program's effects. As a result, this report supplements the econometric analysis with a qualitative assessment of program effects. This assessment describes the activities undertaken under the auspices of the Cotton Program, their potential contribution to recognized industry phenomena, and the associated benefits to producers of those activities.

1.2 ORGANIZATION OF THE REPORT

Section 2 presents an overview of the Cotton Research and Promotion Program, including the basis for its funding, the size of its budget, the allocation of program funds across its four major activities, and its stated strategic directions.

Section 3 is a profile of the cotton industry. The profile includes a description of major segments of the industry, historical economic trends for the industry, the role of government farm programs for cotton, and technological developments in cotton production over time.

Section 4 describes the conceptual model and analytical methodology used to develop the econometric model and calculate the Cotton Program's rate of return.

Section 5 presents the results from econometric estimation of the cotton market model. The discussion focuses on the statistical and economic significance of the key policy variables of interest (e.g., program expenditure effects on cotton demand). The section also presents information from sensitivity analyses performed to gauge the robustness of the model to changes in specification. Much of the econometric model detail is described in technical appendices at the end of the report.

Calculations for the rate of return of the cotton program are calculated and discussed in Section 6. Results are presented in aggregate and for the different stakeholder groups involved (e.g., growers and importers).

As indicated above, econometric models cannot capture some aspects of program performance, either because they are difficult to detect in the data or are effectively nonquantifiable. As a result, Section 7 presents a qualitative assessment of potentially important factors not captured in the econometric analysis.

Section 8 concludes the report with a summary of key findings and caveats to the analysis.

2 The Cotton Research and Promotion Program

This section presents an overview of the Cotton Research and Promotion Program, with a focus on the efforts of Cotton Incorporated (CI) to execute the program authorized by Congress and funded by producers and importers. We begin with a brief history of the program, including the enabling legislation and present organization. The second section presents details of the funding and spending history, including the breakdown into the various areas of effort. The third section contains a description of current activities in all of CI's program areas.

2.1 BACKGROUND AND HISTORY

Until the development of petroleum-derived synthetic fibers in the 1950s, cotton was unrivaled as the dominant fiber in clothing and home textiles in the U.S. This situation had existed since before 1800, when the introduction of the cotton gin not only ushered in cotton's use in clothing and other textiles, but also created the nation's largest agricultural export for the next 150 years. The introduction and rapid quality and cost improvement of polyester and nylon fibers led to a sustained decline in the demand for cotton for all uses beginning in about 1960. By 1966, cotton's decline had progressed to the point that Congress felt a need to intervene, eventually passing the Cotton Research and Promotion Act of 1966.

The expressed purpose of the Act was "to enable cotton growers to establish, finance, and carry out a coordinated program of research and promotion to improve the competitive position of, and to expand markets for, cotton" [7 U.S.C. 2101-2118, Public Law 89-502]. In passing the law, Congress reasoned that the inroads in the textile fiber market made by synthetic fibers were largely a result of research and promotion conducted by its makers (primarily large chemical firms). Because individual cotton producers did not have the resources to perform these activities or the legal means to join together to fund such work, Congress provided a coordinating mechanism to enable producers to collectively engage in research and promotion.

2.1.1 Details of the Cotton Research Order

On December 31, 1966, the U.S. Department of Agriculture (USDA) put into effect the Cotton Research and Promotion Order after a successful referendum of growers as required by the Act. It covered all upland cotton grown in the U.S., whether consumed domestically or exported. The Order provided for

- a Cotton Board to oversee the program under the guidance of the USDA;
- a check-off program to fund the research and promotion activities; and
- authorization for the Board to evaluate, supervise, and pay for these activities.

The Cotton Board was charged to establish and carry out research and promotion projects with respect to production, ginning, processing, distribution, or use of upland cotton and its products, to the end that marketing and use of cotton might be encouraged, expanded, improved, or made more efficient. The Board was to comprise at least one member from each producing state, with additional representation in proportion to the state's production of upland cotton. Each state's representative was to have an alternate, and both of them were to be chosen by the producers of the state. In addition, one member was to be selected by the Secretary of Agriculture to represent the public at large.

The Order required participating producers to pay an assessment on each bale of upland cotton, to be collected by the first handler. These funds were then to be pooled for use in promotion and research activities by the Board. Although the two-thirds vote required by the referendum assured broad support, any producer who did not wish to participate in the check-off program could apply for a refund of all assessed amounts.

The Board was directed by the Order to contract with another organization to submit research and promotion plans for approval, carry out these plans, and pay for projects with the funds collected. Any such organization was to have a governing body consisting of cotton producers, also chosen in proportion to their state's marketing volumes. The first such organization chosen by the board was the Cotton Producer Institute. In 1970, CI took over these tasks and remains the contractor today.

2.1.2 Changes from the Cotton Research and Promotion Act of 1990

The Cotton Research and Promotion Act was modified significantly in 1990, in an effort to boost its impact on the overall textile market. Most notably, importers of textiles containing upland-type cotton were to be subject to the same assessments as domestic producers. The Board was expanded to include four importer representatives; the Secretary of Agriculture was authorized to change that number over time, as long as at least two importer representatives were named. Interestingly, Congress did not add a requirement to include importers in the governing body of CI.

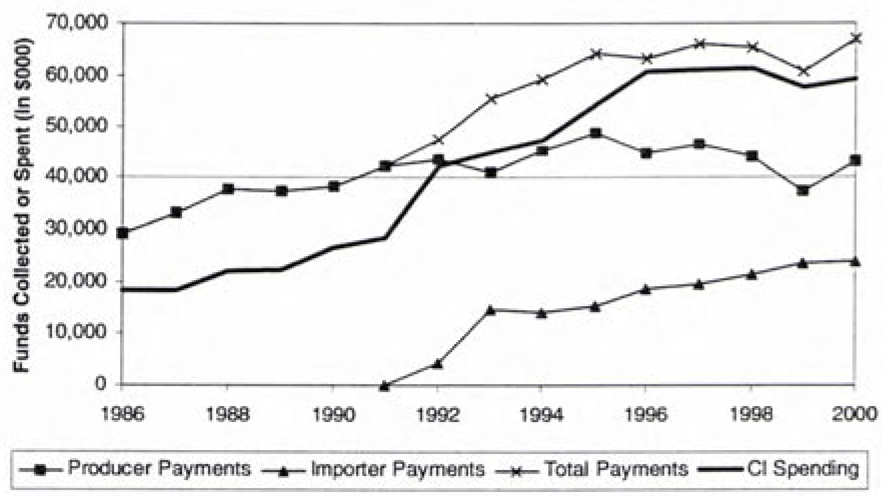
Two other significant changes were made in the 1990 Act. Elimination of the refund provision made the program mandatory for all U.S. growers of upland cotton. The Secretary of Agriculture was required to review the program's effectiveness every 5 years and was authorized to order a referendum if he or she determined it necessary. Producers themselves could demand a referendum upon the request of at least 10 percent of them, as long as no more than 20 percent of the requests came from importers or one state.

2.2 PROGRAM FUNDING AND SPENDING HISTORY

The Cotton Program currently requires producers and importers to pay $1 per bale, plus an additional assessment of one-half of 1 percent of the value. The Secretary of Agriculture may change this latter figure, but it may not exceed 1 percent. The check-off is collected by the first handler, typically a marketer, merchant, or textile mill. For imports, the U.S. Customs Service handles the payments; the program order allows Customs to recover some of their costs of managing the process. In the case of crops delivered to the Commodity Credit Corporation (CCC) to settle marketing assistance loans, the USDA collects the assessment directly.

Figure 2-1 shows the total amount of program funds collected, broken out by the source of funds. U.S. producers have paid about two-thirds of the total check-off since 1990, averaging $43 million over the past 5 years. The share paid by importers has grown significantly as imports capture a larger share of total cotton consumption. To avoid double-taxing the import of textiles containing U.S. cotton, importers can apply for exemption from the assessment if they can demonstrate that their products contain U.S. upland cotton. Reimbursement of funds already paid is also provided if satisfactory proof of U.S. origin can be shown.

Figure 2-1. Cotton Program Assessments and Spending, 1986–2000

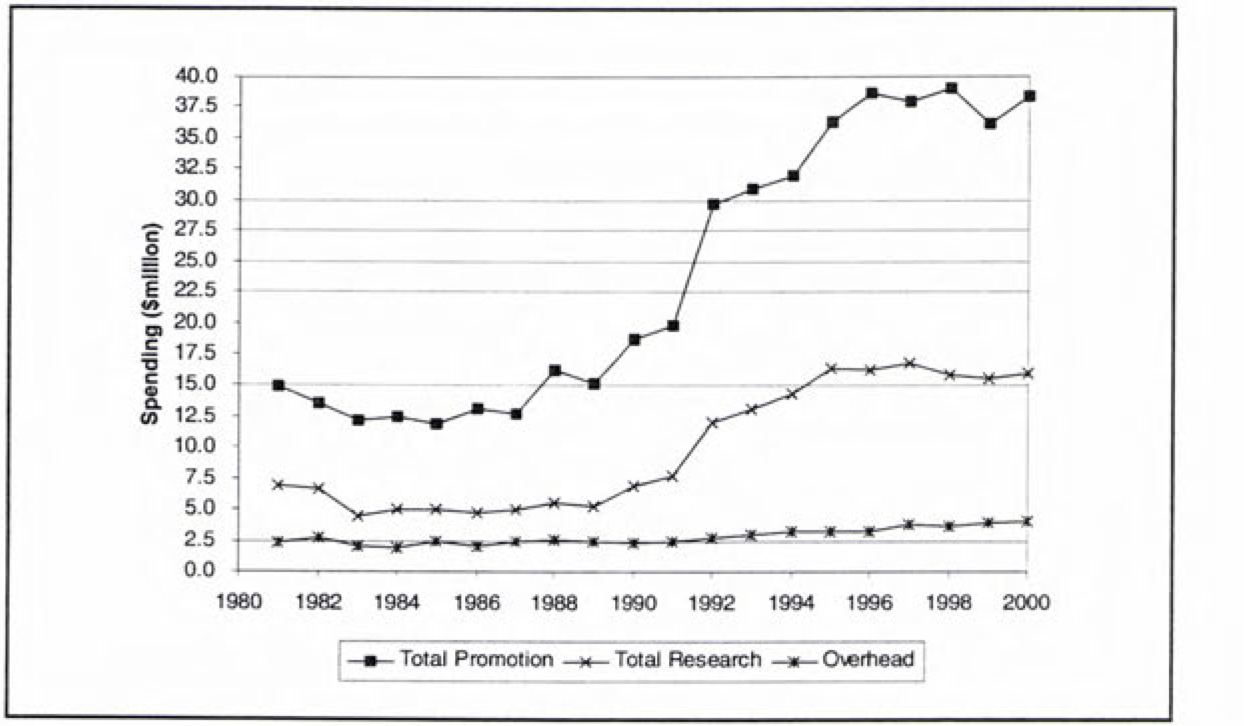


Except as noted, the description of CI's organization and program activities, as well as budget and spending information, was obtained directly from CI during 2 days of on-site meetings at their Cary, North Carolina, headquarters (CI,2001).

Most of the funds collected are transferred directly to the Cotton Board. USDA retains a small amount to manage its part of the program, including the expenses of up to five full-time employees. The Cotton Board pays for its activities out of the net proceeds of the assessment. It must reimburse any governmental agencies that assist with the import provision, such as the Customs Service. Finally, the Board is obligated to pay $300,000 for any referendum ordered by the Secretary of Agriculture or requested by producers or importers. The balance of the funds is transferred to CI for use in research and promotional activities.

Figure 2-2 illustrates CI's budget over the 20 years for which records were provided. The figure illustrates the large increase in program resources resulting from including importers after 1990. Since inception of the program, promotion has captured about two-thirds of program expenditures, with research accounting for one-third. It is notable that administrative expenses have risen only modestly over this time period and have actually fallen considerably as a percentage of total program funds.

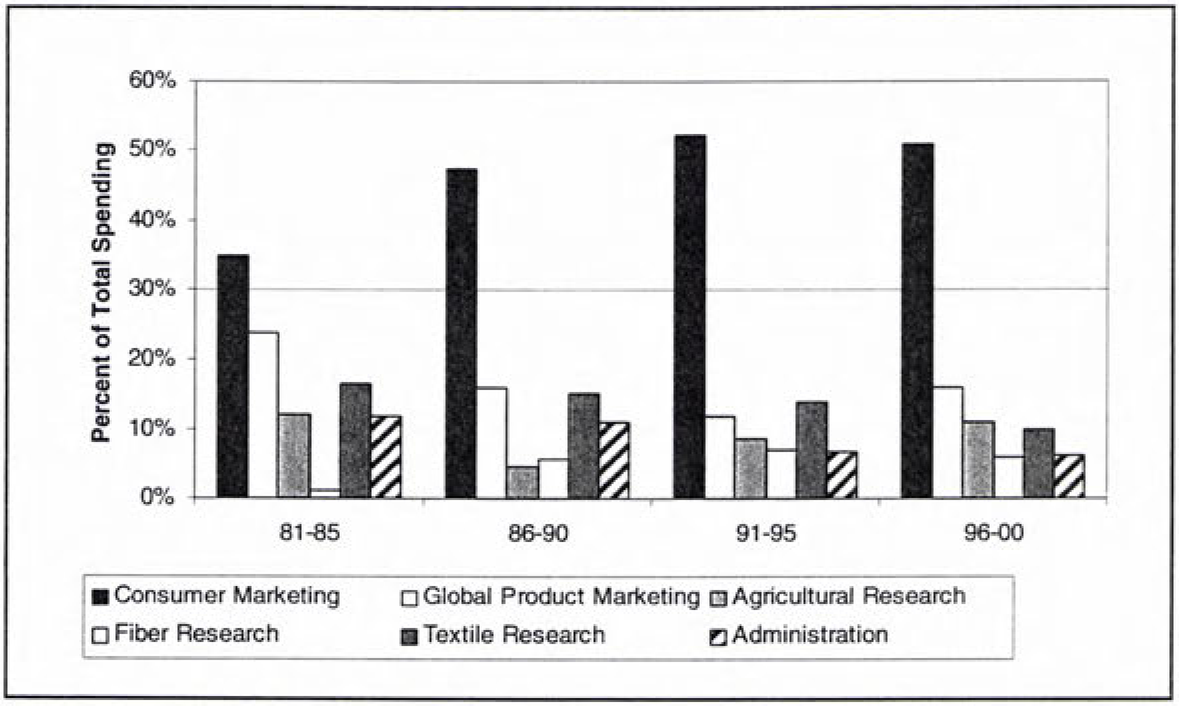
Figure 2-2. CI Program Area Spending



2.3 CI PROGRAM ACTIVITIES

CI engages in a wide variety of research and promotion activities, aimed at fulfilling its mandate from the Cotton Board and the U.S. Congress. For organizational and budgeting purposes, CI divides its efforts into program areas including agricultural research, fiber and textile research, global product marketing (GPM), and consumer marketing. Its support staff includes a strategic planning function as well as executive and administrative personnel. Figure 2-3 illustrates the allocation of spending across these functions over the past 20 years.

Figure 2-3. Spending by Program Area: 5-Year Averages



Although the spending patterns have evolved over the 20-year period for which we have data, the stability of these proportions from year to year is notable. Over the past 5 years, for example, agricultural research has taken a consistent 11 percent of the budget, fiber and textile research 16 percent, consumer marketing (primarily advertising) about 50 percent, and GPM about 16 percent. Spending has been flat in absolute terms over the 1996 to 2000 period, as growth in domestic and export markets has slowed. The most noticeable recent change in CI's spending has been *within* the GPM area, in which an increasing international share matches the gradual move of textile processing offshore.

The primary objectives differ across each of the program areas. Agricultural research is directed at improving the quality of and decreasing production costs for cotton. In the econometric analyses that follow, we view agricultural research as shifting out the supply function for cotton production. Fiber quality research and GPM activities are directed at mills and other primary users of raw cotton and, as such, affect the demand function for cotton. Textile research and consumer marketing are aimed at improving consumers' perceptions and valuation of cotton as a fabric choice. The effects here are on the demand for cotton-containing textile products, providing increases in the derived demand for raw cotton. The next sections discuss recent activities and accomplishments in each of the program areas.

2.3.1 Agricultural Research

Research in the growing, ginning, and processing of cotton has been a critical factor in its continued success as a textile fiber and source of export revenue. The funds allocated to research from the check-off program are a small, but significant part of total research spending in the U.S., which includes work in corporations, universities, nonprofit organizations, and the federal government. Over the past 5 years, CI has spent about $6.5 million annually in support of agricultural research. For perspective, the USDA spends $45 million per year on cotton, the bulk of it in supporting academic and other nonprofit research (CI, 2001).

A breakdown by type of research would be informative.

CI does not conduct agricultural research in-house, but like the USDA, sponsors and funds projects proposed by others. CI receives proposals from across the country, evaluates the technical merit and potential of each project, and awards funds to those it deems most promising. Around two-thirds of the budget is committed to projects nominated by the states, in proportion to their cotton production; the remaining funds are for projects evaluated and awarded directly by CI. Regardless of the location of the project, however, CI approves their technical objectives, oversees the research performed, and assesses the completed projects.

Some of the more important results of the nation's cotton research effort are discussed in Section 3, along with contributions made by CI and its sponsored projects. There are at least two reasons to believe that CI's contribution to agricultural research may be larger than its share of funding. First, by focusing on the needs of the producers and processors, the research organization raises the probability that its awards will directly improve the competitiveness of U.S. grown upland cotton. Secondly, frequent interaction with the fabric and textile research and marketing personnel at CI ensures that breakthroughs in cost and quality are communicated rapidly to customers of both raw cotton and cotton textiles.

2.3.2 Fiber Quality and Fiber Management Research

Two other research program areas, Fiber Quality and Fiber Management, provide measurement and data analysis services and engage in technical support related to fiber quality characteristics such as color, staple length, strength, micronaire, and stickiness. In addition, ongoing projects assess fiber performance in finished textiles, including shrinkage, fading, and smoothness. CI's High Volume Instrument/Engineered Fiber Selection (HVI/EFS) system is the standard for measuring cotton fiber quality and is used by merchants and mills to track the performance of each year's crop and to select the optimal mix of cotton bales for their specific needs. These two research units spent $3.5 million in 2000, or about 6 percent of the firm's total.

2.3.3 Textile Research and Implementation

The final research unit is dedicated to textile research, both in processing and fashion fabrics. In effect, this group acts as an R&D organization for U.S. and overseas textile mills, performing many activities that in another industry might be done by individual firms. CI maintains a state-of-the-art pilot plant, with spinning, knitting, and dyeing and finishing operations. The firm rents time on weaving machinery at a Dan River Inc. plant and on nonwovens equipment at a North Carolina State University laboratory.

One of the products of this pilot-scale production facility is a wide array of fabrics of many different weaves and in a multitude of colors. Swatches of these knitted and woven fabrics are compiled into an annual Fabricast product release, which is made available to fashion and designers and clothing manufacturers. Over the past 5 years, more than 20,000 samples have been requested and delivered annually.

The annual budget of the textile research group is about $5 million, or 10 percent of total spending. The *process* R&D performed by CI benefits the textile mills directly and by improving their ability to process cotton and cotton-containing blends encourages them to increase their use of upland cotton. The *product* R&D, in the form of fashion fabrics, increases the desirability of cotton apparel to the final consumer, which then exerts a demand pull similar to advertising and consumer promotion. Although the textile mills might be expected to engage in both types of R&D, their efforts have historically been funded by the chemical firms that produce polyester and other synthetics. CI views their spending on behalf of cotton as a leveling of the textile fiber playing field.

2.3.4 Global Product Marketing

CI's GPM group describes itself as "cotton's sales force." Their mission is to communicate to textile mills and clothing retailers around the globe the CI products and services, make them aware of new products and processes developed by CI and its research partners, and convince them that consumers will demand cotton-containing products. Employees in this group make presentations at trade shows, distribute CI publications, and call on key customers both in the U.S. and abroad.

The GPM organization is, therefore, the primary conduit through which the work of the fiber quality, fiber management, and textile research groups reach cotton customers. In addition, they communicate the most recent consumer preference and awareness data generated by the Consumer Marketing and Strategic Planning groups. An important goal is to present cotton as a superior alternative to synthetic fibers across the spectrum of textile mills production. They attempt to reinforce CI's value proposition to the mills by offering processing support, quality troubleshooting, and other forms of technical service.

The share of CI's budget spent on GPM has varied more over the years than any other category. This area consumed more than 20 percent of total spending in the first few years after 1980, but fell to about 10 percent from 1990 to 1995. Since 1996, outlays have increased again to an average of $10 million per year, or about 16 percent of the total. The split between domestic and international spending within GPM has changed considerably as well. As overseas mills process an ever-greater share of U.S.-produced cotton, the proportion of funds spent on international GPM is increasing appropriately. Over the past 5 years, less than 20 percent of their budget has been spent on domestic GPM, and with U.S. mills still relocating in large numbers, this proportion should be expected to shrink further.

2.3.5 Consumer Marketing

By far the largest program area in terms of expenditure and influence is Consumer Marketing, consisting of advertising and public relations, fashion marketing, and retail merchandising. Approximately $25 million has been spent on advertising alone each year since 1995, and the other two programs each require more than $2 million per year. The most visible element in the consumer marketing effort, the brand image represented by the "Cotton Seal" is maintained and enhanced by these groups, through media promotion, merchandizing events, primary data collection, and strategic partnerships.

As of today, more than 75 percent of all consumers know about the Cotton Seal, and awareness is even higher among the target audience (women 18 to 49 years of age) (CI, 2001). CI's advertising has managed to convey positive images of cotton in apparel and home textiles and should help establish credibility in new product areas, including nonwovens. The fragmenting of media markets has made reaching the consumer more difficult in recent years, but the advertising group has copy reaching consumers in television, magazines, and other print media, and on the Internet.

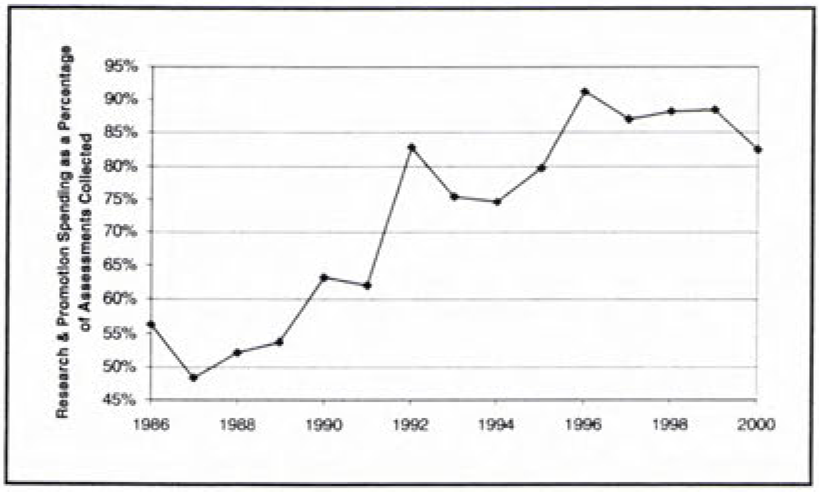
With a limited budget determined by cotton prices and domestic production, CI has increasingly emphasized strategic partnerships with other corporations who have a shared interest in promoting cotton-containing products. Tie-ins with apparel retailers like J.C. Penney have allowed CI to expand its presence in a number of media markets, including prominent display in fashion catalogs. In another innovative link, Procter & Gamble has placed the Cotton Seal on its detergents, which are promoted as being safe for cotton.

2.3.6 Administration

Two final groups are involved in administrative functions within CI: the management staff and a strategic planning organization. The latter group is charged with ensuring that the funds allocated to CI are spent for maximum impact in achieving the Cotton Board's mission. With the rapid pace of change in world fiber markets and the textile supply chain, a forward-looking planning function is vital. It is noteworthy that CI has managed to introduce the strategic planning function and build and operate a new headquarters building without a significant increase in the overhead load. In fact, the share of total expenditures represented by the administration and planning functions has fallen from more than 10 percent in 1981–1985 to about 6.5 percent over the past 5 years.

In terms of overall delivery of check-off assessments to research and promotion, the USDA, Cotton Board, and CI have improved their performance continually over time, as Figure 2-4 shows. Spending on all research and promotion areas averaged 87.5 percent of total assessments received during the 1996–2000 period. Of the 12.5 percent in total overhead, slightly less than half was accounted for by CI's administration and strategic planning functions, with the balance going to the Cotton Board, the USDA, and other government agencies supporting the Cotton Research and Promotion Program.

Figure 2-4. Delivery of Check-off Funds to Research and Promotion: 1986–2000



3 A Profile of the Cotton Industry

This section describes the cotton industry's role in the economy and how this role has changed over time. Understanding the role of the cotton industry and how other factors may have combined with the Cotton Program to affect the demand for and profitability of U.S. cotton is important for this analysis. Moreover, this industry profile highlights the critical role that technical change has played in the growth, distribution, and use of cotton.

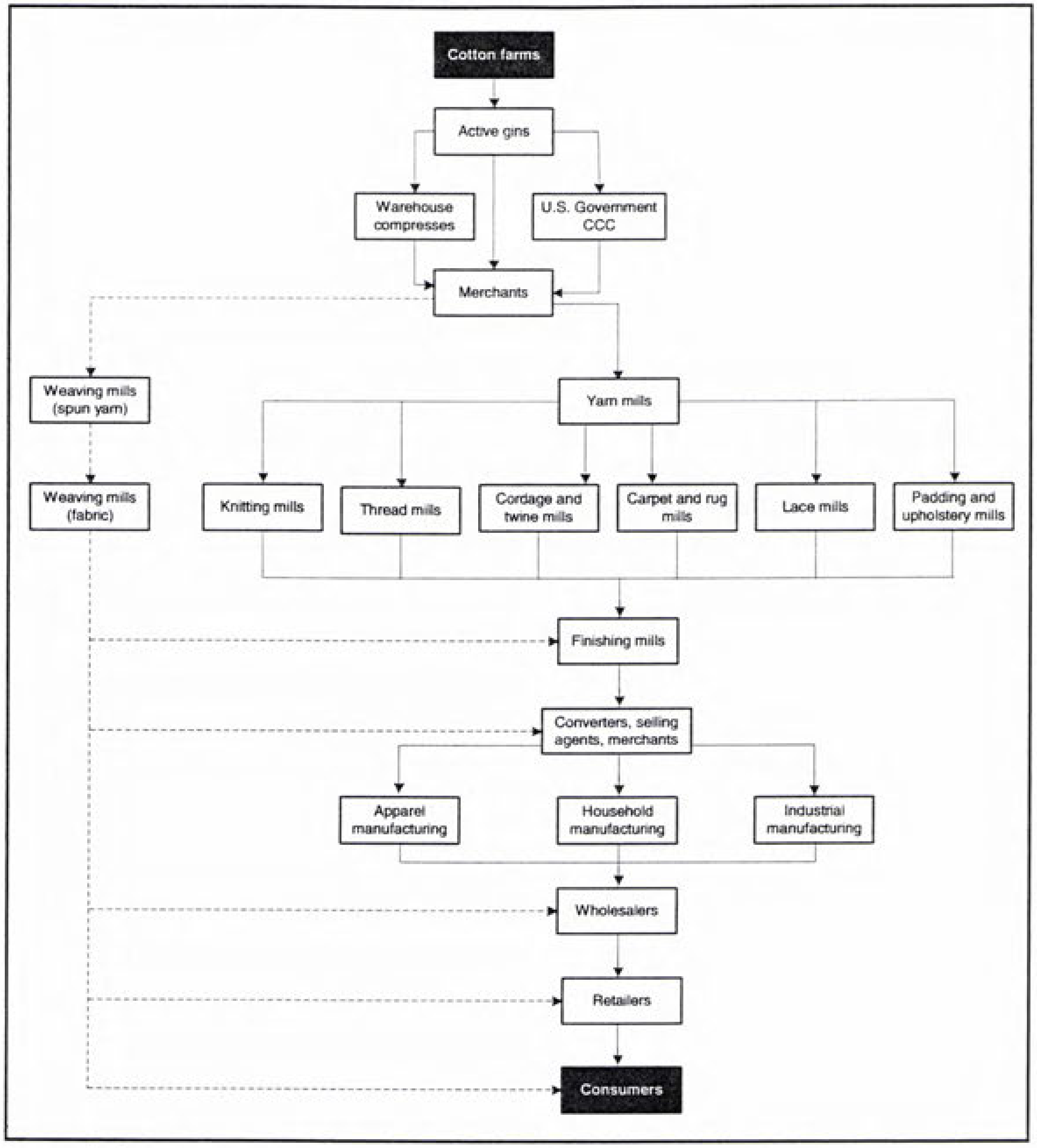
This section describes the cotton industry's basic structure from farm to customer and presents historical data on cotton production, consumption, and prices. Then, we discuss the role of USDA farm programs on cotton producer prices and decisions. The section concludes with a summary discussion of technical change in cotton production and use over time.

3.1 STRUCTURE OF THE U.S. COTTON INDUSTRY

The production and marketing of cotton from farms to final consumers is a complex process that requires coordination among many parties, as shown in Figure 3-1. The cotton industry comprises six sectors: farms, gins, merchants, warehouses, cottonseed oil mills, and textile mills. This industry employs over 440,000 people and generates ~~$40 billion in~~ revenue. As Table 3-1 indicates, roughly half of the employment and revenue are attributed to the textile sector of the industry.

Are these numbers additive? (i.e., is revenue beyond the farm added revenue?)

Figure 3-1. Production and Marketing of Cotton



Source: Glade, E., L. Meyer, and H. Stults. 1996. *The Cotton Industry in the United States.* USDA—Economic Research Service, Agricultural Economic Report No. 739.

This chart is probably adequate for a general representation. However, it attempts to combine elements of both the physical flow and the ownership flow and is, consequently, not ~~pure~~ fully accurate.

Table 3-1. Cotton Industry Employment and Revenue, by Sector, 1997

Sector	Number of Jobs	Revenue
Farms	173,446	6,115,526,776
Gins	42,511	802,388,570
Merchants	2,844	8,297,276,000
Warehouses	9,938	277,795,000
Cottonseed oil mills	1,520	1,104,641,145
Textile mills	213,095	23,545,105,000
Total	**443,353**	**$40,142,732,491**

Source: National Cotton Council. 1999. "Sharing a Common Thread: Textiles Thrive on Cotton." <www.cotton.org>. As obtained on May 12, 2001.

For purposes of this report, we have categorized the various sectors of the industry into two broad categories: production and processing. Production consists of growing, harvesting, and ginning the cotton, and processing consists of all activities after the cotton is formed into a bale.

3.1.1 Cotton Production

The planting season for cotton typically occurs from February to June, depending on the region. The seedlings emerge 5 to 15 days after planting, and branches begin to form 3 to 4 weeks later. The cotton plant produces both vegetative and reproductive (fruiting) branches. Squares, or buds, develop on the fruiting branches, representing the first stage in cotton fruit formation. After an average of 23 days (or from late June to mid-August in most of the Cotton Belt), white or cream-colored flowers appear. The petals turn pink and are then shed after fertilization, and the cotton boll begins to develop. The bolls reach full size after 24 days, but need 24 to 40 more days for the fibers to stretch, thicken, and mature and for the boll to open. Although this represents the typical, or ideal, growth pattern, many factors, such as the variety, temperature, length of growing season, soil moisture and fertility, insects, weeds, and disease, can influence the development of a cotton plant (Deterling, 1982).

Each boll of harvested cotton contains between 28 and 45 seeds, which are separated from the fibers at the ginning stage.

When harvested, the cotton crop is composed of lint and cottonseed. Cotton lint is the most valuable portion of the cotton plant (see Table 3-2), but cottonseed is another major component. As shown in Figure 3-2, cottonseed is used in many ways once it is separated from the lint. Approximately 2 percent of the seed is used for re-planting; 38 percent is fed to livestock; and the remaining 60 percent is processed into oil, meal, hulls, and linters (Basra, 1999).

Table 3-2. Retail Value of Cotton Crop, 1993–1994

Product	Pounds Produced	Retail Value
Lint	8,592,000,000	$116,658,587,361
Kernels (for feed)	NR	$1,877,660,322
Kernels (for oil)	2,048,789,000	$1,741,470,650
Hulls	3,387,162,000	$135,486,480
Linters	1,040,252,000	$187,245,360
Total		**$120,600,450,173**

NR = Not reported.

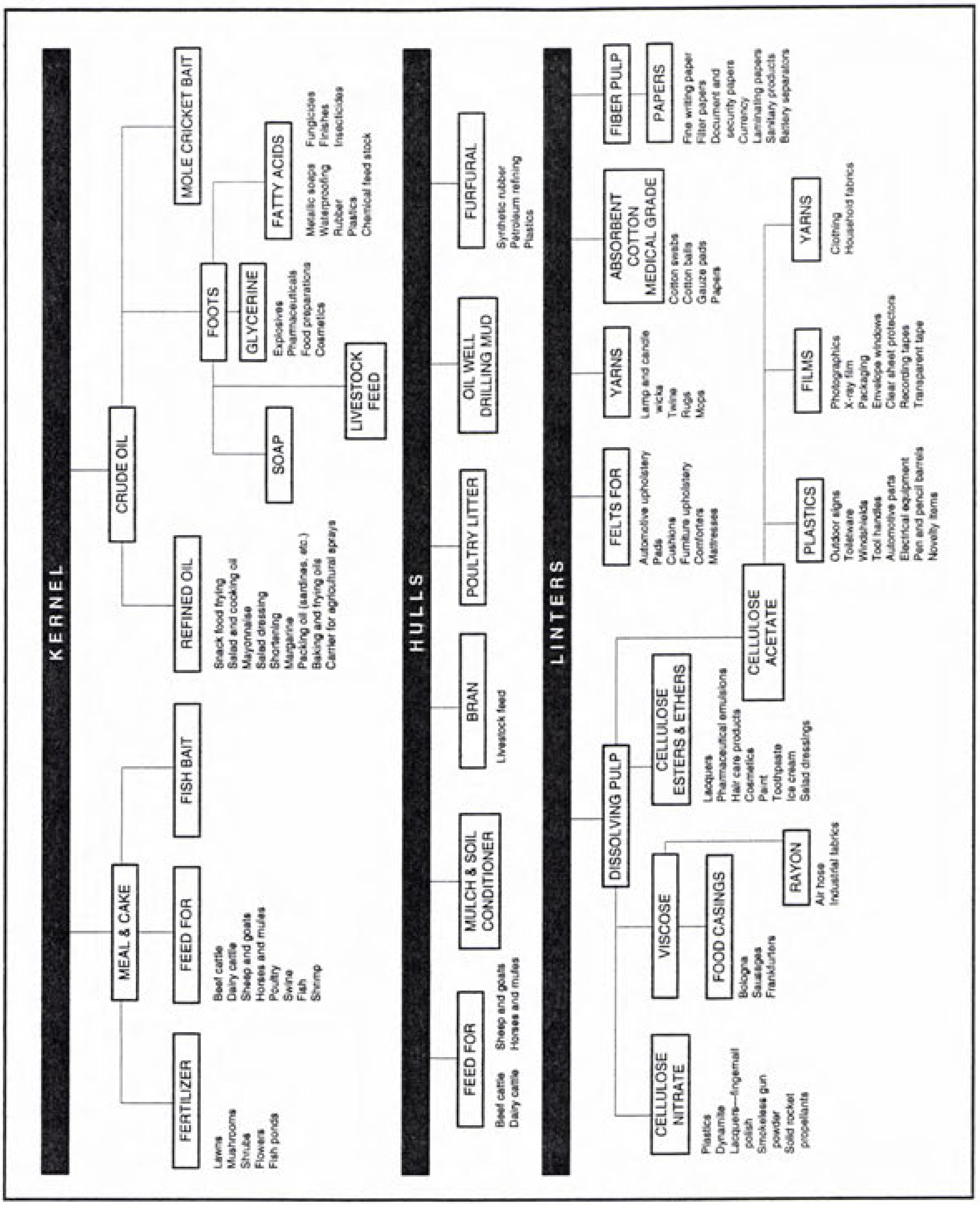
Source: National Cotton Council. 2001. "Weekly Export Report." <www.cotton.org>. As obtained on June 18, 2001.

Cotton is grown in the southern part of the U.S., where abundant sunshine and moisture allow for ideal growing conditions. This area of 17 states is commonly called the "Cotton Belt." Texas is the largest producer of upland cotton, producing over 4.4 million bales in 1995. Table 3-3 provides a breakdown of cotton production by region. About 98 percent of the cotton that is produced in the U.S. is upland cotton, the type of cotton this report focuses on. The remainder is extra-long staple (ELS) or American Pima cotton, which is grown in the western part of the Cotton Belt.

As of 1997, cotton farms could be described as having the following characteristics:

- 54 percent of cotton farms had sales valued between $100,000 and $500,000;
- 70 percent of cotton farms were individually or family owned, 19 percent were owned by partners, 10 percent were corporate farms, and the remainder were owned by cooperatives or institutions;

Figure 3-2. Cottonseed Products and Their Uses



Source: Gregory, S., E. Hernandez, and B. Savoy. 1999. "Cottonseed Processing." In *Cotton: Origin, History, Technology, and Production*, C.W. Smith and J.T. Cothren, eds., pp. 793-823. New York: John Wiley & Sons, Inc.

Table 3-3. Production of Cotton by Region, 1999–2000 (1,000 bales)

Region	1999	2000
Southeast (Alabama, Georgia, North Carolina, South Carolina, and Virginia)	3,431.8	4,154.0
Delta (Arkansas, Louisiana, Mississippi, Missouri, and Tennessee)	5,127.0	5,375.0
Southwest (Oklahoma and Texas)	5,194.0	4,275.0
West (Arizona, California, and New Mexico)	2,405.0	3,070.0
Other (Florida and Kansas)	135.9	115.0
Total	16,293.7	16,989.0

Source: U.S. Department of Agriculture, National Agricultural Statistics Service (USDA/NASS). <www.usda.gov/nass/pubs/trackrec/track00a.htm#cotton>. As obtained on November 15, 2000.

- 24 percent of cotton farmers were tenant farmers; the remainder were either full or part owners; and
- 88 percent of cotton farmers were age 35 or older.

The process of ginning is the bridge between cotton production and textile manufacturing. The original cotton gin had one purpose—to separate the fiber from the seed. Today's modern gin is required to dry and clean the seedcotton, separate fibers from seeds, further clean the fibers, and package the fiber into bales. Some modern gins can produce up to 100 bales per hour. The ginning sector has seen massive consolidation over the past 30 years. From 1968 to 1997, the number of gins declined by 73 percent, and average output per gin increased by 13,312 bales (Mayfield et al., 1999).

3.1.2 Cotton Processing

Cotton has more value added to it during processing than any other crop (Basra, 1999).

Cotton has more value added to it during processing than any other crop (Basra, 1999). Once textile mills receive the cotton bales, they are opened, conditioned, mixed, carded, and occasionally combed before spinning. The spun yarns are then knitted or woven to produce fabric, and the fabric is transformed into a multitude of end uses. Dyeing and finishing can occur at any of these phases. The movement of cotton throughout these steps is presented in this section.

Cotton bales are shipped from gins and warehouses located throughout the Cotton Belt to both foreign and domestic mills. Cotton merchants arrange the transfer of bales between these parties, although they rarely see the actual bale that they merchandise. Cotton merchants are located throughout the Cotton Belt, and typically maintain small offices, with 55 percent having less than five employees. The marketing system has become much more efficient over the past decade with the use of High Volume Instrumentation (HVI) classification system and electronic data exchange.

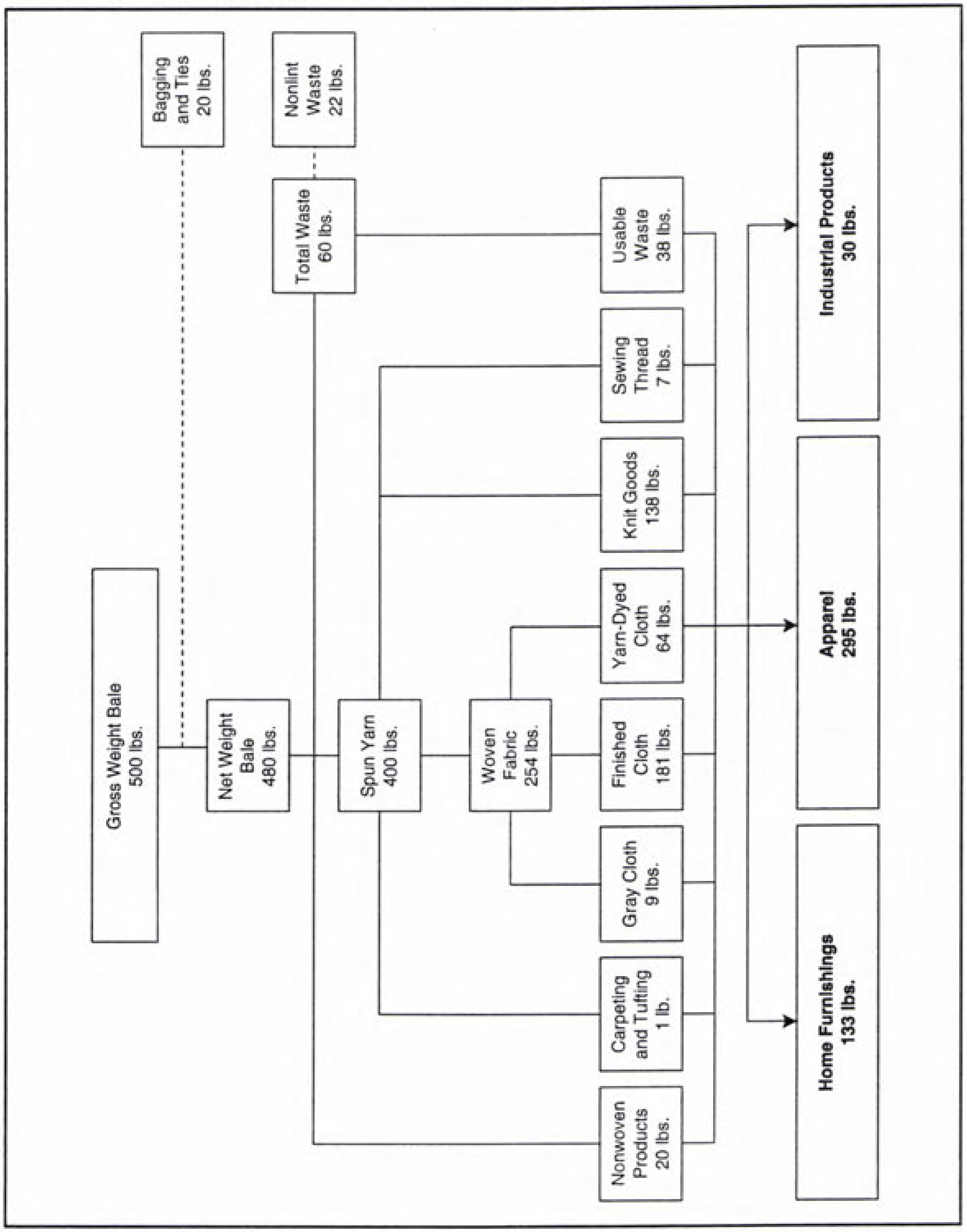
Source? Doesn't the harvest usually end in west Texas in mid-late December?

Cotton is harvested throughout the Cotton Belt in a 6-month time period, beginning in south Texas in mid-July and ending in North Carolina in early December. However, mills use cotton on a continual basis. To facilitate the movement of cotton along the supply chain, the cotton industry has adopted the Quick Response (QR) and Just In Time (JIT) strategies. These systems, which rely on computer and scanner data, reduce the time between consumer demand and production, and allow for lower inventories to be maintained. These also enable the retailer to communicate with the apparel manufacturer about specific inventory needs. One study cited by the U.S. International Trade Commission (2001) stated that QR resulted in substantial savings at the consumer level due to lower prices and better service.

Domestic textile mills are concentrated in four states: Alabama, Georgia, North Carolina, and South Carolina. As of 1997, the last year in which Economic Census data are available, the number of U.S. textile mills increased by 4.6 percent since 1992. However, according to David Link (2001) of the American Textile Manufacturers Institute, the number of textile mills has decreased since 1997, and the rate of closure is increasing in 2001. To compete, many firms have become vertically integrated, with the largest companies combining spinning, weaving, and finishing (Glade, Meyer, and Stults, 1996).

The National Cotton Council has identified 92 major product classifications as end uses for cotton. They are grouped into three broad categories: home furnishings, apparel, and industrial uses. Apparel is the predominant category, accounting for 295 pounds of an average bale (see Figure 3-3). Within the apparel category, men's apparel uses the most cotton (3,705 bales), followed by women's and children's apparel (2,384 and 771 bales,

Figure 3-3. Distribution of an Average Bale of U.S. Cotton



Source: Glade, E., L. Meyer, and H. Stults. 1996. *The Cotton Industry in the United States.* USDA—Economic Research Service, Agricultural Economic Report No. 739.

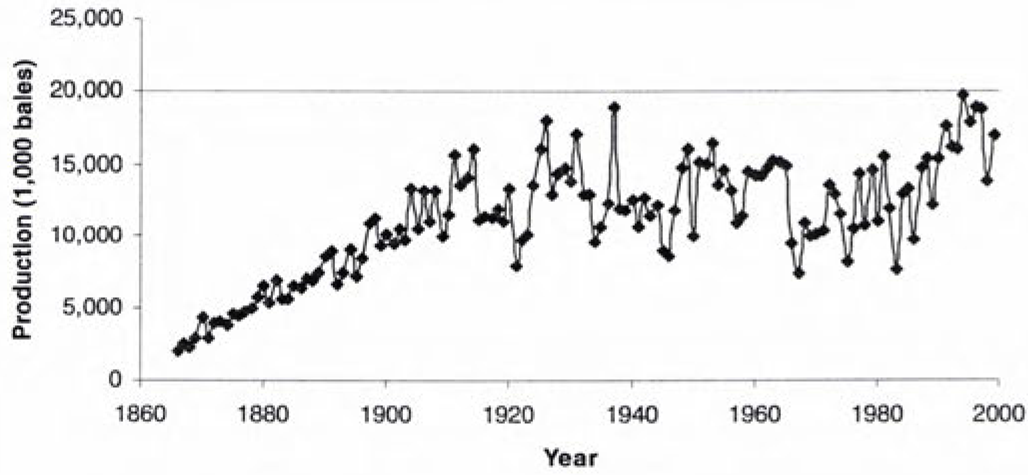
respectively). Also within the apparel category, 52 percent of apparel is constructed of knit fabrics, and 48 percent is of woven fabrics (National Cotton Council, 1998).

3.2 HISTORICAL TRENDS

3.2.1 Raw Cotton

Figure 3-4 shows U.S. production of (farm-level) cotton fiber from 1866 through 1999. The figure depicts a trend of steady expansion from Reconstruction to the mid-twentieth century. This increase was followed by a moderate decline in output, as substitutes for cotton started to take hold in the 1960s and 1970s. Production started to rise again in the late-1970s.

Figure 3-4. U.S. Cotton Production: 1866–1999



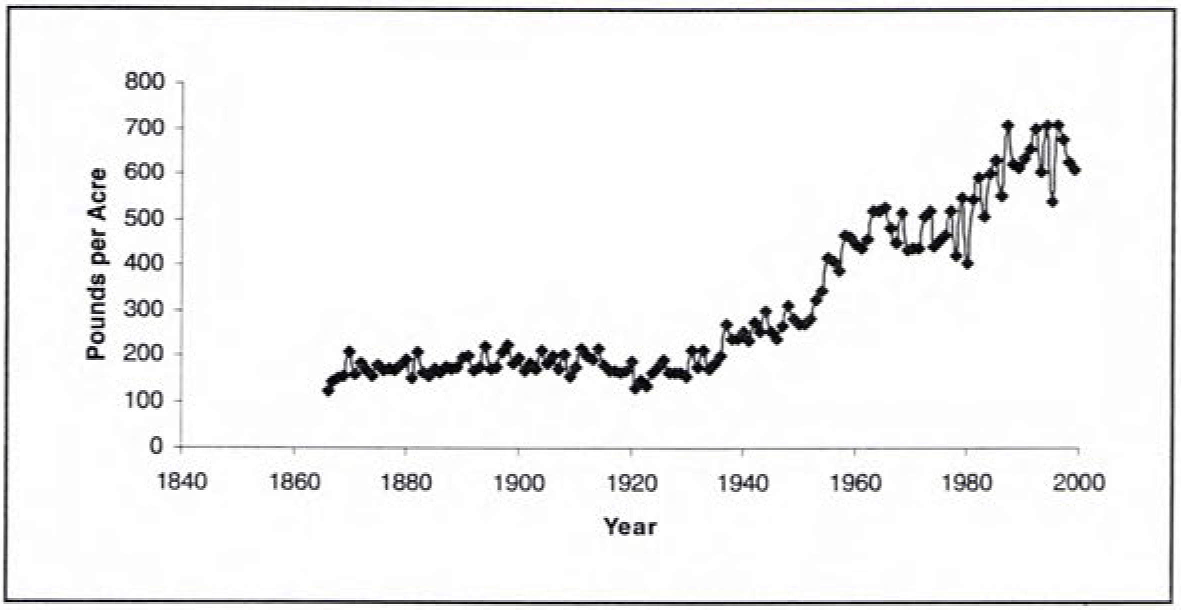
Source: U.S. Department of Agriculture, National Agricultural Statistics Service (USDA/NASS). <www.usda.gov/nass/pubs/trackrec/track00a.htm#cotton>. As obtained on November 15, 2000.

Area planted in cotton peaked at 45 million acres in the mid-1920s and has fallen to about 10 to 15 million acres in recent years. This decline in acreage is attributed to acreage controls, alternative crops, and the presence of the boll weevil (Smith, 1999). The production of cotton has been characterized by regional shifts, with the Southeast region producing 16 percent more cotton in 1997 than in 1986 and the Western region producing 13 percent less. Reasons for the shift from West to East include increased water costs in the West and decreased insect management costs in the Southeast (Anderson, 1999).

A general trend in agriculture has been a decrease in the number of farms, accompanied by an increase in the average number of acres per farm. This trend has also been evident in cotton. There were 31,493 cotton farms in 1997, compared to 34,812 in 1992 and 43,000 in 1987. Further, the average number of acres per farm has increased from 228 in 1987 to 314 in 1992 to 420 in 1997.

Despite acreage decreases, cotton production levels have been maintained as yields per acre have risen considerably over time (see Figure 3-5). These yields reflect the input intensification and genetic improvements in agriculture throughout the twentieth century, in cotton as well as all other commodities, which has been fostered by public and private research and extension expenditures. Some of these improvements are discussed in Section 3.4.

Figure 3-5. U.S. Cotton Yield per Acre: 1866–1999



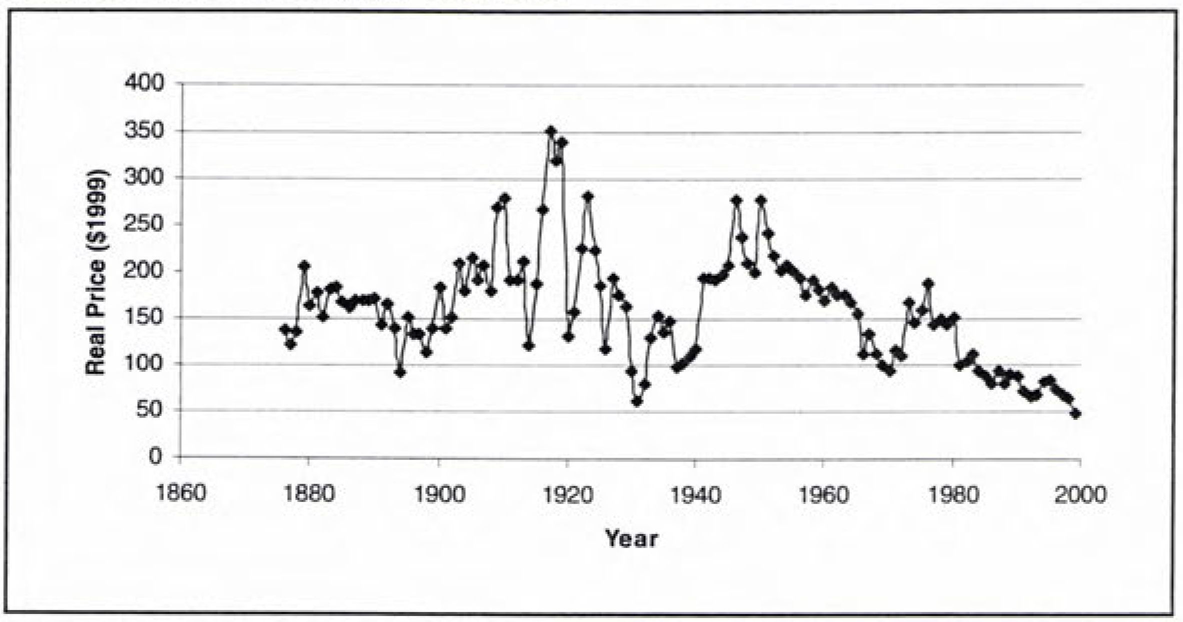
Source: U.S. Department of Agriculture, National Agricultural Statistics Service (USDA/NASS). <www.usda.gov/nass/pubs/trackrec/track00a.htm#cotton>. As obtained on November 15, 2000.

Real prices have steadily declined in the last 50 years.

While these statements are accurate, they may not be useful for the non-economist to comprehend the very complex set of forces at work in these markets. I would recommend an expanded description, but with an eye certain that it fits the objectives.

While increased yields benefit cotton producers, other factors also affect their welfare. Market prices for cotton and inputs are key determinants of profitability. Nominal cotton prices have risen over time, of course, but real (inflation-adjusted) prices have shown a variable pattern over the last 125 years (see Figure 3-6). Real prices have steadily declined in the last 50 years. All else equal, an expansion in the demand for cotton should raise prices received by producers. But all has not remained equal. Synthetic fibers have increased their market share, and fiber production capacity has expanded in foreign nations. For example, low-cost producers from Southeast and East Asia have entered the market at all stages from farm to retail and have put downward pressure on cotton prices (USDA, 1998). Moreover, federal price support programs (e.g., Step 2) complicate supply responses that might otherwise drive market prices higher. Thus, the recent decline in real prices does not mean that promotion has not successfully expanded cotton demand. Rather, the factors encouraging lower prices, such as new market entrants and higher yields, have apparently dominated price-enhancing factors such as advertising and promotion. The econometrics section of this report will examine these effects more rigorously.

Figure 3-6. Real Price of Cotton: 1876–1999



Source: U.S. Department of Agriculture, National Agricultural Statistics Service (USDA/NASS). <www.usda.gov/nass/pubs/trackrec/track00a.htm#cotton>. As obtained on November 15, 2000.

3.2.2 Textiles and Apparel

Demand for all fibers by the textile, apparel, and home furnishing industries has generally risen over time with population and economic growth. On a per capita basis, U.S. total fiber demand more than doubled between 1962 and 1999, reaching more than 80 pounds per person in 1999. While per capita demand has shown a general upward trend over time, per capita demand also tends to move with economic cycles. Contractions of the economy during recessions in 1974–1975 and 1981–1982 are reflected in falling demand, while recent expansion has moved total per capita fiber demand to its highest level to date. However, changes in demand for specific fibers, such as cotton, are strongly affected by changes in fashion trends, product acceptance, and consumers' lifestyles.

> Raw cotton is the largest investment for a textile mill, representing 64.7 percent of the yarn costs.

An important part of the total story -- global fiber use -- is missing. Globally, cotton has lost share to polyester every year for a decade. See, e.g., Hudson & Ethridge, AJAE, Dec. 2000.

As a major raw material of the U.S. textile industry, cotton has seen its popularity decline and rebound over the past 50 years. Although the first of the synthetic fibers, rayon, was introduced in France in 1884, and both nylon and acrylic were introduced commercially in the 1940s, there was little effect on cotton's market share until the early 1950s. Polyester, the chief synthetic competitor to cotton, was introduced commercially in 1953. At the time of polyester's introduction, cotton had a market share near 65 percent, but cotton's share plunged to 30 percent by 1973. From the early 1960s to the early 1980s, cotton's share of the total fiber market was cut in half as synthetic fibers grew in popularity.

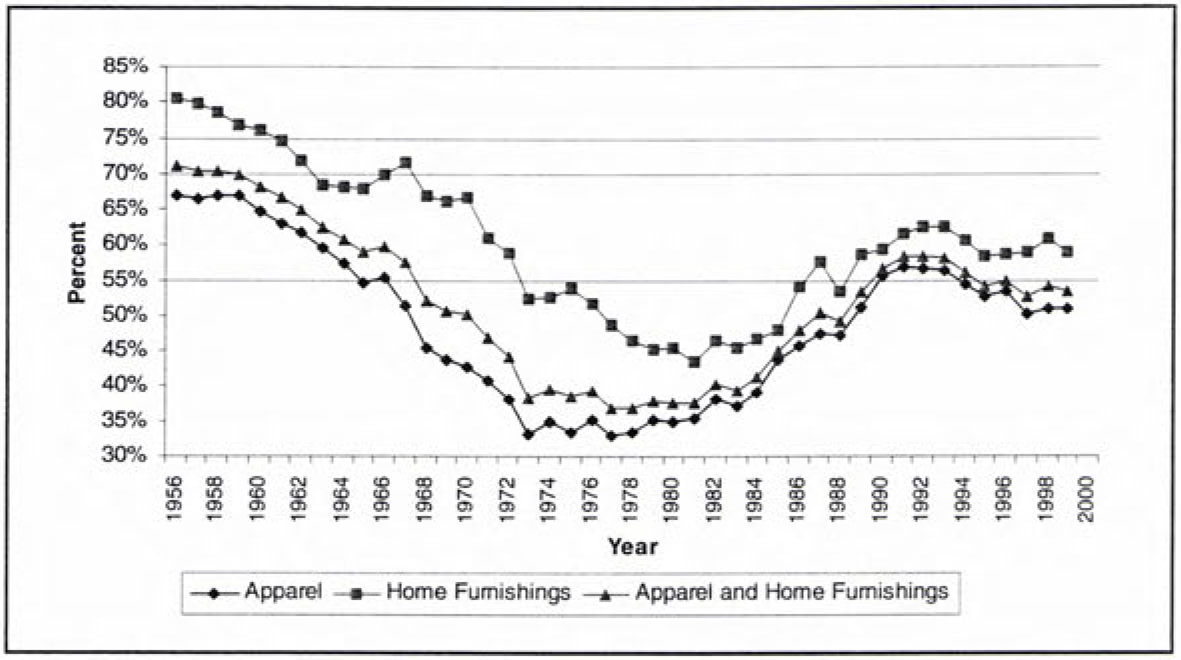
Because of the popularity of synthetics, rayon returned to the fashion scene in the 1980s after being largely disregarded in the 1960s and 1970s. Rayon production dropped steadily in the latter part of the decade, due in part to stricter environmental regulations (Tortora, 1997). The environmental movement continued in the 1990s with consumers able to purchase fabrics dyed with natural dyes, organically grown cotton products, and polyester products made from recycled soda bottles. Also, another new synthetic fiber was introduced, lyocell, that had a pollution-free manufacturing process (Tortora, 1997).

Over the past 15 years, U.S. consumer demand for cotton products has risen dramatically as consumer preferences shifted back towards natural fibers (Meyer, 1999).

Denim became an increasingly popular fabric among younger generations in the 1980s, as it was used in jeans, jackets, skirts, and entire suits (Clancy, 1996). Subsequently, denim production increased by 75 percent from 1984 to 1994 (National Cotton Council, 1999). Since denim is produced almost entirely from cotton, this trend helped cotton gain 29 percent of the apparel market share from 1981 to 1993.

Over the past 15 years, U.S. consumer demand for cotton products has risen dramatically as consumer preferences shifted back towards natural fibers (Meyer, 1999). Figure 3-7 depicts cotton's share of apparel and home furnishings (excluding carpet) at the mill level from 1956 to 1999. Cotton's share of these items at the retail level is higher, because of imports, and has increased from 41 percent in 1986 to 64 percent in the third quarter of 2000. Now that cotton market share is back at levels not seen since the 1960s, Cotton Incorporated (CI) has developed a strategy to "sustain the gain" by maintaining a high market share in denim and towels, building the market share in women's wear, and expanding into new markets such as nonwovens (CI, 2001).

Figure 3-7. Cotton Market Share at U.S. Mills



Source: Textile Economics Bureau. Textile Organon (serial). Various issues. New York: Textile Economics Bureau.

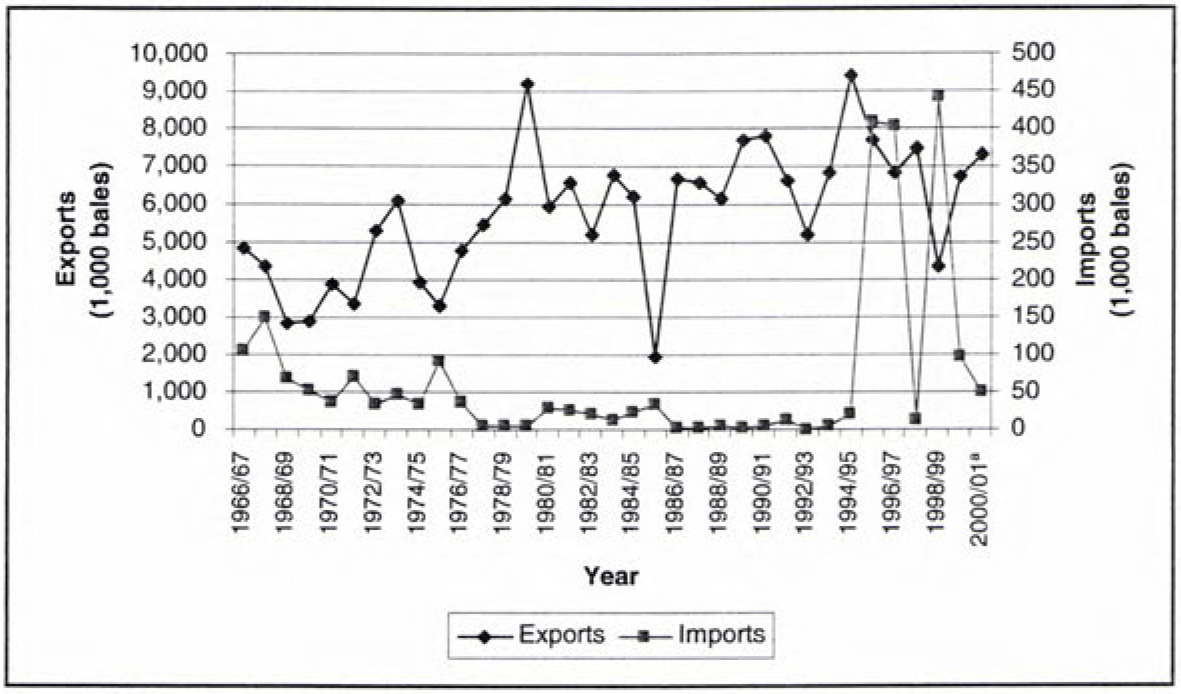
3.2.3 International Trade Issues

International trade affects all sectors of the cotton industry, but the production and processing sectors experience different effects. For cotton production, trade (specifically exports) has become a substantial source of raw cotton demand for U.S. producers. However, trade (specifically imports) has caused substantial dislocation in the U.S. textile and apparel sectors. Both of these are discussed in greater detail below.

Exports of raw cotton have increased since the1960s, with an average of 5.8 million bales per year (see Figure 3-8). Since 1995, the U.S. exported approximately 40 percent of its domestic production (USITC, 2001). The industry has experienced periods of increased volatility, as in 1998 when exports fell by over 3 million bales. This decline was due to a smaller U.S. crop and larger foreign exportable supplies (USDA, 1998). Unlike domestic mills, which receive bales at fairly constant levels throughout the year, foreign mills exhibit seasonal patterns. Most exports are shipped in the first quarter of the year. Primary markets include Mexico, Turkey, and Indonesia (National Cotton Council, 2001).

There is little competition between domestic and foreign cotton in the U.S. Imports of raw cotton accounted for less than 5 percent of domestic mill consumption during 1995–1999, and were less than 1 percent in 1997 and 1999 (USITC, 2001). Imports of raw cotton declined from 1966 to 1994 with an average of 32,000 bales but then increased dramatically to over 400,000 bales in 1995. This sharp increase was primarily due to low stocks in the U.S. at the beginning of the season (Meyer, 2001). Imports in the late 1990s have been extremely volatile, fluctuating from 13,000 bales in 1997 to a 70-year high of 443,000 bales in 1998 and down to 50,000 bales in 2000 (see Figure 3-8). Again, this was due to lower supplies in the U.S. and abundant foreign supplies (USDA, 1998). Primary import sources for the U.S. are Greece, China, and Syria (USITC, 2001).

Figure 3-8. Raw Cotton Trade



[a]Forecast.

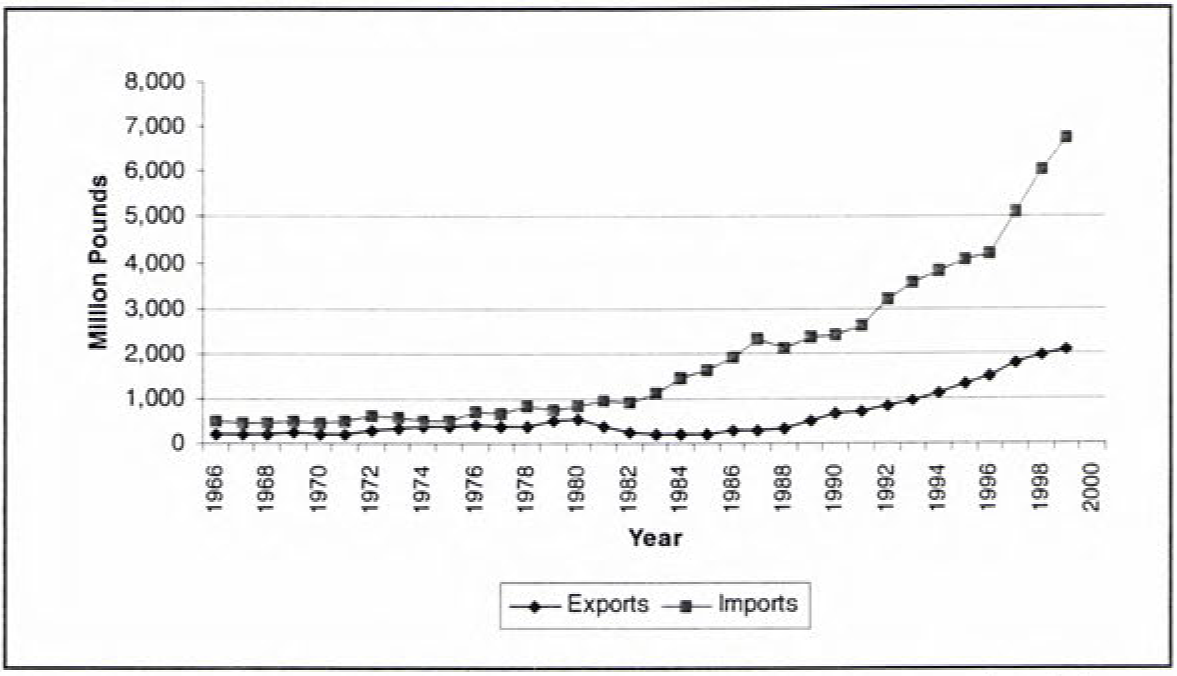
Source: U.S. Department of Agriculture, Foreign Agricultural Service (USDA/FAS). June 2001. *Cotton: World Markets and Trade*. Circular Series FC 06-01. Washington, DC.

The U.S. has been a net importer of cotton textiles and apparel for the past 30 years.

Exports of cotton textile and apparel were very stable from the 1960s through the 1980s, averaging 300 million pounds per year (see Figure 3-9). The 1990s saw a surge in cotton exports, with an average annual growth rate of 15 percent. However, the level of exports has not been able to keep up with the influx of imports. The U.S. has been a net importer of cotton textiles and apparel for the past 30 years. Import penetration of cotton textiles and apparel continues to rise, increasing from 40.4 percent of consumption to 56.5 percent in only 8 years (1989–1997). Almost three-fourths of the imports consist of apparel, while less than 20 percent are fabric and textile products (the remainder consists of headgear and home furnishings). Apparel manufacturing is more labor intensive than textile processing; thus, this facet is being driven towards low-wage developing countries (Steele, 1995). In many cases, the fabric is constructed in the U.S., cut and assembled in other countries, and then imported back into the U.S. as the final good. Unfortunately, the industry does not have an estimate of how much apparel made of U.S. grown cotton is imported into the U.S.

But there is clear evidence on cotton content of trade-- it shows that the cotton textile imports are increasingly made with foreign cotton. The more textiles the U.S. imports, the more the net cotton flows decrease, see Hudson & Ethridge, AJAE, Dec. 2000

Figure 3-9. Cotton Textiles Trade



Source: U.S. Department of Agriculture, Economic Research Service. Various issues. *Cotton & Wool Yearbook*. November. Washington, DC.

Regional trade agreements such as the North American Free Trade Agreement (NAFTA) and the Caribbean Basin Initiative (CBI) have had a major impact on U.S. textile and apparel trade over the past few years (Meyer et al., 2001). These agreements were reached in 1994 and 1983, respectively. Exports of cotton textiles to NAFTA and CBI countries have risen from 65 percent in 1993 to 88 percent in 2000, while those destined for Asian countries have fallen from 14 percent to 3 percent over the same time period. Likewise, cotton textile imports have had a similar pattern. NAFTA and CBI countries are now the source of 41 percent of cotton textile imports, compared to only 18 percent in 1993. Asia, which accounted for 65 percent of cotton textile imports in 1993, now accounts for 46 percent.

3.3 RELEVANT GOVERNMENT PROGRAMS

Since the beginning of the Great Depression, the government has been actively involved in cotton and textile markets, supporting growers, exporters, processors, and textile manufacturers. Over the years, mechanisms used have included tariffs and quotas, output restrictions, price supports, direct payments, and export and use subsidies. In this section, we will discuss the most significant current programs, and identify their impact on the present study.

3.3.1 Farm Programs

Beginning with the Agricultural Adjustment Acts of 1933 and 1938, the government has attempted to support cotton growers' incomes by restricting output and supporting domestic prices. The Federal Agricultural Improvement and Reform Act (FAIR) of 1996, also called the "Freedom to Farm Act," kept several of the long-standing loan and payments provisions but swept away a complicated set of price targets and acreage quotas that had been in place for decades. The FAIR Act covers the period from 1996 to 2002 and includes the following elements: marketing assistance (MA) loans, loan deficiency payments (LDPs), agricultural marketing transition assistance (AMTA) payments, and a three-step competitiveness process (USITC, 2001).

The CCC has been offering nonrecourse MA loans to cotton growers since its founding in 1938. Farmers may request loans on any bales of cotton they have harvested and ginned, as long as they insure them and store them in a USDA-approved warehouse. The loan rate is based on the lower of the adjusted world price (AWP) or 85 percent of the price received over the past 5 years but is guaranteed to be no lower than 50 cents per pound and no higher than 51.92 cents. From this base loan rate, a premium or discount is applied, depending on the region and the quality of the bale being considered. If market prices were to rise during the term of the loan, the grower would be free to sell the cotton and repay the loan, plus fees and charges. If the loan is not paid off within 10 months of the issue date, the grower defaults on the loan and the cotton is forfeited to the CCC.

This provision has been different at different points in time,

As an alternative to placing cotton into the CCC loan program, growers can apply for a LDP, which allows them to sell their cotton on the market and receive a payment from the CCC for the difference between the loan rate and the AWP. Growers can also use this provision to pay off their MA loans at the AWP rather than at the loan rate. With cotton prices having fallen to 33.01 cents per pound as of June 28, 2001, the LDP rate has risen to 18.91 cents per pound (FSA, 2001).

as high as?

Prior to the 1996 FAIR Act, farmers could only take part in the MA or LDP programs if they set aside a portion of their acreage to reduce production. This quota system was intended to keep prices up by reducing supply, but yield increases and pressure from textile imports kept downward pressure on prices. In an attempt to restore market forces to the cotton market, the acreage allotments were eliminated, and a schedule of AMTA payments was established. Growers were offered the opportunity to sign up for the 7-year program, which offered payments for each pound of cotton produced. The intent was to gradually reduce these production flexibility contract (PFC) payments as market forces were restored.

Could be misleading; Payments had no relation to current production-- based on historical production only (was decoupled).

Since 1996, however, U.S. and world prices for cotton have fallen significantly, and in 1998, Congress added marketing loss assistance payments to the PFCs. The net result is that cotton growers received double the 7.88 cents per pound initially planned for 1999, and total contract payments for 2000 were 15.21 cents per pound (USITC, 2001, p. 24). The level of cotton support for 2001 and 2002 will depend on the total allocation Congress sets for these programs, but emergency appropriations are likely to emerge again if world cotton prices remain low.

To mitigate potential negative impacts of the price support programs on exports and the domestic textile industry, a three-step competitiveness process was also put in place by the FAIR Act. Step 1 allows the Secretary of Agriculture to lower the AWP if it falls below 115 percent of the loan rate to provide more income to farmers. Step 2 provides for payments to U.S. mills, marketers, and exporters when the U.S. export price as measured by the Cotlook A-Index exceeds the Northern European price by more than 1.25 cents per pound for 4 consecutive weeks. Step 3 protects domestic users by increasing cotton import quotas when the U.S. price exceeds the Cotlook A-Index by more than that same 1.25 cents per pound for 4 consecutive weeks.

Conservation set-asides have been a popular form of supply limitation for more than 50 years, and current farm programs have a number of these initiatives as well. The 1985 farm bill authorized a Conservation Reserve Program (CRP), which makes annual payments based on the rental value of land voluntarily set aside from production. Any such land must be planted in an approved vegetative cover. Land eligible for the CRP include wetlands, designated conservation priority areas, highly erodible land, and cropland surrounded by noncropped wetlands. The 1985 law provided for a maximum of 15 annual payments, but those contracts due to expire in 2000 were extended for a year by the Secretary of Agriculture last summer.

Focus changed substantially in 1996 -- much heavier emphasis on wetlands.

3.3.2 Textile and Apparel Trade Agreements

Prior to the 1970s, a trade agreement referred to as the Long Term Agreement Regarding International Trade in Cotton Textiles (LTA) was in effect. Thirty-three countries were signatories of this agreement, which was extended twice in 1967 and 1970. This agreement allowed the U.S. to limit volume growth of cotton textile imports at 5 percent per year (Dickerson, 1999).

There were no restrictions on man-made fiber imports during the years 1964 to 1971.

There were no restrictions on man-made fiber imports during the years 1964 to 1971. In this time period, man-made fiber imports increased by 1,200 percent (Nordquist, 1984). Partly because of this influx of imports, the U.S. was one of 38 countries and the European Economic Community to sign the Multi-Fiber Arrangement (MFA) in 1973. Import quotas were established by the participating countries according to product type and country of origin. Products included in the MFA included tops, yarns, piece goods, and apparel made from cotton, wool, and man-made fibers. Most of the arrangements between countries were flexible, allowing "carry-over" of unused quota from a previous year, "carry-forward" of borrowed quota from a succeeding year, and "swing" of unused quota from one category to another in a given year (Yang, 1997).

The MFA was renewed in 1977, 1981, and 1986, with slight changes made each time. The MFA renewal in 1978 was more restrictive than the first arrangement, making quota frauds more frequent. Imports of items not covered under terms of the MFA, such as silk, ramie, and linen, grew significantly in the 1980s (Glock and Kunz, 1995). For this reason, these fibers were appended to the arrangement terms in 1986 (Yang, 1997).

In 1993 at the GATT Uruguay Round, the Agreement on Textiles and Clothing was realized to phase-out the MFA by the year 2005. Products will be released from quota at four different time periods, and remaining quotas will be expanded in three phases. The first two stages of the phase-out occurred in 1995 and 1998; the last two are expected to occur in 2002 and 2005. Because importing countries are allowed the decision of what products to liberalize, it is expected that the most sensitive products will not have their quotas removed until the last stage. Tariffs on imported goods will remain, although at a lower rate. Textiles and clothing tariffs of 12 percent will be higher than for all other goods, which is only 4 percent (Majmudar, 1996).

The above-mentioned trade agreements all sought to limit trade through quotas and tariffs. The U.S. has also entered into agreements that promote trade between various countries or regions. These agreements, specifically NAFTA and various Caribbean policies, were encouraged by manufacturers with facilities in these regions. They can take advantage of low labor costs, yet still be in a geographic location that is close to the domestic market (Dickerson, 1999). Canada and Mexico have complete free trade with the U.S., while Caribbean countries pay tariffs only on the value added during the production process. Another important program for the Caribbean region is the Caribbean Basin Textile Access Program (implemented in 1986), which provides a less stringent quota for apparel if the fabric is both made and cut in the U.S.

3.4 TECHNOLOGICAL DEVELOPMENTS

There is concern that some of the benefits to cotton producers and importers provided by the cotton program may prove difficult to quantify using conventional econometric analysis. Although econometrics provides a useful tool for program assessment, it will not capture features of the program that are not reflected in market data such as prices, consumption levels, and trade flows. Thus, the quantitative analysis presented in Sections 4 through 6 is supplemented here with a qualitative evaluation of the types of activities CI conducts. As part of this assessment, we describe key technological developments in cotton since the 1960s and identify, when possible, any ties between these developments and CI funding. Overall improvements in production and processing efficiency, as well as in fiber quality, are presented, followed by specific examples of technological breakthroughs.

Although the focus of this discussion is on CI's contributions to the cotton industry, it should be noted that other research organizations perform cotton research as well. For example, USDA spent $39.1 million on cotton research in 1999. This funding was committed to both production and processing of upland cotton. The Agriculture Research Service (ARS) division of USDA has at least 10 research units throughout the Cotton Belt that are devoted solely to cotton. Other USDA research units conduct general crop research as well, which includes cotton. Some USDA funding is also directed towards land-grant universities to conduct cotton research. Additionally, the USDA funded over $2.6 million on general clothing and textiles research in 1999, although this is not limited to cotton clothing and textiles.

The International Textile Center (ITC) is another example of a textile research organization. Located in Lubbock, Texas, it is an auxiliary to Texas Tech University. The activities of the ITC revolve around research, testing, and evaluation of textile processing, dyeing, and finishing. While CI only conducts research on upland cotton, the ITC also researches pima cotton, naturally colored cotton, and other natural fibers native to Texas (Alspaugh, 2001). The ITC conducts an average of 75 major projects each year and responds to more that 500 requests for testing, evaluation, specialty processing, and manufacturing (ITC, 2001).

The National Cotton Council (NCC) is an organization representing seven segments of the raw cotton industry—producers, ginners, warehousers, merchants, crushers, cooperatives, and manufacturers. It is supported financially by voluntary contributions from the seven segments on a per-bale or per-ton-of-seed basis. The NCC is involved in activities ranging from cotton program policy, export promotion, trade policy, gin safety, classing issues, pest control, worker protection standards to flammability standards for home furnishings, clothing, and cotton batting. Thus, the NCC is more involved in government and trade issues than scientific research.

In many instances, CI works in conjunction with these other research organizations to solve common problems. For example, the ITC performs some fiber quality research for CI, and the two research organizations often collaborate on projects (Alspaugh, 2001). According to the ITC Communications Director, a mutually beneficial relationship exists between CI and the ITC (Alspaugh, 2001). As another example, CI has established a research partnership with the Hides, Lipids, and Wool Research Unit at the USDA-ARS Eastern Regional Research Center. This partnership has resulted in the development of a dyeing process that enables cotton and wool blends to be dyed in one step, instead of the two-step method used traditionally. Using this process could increase the demand for cotton, especially in upscale markets, because textile mills may be more willing to create cotton/wool blends (Weaver-Missick, 2000).

3.4.1 Technological Improvements

Vast improvements in technology and practices have been made in the cotton industry over the past few decades. Increases in fiber quality and production efficiency, coupled with decreases in growth time, have contributed to these advancements. Research related to fiber quality has primarily focused on maximizing length and strength of cotton fibers. Length, strength, and fineness are the most important cotton fiber qualities related to dry processing (spinning, weaving, and knitting). The focus on fiber strength occurred with the advent of rotor spinning in the 1970s (Smith, 1999). Additionally, cotton production has become much more efficient, resulting in increases in yield and decreases in production time. Likewise, cotton processing facilities have invested in new equipment, which has enabled productivity gains and greater flexibility. The following list provides specific examples of improvements made in cotton production and processing:

- The average staple length of cotton in the U.S. increased from 32.2 thirty-seconds of an inch in 1945 to 35.0 in 1995. This represents an increase in length of 4 to 16 percent, depending on the state (Smith, 1999).
- From 1982 to 1992, fiber length increased at an average rate of 0.0076 cm per year (Benedict, Kohel, and Lewis, 1999).
- In the same time period, cotton fiber gained an average of 0.25 g/tex in strength (Benedict, Kohel, and Lewis, 1999).
- Fiber bundle strength increased by 17 percent between 1985 and 1995 (Smith, 1999).
- The average yield per acre increased from 269 lbs. in 1950 to 537 lbs. in 1995 (Smith, 1999).
- In 1965, 5 labor hours were required to produce 100 lbs. of cotton lint. In 1975, this decreased to 2 to 3 hours. By

1987, the labor hours required for 100 lbs. of cotton lint further decreased to 1.5 to 2 hours (USDA, not dated).

- The average productivity gain in producing U.S. cotton between 1939 and 1978 was 5.2 percent per year. Of this, 4.7 percent was due to mechanical technology and 0.5 percent was due to improvements in yield. Annual productivity increased further to 5.6 percent between 1978 and 1982 (Glade, Meyer, and Stults, 1996).
- The 1995 crop (over 18 million bales) was grown on half as much land as was required to produce a similar-sized crop in the 1930s (Smith, 1999).
- Ten years ago, textile mills could spin 200 lbs. of cotton into yarn per spindle each year. They can now spin 600 lbs. per spindle per year (National Cotton Council, 1999).
- From 1984 to 1995, total weaving productivity in the U.S. has remained the same at about 16.5 billion square yards annually, with a decrease in the number of weaving machines from more than 180,000 to less than 80,000. Productivity of each weaving machine has increased by a factor of almost 2.5 (Isaacs, 1997).

3.4.2 Examples of New Technologies

Cotton farmers have many new technologies that help them to control weeds, insects, plant size, and timing of harvest.

The above-mentioned advances are the results of many technological breakthroughs. Some of these technologies are listed in Table 3-4. However, because of time and space limitations, only those findings that have had a significant impact are included. Thus, this list is not exhaustive of all breakthroughs in the cotton industry. It should also be noted that some of the technologies were not developed specifically for cotton but were later adapted to this crop. Further, adoption rates of new technologies have ranged from less than 1 year to over 15 years.

We believe that one new technology, developed in 1996, warrants further discussion. This technology, whose effects may not yet be captured in the supply models discussed later in this report, is bioengineered cotton. Cotton is a lead crop in genetic engineering, and production of genetically engineered cotton has been one of the most rapidly adopted technologies ever. The first report of genetically engineered cotton was by Umbeck et al. (1987) in 1987, and by 1994 the molecular mapping of the cotton genome had begun. There are two basic categories of genetically engineered cotton: insect resistant and herbicide resistant. The only insect resistant cotton presently available is Bollgard® cotton

Table 3-4. Selected Technological Breakthroughs in the U.S. Cotton Industry

Technology	Date Invented	Developer	Role of CI[a]	Significant Fact
Bioengineered cotton	1996 Bt and BXN cotton available; 1997 Roundup Ready cotton available; 1998 stacked gene cotton available (combines Bt and RR)	Private firms	CI assisted in scientific evaluation and development of refuge plans that influenced the regulation process for the allowance of Bt varieties, and they have monitored for Bt and applied pesticide resistance in pink bollworm, cotton bollworm, cotton budworm, and in non-Bt targeted pests.	U.S. cotton farmers used 450,000 kg less pesticides on Bt cotton than they would have used on conventional varieties in 1998 (Ferber, 1999).
Boll weevil eradication program	Late 1970s	Concerted effort among cotton growers, USDA, APHIS, and CI. Pilot programs first conducted in North Carolina and Virginia.	CI continues to contribute to the program through monitoring of weevil populations for resistance to malathion, the most efficacious, safe, and cost-effective pesticide for the eradication program.	In those states where the boll weevil had been fully eradicated by 1995 (Virginia, North and South Carolina, Georgia, and Florida), there was an increase in cotton acreage of 2,495,000 acres from 1980 to 1995.
Defoliants and desiccants	1950s	NA	CI completed a 5-year study in 1998 that proved that defoliants and desiccants have no effect on the dying properties of cotton fibers.	The use of one common defoliant, ethephon, more than doubled between 1991 and 1999 to over 5 million pounds (USDA/NASS, 1991, 2000).
Cotton picker	1850 mule drawn; 1948 first mechanical picker available commercially	International Harvester Company first to produce for commercial sale.	CI funded operations-research-type studies that encouraged harvester manufacturers to produce large-capacity baskets. This significantly increased the field capacity of pickers.	A six-row picker is able to pick approximately 75 acres of cotton in a 10-hour day, which is about 65 percent more than a four-row picker (John Deere, 2001).

(continued)

Table 3-4. Selected Technological Breakthroughs in the U.S. Cotton Industry (continued)

Technology	Date Invented	Developer	Role of CI[a]	Significant Fact
Cotton stripper	1871 in principle; mid-1940s widely adopted		CI supported mechanical and economic feasibility studies of using harvester-mounted cleaners on cotton strippers.	Newer models have cleaners that remove up to 500 pounds of trash from every bale and improve turnout by up to 8 percent (John Deere, 2001).
Module system	1972; approximately 15-year total diffusion rate	Texas A&M University	This project had approximately 80 percent financial support from CI.	The module system of handling and storing seed cotton has affected ginning more than any development in several decades… it extended the ginning season, made it easier to handle the larger crop, and reduced the cost of ginning (Mayfield et al., 1999).
EasiFlo cottonseed	1996	CI and USDA Lubbock		Three plants in the U.S. produce EasiFlo, at a cost of $5 per ton. There is a premium for this cottonseed ranging from $15 to $30 per ton.
High-Volume Instrument (HVI)	1968	Created for USDA by Motion Control, Inc., with assistance from Plains Cotton Cooperative Association	CI was involved in demonstrations and pilot runs in the beginning and now assists with calibration checks on an annual basis.	HVI usage spread in the 1980s and was made the official testing instrument by USDA in 1991 (Ramey, 1999).
Engineered Fiber Selection (EFS) Cotton Fiber Management System	1981	CI	Fully developed by CI	According to CI, this software package is the most widely used HVI cotton data management system in the market (CI, EFS brochure, 2000).

(continued)

Table 3-4. Selected Technological Breakthroughs in the U.S. Cotton Industry (continued)

Technology	Date Invented	Developer	Role of CI[a]	Significant Fact
Ring spinning machine	1830	John Thorpe, an American inventor	CI has done numerous research projects to evaluate the effects of cotton fiber properties on ring spinning performance and ring spun yarn quality.	In the 1960s, it appeared that the speed of ring spinners had peaked at 12,000 rpm. By 2000, new advances were made and speeds of 25,000 rpm are now capable.
Rotor (open-end) spinning machine	1960s	N/A	CI has two rotor spinning machines in their laboratories, which allows them to explore the technology as it relates to cotton. Results are communicated to yarn manufacturers and machinery manufacturers for further development.	One of the latest models operates at speeds of 150,000 rpm.
Murata air-jet and Vortex spinning machines	1981 and 1999	Murata, a Japanese equipment manufacturer	A joint project between CI and Murata resulted in a modification of the equipment so that it could run high cotton blends and eventually 100 percent cotton.	The vortex spinning machine can produce 100 percent cotton yarns at 440 meters per minute. This is two times faster than open-end and 20 times faster than ring spinning.
Shuttleless weaving machines	1950s	N/A	While CI does not have a weaving machine in their laboratories, they do sponsor research at various universities to determine how new weaving technologies can be applied to cotton.	There are four types of shutteless weaving machines (projectile, rapier, water-jet, and air-jet) with speeds that range from 1,260 to 2,160 meters of yarn per minute (Tortora and Collier, 1997).
Continuous bleaching for nonwoven purposes	1987	CI patent; licensed to Edward Hall of the United Kingdom		Bleached cotton from this technology has improved properties, including more uniformity, less static build-up, and reduced nep formation (Hollis and Rhodes, 1987).

(continued)

Table 3-4. Selected Technological Breakthroughs in the U.S. Cotton Industry (continued)

Technology	Date Invented	Developer	Role of CI[a]	Significant Fact
Quickwash Plus	1995	Raitech, Inc.	CI worked in collaboration with the developer to improve the initial prototype designs and is working with industry standards organizations to develop recognized testing procedures for this technology.	The Quickwash Plus system uses 2.8 gallons of water, in comparison to 18 gallons used by the current AATCC test method. The total wash/dry time is also reduced from 60 minutes using the current AATCC method to 12 minutes using the Quickwash Plus method.
Garment wrinkle resistant finishing	1987	CI	CI demonstrated this technology to Farah, who was the first apparel manufacturer to use this technology.	Several attempts of wrinkle resistance were made prior to 1987, but these were all done at the fabric level rather than the garment level.

NA = Not available.

[a]All information obtained through personal communication with Dr. Preston Sasser, CI, to Catherine Viator, RTI. March–June 2001.

(commonly called *Bt* cotton), which is resistant to the tobacco budworm and the cotton bollworm. The term *Bt* represents *Bacillus thuringiensis*, a naturally occurring bacteria that is toxic to the above-mentioned lepidopterous insects. Herbicide resistant cottons include BXN® cotton (resistant to Buctril®, or bromoxynil, herbicide) and Roundup Ready® cotton (resistant to glyphosate). Both of these allow for the herbicide to be sprayed over the crop canopy without affecting the cotton plant.

Bollgard® cotton and BXN® cotton were commercially available beginning with the 1996 crop season. The number of acres of Bollgard® cotton jumped from 1.8 million acres in 1996 to 4.2 million acres in 1999. Following the introduction of Bollgard® cotton in 1996, Monsanto Corporation commercialized Roundup Ready® cotton in 1997. This is now the dominant genetically engineered cotton, and it accounted for 37 percent of the U.S. cotton acreage in 1999 (ICAC, 2000). Stacked gene cotton, which combines Bollgard® and Roundup Ready® cotton, has also been available since 1998. Direct benefits of genetically engineered cotton include reduced chemical usage, production costs, and farming risk, and increased yield, profitability, and crop management effectiveness. The International Cotton Advisory Committee (2000) reports spray reductions ranging from 1.0 to 7.7 sprays per crop season. However, recent consumer surveys have shown increased concerns about bioengineered crops and foods, which could negatively affect the amount of bioengineered cotton that is planted in the future.

All of the genetic engineering technologies were introduced by private firms, yet CI has played a part in their development.

All of the genetic engineering technologies were introduced by private firms, yet CI has played a part in their development. In addition to their role that is listed in Table 3-4, CI has also evaluated the efficacy of different *Bt* cotton constructs/varieties and researched the economics of *Bt* cotton systems at various locations (Cotton Incorporated, 2001). It is not possible to separate the contribution of CI from other sources in the development of *Bt* cotton.

New technologies are constantly in development for the improvement of cotton production and processing. Biotechnology continues to be the main focus in cotton production research, while the main focus in cotton processing research is the combination or elimination of steps in creating, dyeing, and finishing cotton fabric.

CI is currently involved in numerous research projects in these areas, as shown in Appendix A.

Much of this is a matter of perspective. As far as I am aware, CI's involvement in biotech. cotton has been minimal. However, CI played a substantial role in the development of module handling systems, a revolution in harvesting, transport, & ginning. Their role in the adoption of HVI grading was quite important, Their EFS system has been instrumental in the industry moving toward computerization & more sophisticated information technology.

In short, I would submit that their more important research efforts have not been in biotechnology.

4 Conceptual Cotton Market Models

Measuring the net benefits of the Program requires

- a conceptual structural model of the industry market equilibrium;
- estimates of supply and demand parameters that can be used to parameterize the structural model;
- estimates of the demand response to promotion and nonagricultural research expenditures;
- estimates of the supply response to agricultural research expenditures;
- simulation of the cotton market in the absence of Program expenditures; and
- transformation of the simulated effects of research and promotion (through retail demand shifts, cotton mill-level demand shifts, and commodity supply shifts) and assessments (through commodity supply shifts) into measures of benefits and costs.

This section discusses the conceptual structural model developed to describe the cotton market. We provide background information on the theory informing the development of our market models and present our model of the cotton market. Estimation of this model provides estimates of the parameters necessary for evaluation of the Program (see Section 5). Finally in Section 6, the estimated parameters are used to simulate the market in the absence of the Program and to calculate the benefits of Program activities to producers.

Because some aspects of Program activity are difficult to quantify and may not be fully captured by the econometric analysis, our quantitative approach is complemented by a qualitative discussion of Program activities. This qualitative discussion is included in Section 7 of this report.

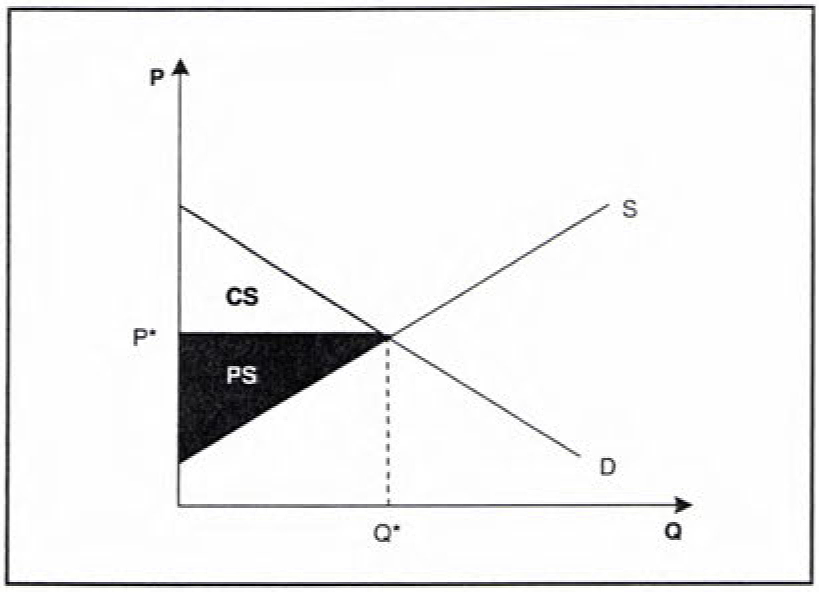
4.1 CONCEPTUAL FOUNDATION

Expenditures on generic cotton research and promotion may affect both the demand for cotton and the supply of cotton. Producers may benefit in either case because spending on promotion will increase consumer demand for retail products (and therefore the derived demand for raw cotton), while research on marketing methods (storage, transport, processing, and distribution services) will directly increase the demand for cotton by textile mills, and research on farm production methods will reduce the costs of producing cotton. All of the potential effects of the Program mentioned above have positive benefits to producers, but the important question from a net benefit perspective is whether the gains from Program activities outweigh the costs to producers.

Figure 4-1 displays conceptual supply and demand relationships. Demand curves normally slope downward because, everything else being equal, consumers will purchase more of a product as its price declines. Supply curves, on the other hand, generally slope upward because the higher the price of a good, the greater the quantity of that good sellers are willing to make available. For an agricultural product such as cotton, there are biological lags in changing the quantity produced in response to a price change. This may mean that the quantity harvested in a given year is relatively unresponsive to changes in price that occur after the planting season.[1] Nonetheless, because cotton is a storable commodity, the quantity supplied to domestic and foreign textile mills out of cotton stocks over a given time period (e.g., monthly) is expected to increase immediately as prices rise. Over time, it is likely that there will be an increase in cotton acreage planted in response to an increase in the returns to producing cotton.

[1] Some responsiveness of production to price is expected even after the cotton crop has been planted because a higher cotton price is expected to induce more effort on the part of producers to care for the crop. In addition, cotton acreage is more likely to be harvested rather than abandoned when prices are high.

Figure 4-1. Consumer and Producer Surplus



Supply and demand curves show the quantity of a good that will be supplied and demanded, respectively, at each price. The intersection of these two curves determines the market equilibrium price and quantity. The market equilibrium is the only point at which the quantity that buyers want to purchase is equal to the quantity that sellers are willing to make available. If price were not equal to the market equilibrium price, then there would be either a surplus or a shortage in the market, depending on whether price was above or below the equilibrium level. Thus, at any other point, there would be pressure on the price to move towards equilibrium.[2] We assume that all of our observations of price and quantity reflect the market in equilibrium.

An important assumption necessary to draw supply and demand curves is that all factors other than price are held constant. If any factor that affects demand or supply (other than price) changes (e.g., the level of Program expenditures), then there will be a shift in the affected curve. In other words, rather than moving along the

[2]If the price were higher than equilibrium, then sellers would be trying to sell a larger quantity than buyers were willing to purchase, leading to a surplus and putting downward pressure on the price. On the other hand, if price were below equilibrium, then buyers would want to purchase a larger quantity than sellers were willing to make available, leading to a shortage and upward pressure on price.

curve as in the case of a change in price, there will be a change in the quantity demanded (supplied) at every price following the shift in demand (supply) when one of these other factors changes.

For example, one goal of the Cotton Program is to make consumers aware of the advantages of cotton through promotional expenditures. Assuming these activities are successful, consumers will place a higher value on cotton products than they did previously, and this higher valuation will be reflected in an increase in the quantity of cotton products demanded at every price along the entire retail demand curve. Because the demand for cotton products at retail has increased, there will be an increased demand for the cotton products produced by textile mills, and a corresponding increase in the derived demand for raw cotton facing cotton producers.[3] Another activity performed under the Cotton Program is agricultural research on cotton. Successful agricultural research will typically have effects such as increases in yield and/or lower production costs. Either of these effects would lead to an increase in the supply of raw cotton (possibly with some lag) (e.g., more cotton would be made available at any given price because of the improvement in returns available to producers).

The shift in demand and/or supply caused by the Program will affect consumer and producer surplus measures, which economists commonly use to estimate changes in the welfare of market participants. Conceptually, consumer surplus is the maximum amount that consumers would have been willing to pay for the quantity of a good purchased less their expenditures on that good. Thus, consumer surplus is a measure of the gain that consumers get from being able to purchase a good for less than their valuation of that good. The demand curve represents the maximum amount that consumers would be willing to pay for each unit of output. Therefore, consumer surplus is measured as the distance between the demand curve and the equilibrium price summed across all units of the good purchased. When there is an increase in demand for a good (rightward shift of the demand curve), this means consumers' valuation of the good has increased. While an increase in demand will also increase equilibrium price, other things being

[3]This market linkage is discussed in more detail later in this section.

equal, the increase in valuation typically outweighs the increase in price so that consumer surplus rises.

Producer surplus, on the other hand, is the total revenue that producers receive for their product less the minimum amount necessary for them to make the product available. The supply curve represents the minimum amount that sellers would be willing to accept for each unit of output, which is equal to their marginal costs. In the case of an outward shift in demand, the price that producers receive will increase for all units sold and they will be able to sell more units. Both of these effects will increase producer surplus. Figure 4-1 graphically illustrates the areas of consumer and producer surplus in a typical competitive market, where Q* is the equilibrium quantity, P* is the equilibrium price, CS is consumer surplus, PS is producer surplus, and S and D denote the supply and demand curves, respectively.

As described above, changes in supply and demand lead to changes in consumer and producer surplus. Figure 4-2 provides an example. Here, an increase in demand from D to D′ leads to an increase in equilibrium price from P* to P′ and an increase in equilibrium quantity from Q* to Q′. As a result of these changes, consumer surplus increases by A–B, and producer surplus increases by B+C.[4] Overall, the total surplus to consumers and producers increases by the area A+C following this increase in demand. It will generally be the case that both consumers and producers will benefit from Program activities that increase demand and/or supply. The main factors that determine the share of benefits going to each are the slopes (steepness) of the supply and demand curves. For example, as the demand curve becomes more vertical, price will increase less in response to a given increase in demand (outward shift of the demand curve). This implies that as the demand curve becomes more vertical, the share of benefits from promotion going to producers will decrease, although their benefits will still be positive.

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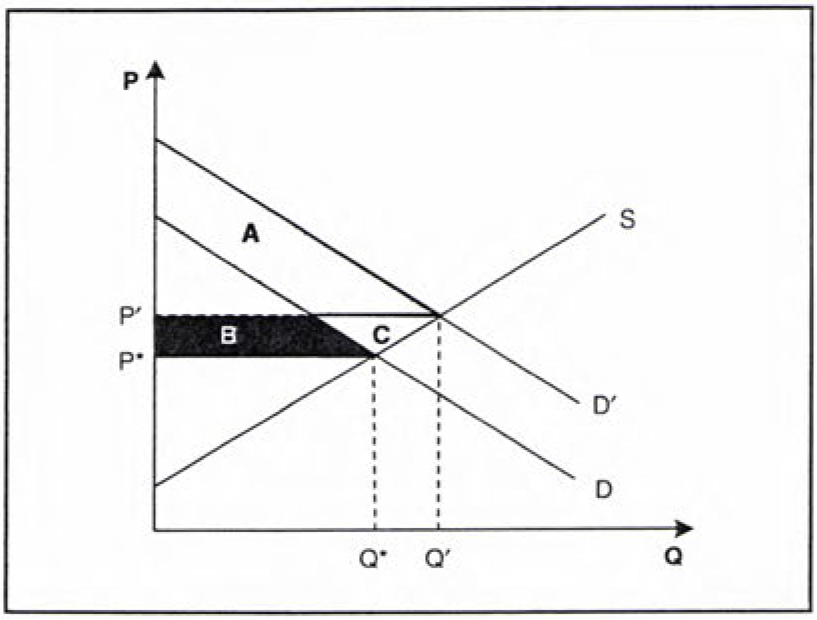
[4]Consumer surplus increases by the area A–B because consumers gain the area A as a result of their increased willingness to pay for this product but lose area B because the price of each unit has increased. Producer surplus increases by B+C because producers both get a higher price and sell a greater quantity as a result of the increased demand.

Figure 4-2. Change in Consumer and Producer Surplus due to Increase in Demand



As a measure of the changes in welfare brought about by the Program, we estimated the changes in demand and supply caused by the Program and calculated the resulting changes in consumer and producer surplus. The changes in price and quantity attributable to the Program are used to estimate the rate of return for cotton producers and importers, as well as the overall rate of return associated with the Program.

To estimate the changes in supply and demand that would result if there were no Program, we first need to estimate the supply and demand curves for the cotton market under the actual conditions that have prevailed in recent years. Our approach recognizes that there is a linkage between the farm-level market for cotton, the textile market (the largest purchaser of raw cotton), and the retail market for final products made from cotton such as apparel and home furnishings. It is assumed that each of these markets can be represented by supply and demand functions and that an equilibrium market price and quantity exist at each market level. The effect of generic research and promotion is revealed by the change in market equilibrium conditions when there is spending on research and promotion relative to the case where this spending is absent.

Figure 4-3 shows the impact of promotion and research on prices, quantities, consumer surplus, and producer surplus for a single commodity in a multistage production system, such as cotton.[5] Derived demand at the farm level (D_f) is equal to retail demand (D_r) less the constant absolute margin (M) at each quantity value.[6] The market is initially in equilibrium where the farm supply curve (S_f) intersects the derived demand curve (D_f). Quantity produced and sold to consumers is given by Q*. Price at the farm level is P_f and price to consumers is P_r.

Suppose promotion causes retail demand to increase from D_r to D_r' and farm-level demand to increase from D_f to D_f'. Farm price increases from P_f to P_f', the retail price increases from P_r to P_r', and quantity produced and consumed increases from Q* to Q′. Consumers gain the area A–B and producers gain the area C in Figure 4-3a.

Under a research-induced reduction in production costs where the farm supply shifts down parallel from S_f to S_f', farm price falls to P_f'', retail price falls to P_r'', and quantity rises to Q″. Consumer surplus increases by the area D, and producer surplus increases by the area F–E in Figure 4-3b.

Finally, a research-induced reduction in the costs associated with the production of intermediate textile products that leads to a reduction in absolute margin from M to M′ will cause the derived demand for raw cotton to increase from D_f to D_f'' and will increase consumer surplus by the area G and producer surplus by the area H. This case is shown in Figure 4-3c.

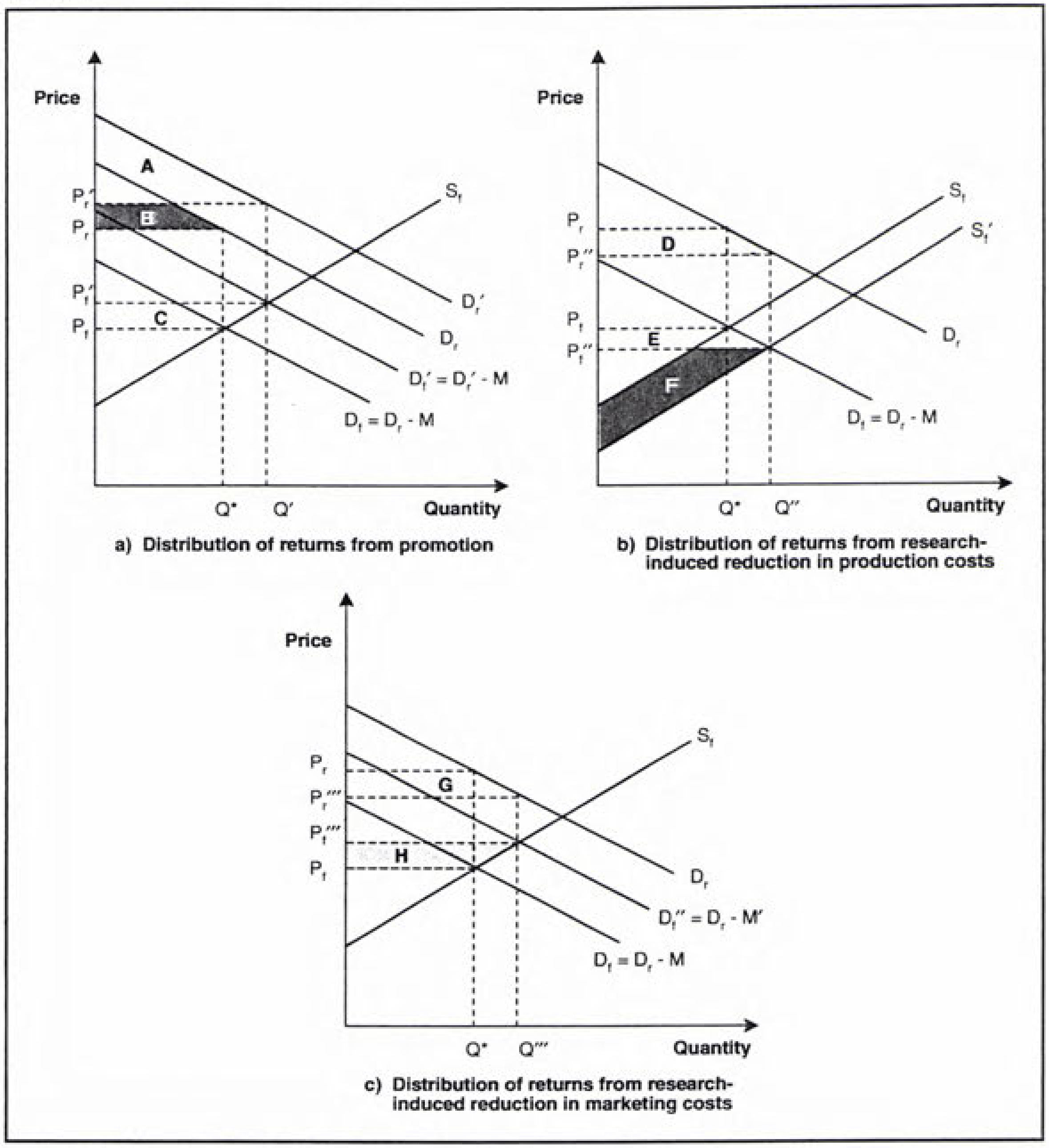
4.2 STRUCTURAL MODEL

It is expected that the activities performed under the Cotton Program will simultaneously cause each of the three types of shifts shown in Figure 4-3 to occur in the domestic market for cotton. This is because the Program engages in promotion designed to

[5] This figure shows two stages of the production process (retail and farm level) assuming fixed input proportions and a perfectly elastic (flat) supply curve for the intermediate product.

[6] The margin M is the difference between farm prices and the price to consumers, which represents "marketing" costs, which include all of the processing, transportation, etc. that take place between the farm and retail levels.

Figure 4-3. Distribution of Returns from Research and Promotion in a Multistage Production System



a) Distribution of returns from promotion

b) Distribution of returns from research-induced reduction in production costs

c) Distribution of returns from research-induced reduction in marketing costs increase retail demand, research into fiber and textile quality that is aimed at increasing mill-level demand directly (because of reductions in the cost of processing cotton)[7], and agricultural research into methods of reducing production costs. In addition, there is a shift in the supply curve resulting from the assessment itself. The assessment increases the cost of production, resulting in a decrease in the supply curve. Because the assessment and the results of agricultural research shift the supply curve in opposite directions, the net shift of the supply curve depends on which effect is larger.

To assess these changes in supply and demand resulting from the Program, we developed a structural model of the domestic cotton industry. The linkages between the relevant market levels must be included to ensure that all of the Program impacts are being considered. The framework for such a market linkage model is found in Piggott, Piggott, and Wright (1995); Wohlgenant (1993); and Wohlgenant and Clary (1993), among others. The retail market consists of the apparel market, the home furnishings market, and others. The textile market consists of intermediate textile producers and consumers in the U.S. and is the major demander of raw cotton.[8] To model the impact of Program promotion and research activities on the demand and supply for cotton, we define the structural market model for domestic cotton as follows (see Table 4-1 for a summary of the variables included in each function):

$$Q_{rd}^{d} = D_{rd}(P_{rd}, P_{rm}, A_g, A_b, A_f, Z_r)$$
Retail demand for domestic cotton products (4.1)

$$Q_{rd}^{s} = S_{rd}(P_{rd}, P_{td}, P_{tm}, W_r)$$
Retail supply of domestic cotton products (4.2)

$$Q_{td}^{d} = D_{td}(P_{rd}, P_{td}, P_{tm}, W_r)$$
Derived demand for intermediate textiles (4.3)

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[7]This research may also increase retail demand if the quality of retail products improves as a result of the research activities.

[8]The term "textiles" as used in this model includes all intermediate products that will be used as inputs into making apparel, home furnishings, or other retail products.

Table 4-1. Summary of Variables Included in Domestic Raw Cotton Fiber Production Structural Market Model and Where They Enter Supply and Demand Functions

	Retail-Level		Textile Market		Farm Level		Trade	
Variable	Demand	Supply	Derived Demand for Cotton	Supply	Demand	Supply	Imports	Exports
Retail Price of Domestic Products	x	x	x					
Retail Price of Imported Products	x	x	x					
Price of Domestic Textiles		x	x	x	x			
Price of Imported Textiles		x	x	x	x			
Domestic Mill Price of Cotton			x	x	x	x	x	x
Imported Cotton Fiber Price				x	x		x	x
Generic Promotion Expenditure	x							
Branded Advertising for Cotton	x							
Advertising for Man-made Fibers	x							
Textile Research Expenditure			x	x				
Demand Factors in Retail Market	x							
Supply Factors in Retail Market		x	x					
Supply Factors in Textile Market				x				
Demand Factors for Export Markets								x
Agricultural Research Expenditure						x		
Supply Factors at Farm Level						x		

$$Q_{td}^{s} = S_{td}(P_{td}, P_{tm}, P_{cd}, P_{cf}, R_t, W_t)$$

Supply of intermediate textiles (4.4)

$$Q_{fd}^{d} = D_{fd}(P_{td}, P_{tm}, P_{cd}, P_{cf}, R_t, W_t)$$

U.S. demand for domestic raw cotton fiber (4.5)

$$Q_{fd}^{s} = S_{fd}(P_{cd}, R_a, W_f)$$

U.S. supply of raw cotton fiber (4.6)

$$Q_{fx}^{d} = D_{fx}(P_{cd}, P_{cf}, Z_x, W_m, T_f)$$

Export demand for raw U.S. cotton fiber (4.7)

$P_{tm} = MC_{tm}(P_{cd}, P_{cf}, W_m)$
Price of imported textile products (4.8)

$P_{td} = MC_{td}(P_{cd}, P_{cf}, W_t)$
Price of domestic textile products (4.9)

$Q^d_{rd} = Q^s_{rd}$
Retail market clearance (4.10)

$Q^d_{td} = Q^s_{td}$
Textile market clearance (4.11)

$Q^d_{fd} + Q^d_{fx} = Q^s_{fd}$
Farm-level market clearance (4.12)

where Q^k_{ij} represents quantities for which k denotes quantity supplied (s) or demanded (d); i denotes market level (retail (r), textile (t), or farm (f)); and j denotes domestic (d), export (x), or foreign (f). In addition, P_{rd} is the retail price for domestic cotton products, P_{rm} is the retail price for imported cotton products, A_g is generic promotion expenditures for cotton, A_b is branded advertising expenditures for cotton, A_f is advertising expenditures for man-made fibers, Z_r is a vector of demand factors in the retail market other than advertising (e.g., income), P_{td} is the price of domestic intermediate cotton textiles, P_{tm} is the price of imported intermediate cotton textiles, W_r is a vector of supply factors in the retail market (e.g., retail wages, energy costs), P_{cd} is the domestic price of cotton at the mill level, P_{cf} is the price of imported cotton fiber, R_a is agricultural cotton research expenditures (made by both CI and public institutions funding cotton research), R_t is cotton textile research expenditures made by CI (including all nonagricultural research expenditures), W_t is a vector of supply shifters for the cotton textile market (e.g., textile wages, energy costs), W_f is a vector of supply factors for cotton producers (e.g., input costs, prices of alternative crops), Z_x is a vector of demand factors for export markets, W_m is a vector of supply factors for imported cotton textiles, and T_f represents shifters of the supply of raw foreign cotton.

Although research and promotion are specific types of supply and demand shifters and could be included under the more general vectors of factors affecting supply and demand, they are listed separately because evaluating their effects is the primary aim of this study. Therefore, it is useful to make a special point of noting where these expenditures enter the model. Among promotion and research activities, there exist both "generic" expenditures and "branded" expenditures. The distinction between generic and branded promotion and research expenditures is that generic expenditures are designed to increase demand for a given commodity, while branded expenditures are designed primarily to increase the demand for a particular company's product. To accurately estimate the impact of the generic research and promotion activities funded by the Program on the cotton market, we need to separate the effects of this Program from the effects generated by other sources, if those effects are significant.

Branded advertising expenditures, while directed at promoting the specific product of a particular firm, could also increase market demand and therefore producer returns. This is especially true if the advertising message emphasizes product attributes common to the product class (e.g., cotton). This point is discussed in Clary (1993). If the impact of branded advertising is not considered, then the results of the estimation may be biased. The direction of the bias is not clear, however, because branded and generic promotion could be either substitutes or complements for one another.

Additional important determinants of the demand for domestic cotton are the prices of substitute fibers such as foreign cotton, polyester, and rayon. However, Shui, Behgin, and Wohlgenant (1993) find that factors other than relative fiber prices accounted for the majority of the shift away from natural fibers and towards man-made fibers that occurred between 1950 and 1987. In all four specifications that they tested, they found that nonprice effects accounted for about 70 percent of the predicted decline in natural fiber market share. The effects of nonfiber inputs (especially energy and labor) have contributed as much or more to changes in cotton market share as have relative fiber prices. Technical change over this period increased the use of man-made fibers and reduced the use of natural fibers as the fiber industry increased its share of capital inputs used in production (natural fibers are generally more labor-intensive to process). This work provides additional support for the notion that the relationship between cotton and man-made fibers needs to be carefully specified and must include variables in addition to fiber prices to accurately capture the complex interactions between these products.

Because our emphasis is on cotton producers and that is the market level for which data are available, we will estimate partially reduced-form supply and demand equations at the farm level. To estimate these equations while incorporating effects from the other levels of the market, we must substitute the determinants of retail and intermediate textile demand into the farm-level demand equation. We can obtain reduced forms for prices, which have the following form:

$$P_{rd} = P_{rd}(P_{td}, P_{tm}, A_g, A_b, A_f, W_r, Z_r), \text{ and} \quad (4.13)$$

$$P_{rm} = P_{rm}(P_{td}, P_{tm}, A_g, A_b, A_f, W_r, Z_r). \quad (4.14)$$

Substituting Eqs. (4.8) and (4.9) into these equations for P_{tm} and P_{td} and substituting Eqs. (4.13) and (4.14) into Eq. (4.5) gives us a partially reduced-form equation for domestic demand for domestically produced cotton (i.e., the domestic industry derived demand for domestic cotton):

$$Q_{fd} = DD_{fd}(P_{cd}, P_{cf}, A_g, A_b, A_f, R_t, W_r, W_t, Z_r). \quad (4.15)$$

This is our representation of mill-level demand for domestic cotton. In addition, we model the export demand for raw U.S. cotton as

$$Q_{fx} = D_{fx}(P_{cd}, P_{cf}, W_m, Z_x, T_f). \quad (4.16)$$

Domestic demand plus export demand gives us total demand for domestically produced cotton.

In addition to a model of the demand for domestically produced cotton, a model of the domestic supply of cotton is necessary to estimate the equilibrium price and quantity of cotton produced domestically. Domestic producers' decisions regarding the amount of cotton they will supply to the market can be thought of as a two-stage process. First, they decide how much acreage to plant in cotton and what varieties to plant. Annual production of cotton depends on the expected effective price of cotton (i.e., the price producers expect to receive when they sell their output adjusting for government programs) and other factors that shift the supply function (e.g., input costs) because these factors affect the planting decision. Once the planting decision has been made, additional factors such as the level of insect damage and weather conditions affect the annual production level. The second stage is determining how much cotton to sell out of stocks each month.[9] Monthly supply of cotton depends on such factors as annual production, the level of cotton stocks, storage costs, cotton spot prices, and cotton futures prices.

Although a monthly supply equation could be estimated, we relied on an annual supply function to estimate changes in producer surplus resulting from the Program.[10] This is because we are interested in the returns to domestic producers and use of a monthly supply function will not necessarily provide us with an accurate picture of the effects on the domestic producers. Use of the monthly supply function in estimating the benefits to producers may capture benefits that do not accrue to cotton producers. Instead, some of these benefits may be flowing to merchants, speculators, etc. Thus, the domestic supply of cotton was modeled as

$$Q_{fd} = Q_{fd}(EP_{cd}, R_a, W_f) \qquad (4.17)$$

where EP_{cd} is the expected effective price of cotton. This is an expected price because of the lag between planting, harvesting, and selling cotton.

Eqs. (4.15), (4.16), and (4.17) can then be implemented empirically and estimated econometrically, which provides us with estimates of the statistical relationship between the respective quantities and all of the variables included in the model affecting that quantity. The parameter estimates obtained from this model will provide us with measures of the responsiveness of quantity demanded and supplied to price, promotion, and research (as well as other relevant variables). The responsiveness of one economic variable to another

[9]However, it is not necessarily the cotton producers that are holding the cotton stocks. Often, middlemen, such as the cotton merchants, purchase the cotton from producers and hold it in inventory until sale to textile mills.

[10]This implies that we need to aggregate our estimated monthly demand equation to an annual level for use in determining net effects of the Program in conjunction with the supply function.

is typically reported as an elasticity, which is a unitless ratio of the percentage change in one variable resulting from a given percentage change in another variable. For example, the price elasticity of demand is a measure of how responsive quantity demanded is to price. If the price elasticity of demand is –0.3, this means that a 1 percent increase in the price of the product will lead to a decline in quantity demanded of 0.3 percent.[11] Using our parameter estimates, we calculated elasticities for the relevant variables.

The price elasticities of supply and demand are especially important for this analysis because they play a large role in determining the distribution of net benefits from promotion and research between producers and consumers. In general, as the supply elasticity becomes larger, implying that producers will increase production by a larger percentage in response to a given change in price, producers benefit less from Program activities and consumers benefit more. In addition, as the demand elasticity becomes larger (in absolute value), implying consumers are more responsive to price changes, the benefits to producers will be reduced, other things being equal.

In addition to the model of the domestic cotton market described above, a second model was developed to examine the effects of the Program on cotton importers. Measuring the returns to importers is a more difficult problem than measuring the returns to domestic producers because "importers" are quite heterogeneous. They may be either retailers or wholesalers, for example, and there are extreme differences in size of operations. Conceptually, returns to importers could be measured using the supply function of textile importers:

$$Q_{rm} = S_{rm}(P_{rm}, P_{tm}, W_r). \qquad (4.18)$$

The problem is that this supply curve corresponds to the supply of imports at retail, but not all importers are retailers. However, no data are available that would permit separation of the firms that

[11] The price elasticity of demand will almost always be negative because an increase in price normally leads to a decrease in quantity and vice versa. However, other elasticity measures may be positive or negative depending on whether the variables being compared tend to change in the same direction or not.

actually import the cotton products from the rest of the import supply chain. Thus, the producer surplus attributed to importers may be somewhat overstated using this equation but will still provide useful information on the Program's impacts on importers. To estimate producer surplus to importers, Eq. (4.18) must be estimated and the producer surplus with and without the Program estimated based on the price importers would receive with and without the Program. The version of Eq. (4.18) implemented empirically and the results of the estimation are provided in Section 5.

Much of the validity of the model(s) depends on how the function shifters are handled.

I have concerns about the linkages & second-round effects of the policy structure and technology in the ROW. I see no recognition of these effects in the conceptualization.

5 Econometric Estimation and Results

This section presents our estimated models of U.S. raw cotton supply and demand and of imported cotton products' supply and demand. These models include promotion and research variables to allow direct estimates of the market response to promotion and research activities. The results obtained from these econometric models are used in simulation models in Section 6 to evaluate the benefits and costs of the Program.

5.1 DATA

Prior to presenting our chosen models and estimation results, we provide an overview of data and data sources used in our models.[1] We used monthly, quarterly, and annual data for different parts of the analysis depending on the relevant period and the data available. We estimated U.S. raw cotton production using annual data from the period 1981 through 2000. For estimation of the domestic demand and export demand for U.S. raw cotton, we used monthly data for the period from January 1986 through December 2000. Finally, import supply was estimated using quarterly data from the first quarter of 1990 through the second quarter of 2000.

5.1.1 Quantities

Monthly data on the quantity of raw cotton consumed by domestic mills and the quantity exported was obtained from various issues of

[1] Tables containing all data used in this analysis are provided in Appendix B.

the USDA's *Cotton and Wool Outlook,* which is published 10 times per year (and includes data for all 12 months within those 10 issues). Quarterly data on net imports of textiles in terms of raw fiber equivalents were generated by aggregating across monthly data on textile imports and exports from the *Cotton and Wool Outlook* for the relevant months in each quarter and subtracting total exports from total imports. Annual production levels were collected from various issues of the annual USDA publication, *Cotton and Wool Yearbook.*

5.1.2 Prices

The important prices used for the analysis of the domestic raw cotton market include both the price of U.S. raw cotton at the mill level and the price received by producers,[2] the foreign price of cotton, and rayon and polyester prices. Each of these prices except the price to producers was obtained from the National Cotton Council (2001) web site. The mill price was adjusted for government subsidies by subtracting the average user certificate subsidy value for each month from the reported price. Data on the monthly value of this subsidy for the use of domestic cotton were obtained from CI. All prices obtained from the National Cotton Council were converted into raw fiber equivalent form[3] and deflated using the consumer price index (CPI) with a 1982 to 1984 base.

For the annual supply function, the relevant price is the price that producers expect to receive when they make their planting decision. To capture their expectations, we used the average of the nearby December futures prices over the months of the cotton planting season for each year. These prices were obtained from CI's database. Futures prices should reflect all information available to growers at the time they make their planting decision.

[2]These prices differ because of transportation and other costs incurred between the farm and mill delivery as well as government programs. In addition, the cotton assessment itself creates a gap between the price purchasers pay and producers receive.

[3]More waste is associated with cotton fiber than with polyester or rayon. Thus, more raw cotton is required to generate a pound of usable fiber than for either polyester or rayon. From the mills' perspective, the relevant price is the price per unit of useable fiber. This is taken into account by adjusting prices so that the price per unit of useable fiber is being compared instead of the price of fiber (cotton price is divided by 0.9, while polyester and rayon prices are divided by 0.96).

An increase in the futures price implies that growers expect to receive a higher price for their crop. Other things being equal, a higher expected price at planting time should induce growers to plant more cotton, either on land that was formerly idle or previously had other crops grown on it.

To estimate the impacts of the Program on importers, it is necessary to identify the Program's effect on retail prices. CI provided quarterly data on the average retail prices of a variety of men's and women's apparel (11 categories of men's apparel and 12 categories of women's apparel) from the first quarter of 1990 through the second quarter of 2000. We used these data to create a Fisher price index to represent the average price of apparel at retail in each quarter.

5.1.3 Promotion and Research

CI provided monthly data on Program expenditures for several categories of expenditures for the period from 1986 through 2000. The data used in the domestic and export demand models were monthly data categorized into advertising and nonagricultural research expenditures. Because of the high level of seasonal variability in these expenditures, the data were deseasonalized prior to use in the model. In addition, the annual supply model used annual data on agricultural research from 1981 to 2000 provided by CI. The Cotton Board provided data on the dollar value of assessments collected from domestic producers and importers over the period 1986 to 2000. In addition to the data supplied by CI, data on total agricultural research devoted to cotton were obtained from USDA for fiscal years 1986 through 1999 (Unglesbee, 2001).[4]

5.1.4 Other Variables

In addition to the variables mentioned above, we collected data for several other variables included in the models. The domestic demand model is estimated using per capita quantities. To calculate these quantities and convert other variables to per capita terms, we collected monthly population data for the U.S. from the U.S. Census Bureau (U.S. Census Bureau, 2001). For the domestic demand model, data on income were derived from monthly data

[4]We are anticipating receiving data for additional years going back to 1975 and adding 2000 data that we will incorporate in the final version of this report.

on total personal disposable income for the U.S. taken from the St. Louis Federal Reserve Bank's FRED database on their web site (FRED, 2001). These income data were deflated by the CPI and divided by population to obtain monthly per capita disposable income.

We obtained the wage in the domestic textile industry and a monthly index of energy costs from the U.S. Bureau of Labor Statistics (BLS). Foreign GDP was proxied by GDP for Organisation for Economic Cooperation and Development (OECD) countries after subtracting U.S. GDP from the total.[5] Data for OECD countries were used because those were the only consistent data series on foreign GDP available. These data were available at a quarterly frequency from various issues of *Quarterly National Accounts* and *National Accounts of OECD Countries.* They were converted into monthly estimates using PROC EXPAND using SAS Statistical Software. Although this can potentially lead to misleading results, GDP data tend to be very smooth over time, and this procedure should not cause much distortion. ?

Is this a valid reason to use the data?

Another variable for which PROC EXPAND was used to estimate monthly values is the level of foreign cotton stocks because this variable is only available at the annual level. These data were obtained from USDA's Foreign Agricultural Service (FAS). Finally, changes in farm input prices were estimated using the index of prices paid by farmers for the series Production, Interest, Taxes, and Wage Rates obtained from various issues of *Agricultural Statistics*, an annual USDA publication. Finally, estimates of annual yield were obtained from USDA Costs and Returns data available on the Internet.

All data series denominated in dollars were deflated prior to use in estimation. The CPI is the only price index used as a deflator in this report. CPI data are available online from the U.S. Department of Labor, Bureau of Labor Statistics (BLS, 2001). For all of the models, we used the series for all U.S. urban consumers, including monthly and annual data as appropriate, with 1982–84 = 100.

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[5] In addition, the Czech Republic, Korea, Hungary, and Poland were not included in the series for consistency because their data were not included in the GDP estimate for the entire period.

5.2 DOMESTIC MILL CONSUMPTION OF COTTON

We modeled mill-level demand for cotton as a partially reduced-form equation in which per capita mill consumption of cotton is specified as a function of the price of cotton, prices of substitute fibers, demand and supply shifters of domestically produced textile products, and demand and supply shifters of foreign-produced textile products. The demand and supply shifters of foreign-produced textile products represent the impact of the price of imported textile products on mill-level demand for cotton. It would have been preferable to use a price variable to represent the price of imports, but lack of data for the monthly demand model precluded use of these data in the present model.

The demand for mill use of cotton was estimated with monthly time series data covering the period January 1986 through December 2000, a total of 180 observations. The model was estimated in linear form and the following variables were included in the model:

$MILLUSE_t$	=	U.S. per capita raw cotton used by mills (pounds per person)
$M_{i,t}$	=	monthly dummy variables (M_i =1 for ith month, 0 otherwise) for i = 1,...,11 where December is the reference month with its effect represented by the intercept
$PCOTTON_t$	=	real U.S. raw fiber equivalent price of cotton (cents/lb)
$PPOLY_t$	=	real U.S. raw fiber equivalent price of polyester (cents/lb)
$PRAYON_t$	=	real U.S. raw fiber equivalent price of rayon (cents/lb)
$DTEXW_t$	=	real domestic wage in U.S. textile manufacturing industry ($/hour)
$WPCOT_t$	=	real A index of world cotton price (cents/lb)
$DECI_t$	=	U.S. real energy cost index (1982-84=100)
DPI_t	=	U.S. per capita real disposable income ($1,000/person)
$FGDP_t$	=	real GDP of OECD countries, excluding U.S. (billions of $)
$SAGADV_t$	=	seasonally adjusted CI real promotional expenditures ($)
$SAGNARES_t$	=	seasonally adjusted CI real nonagricultural research expenditures ($)

All "real" variables above were obtained by deflation using the CPI for all items, 1982-84 = 100. In addition to promotional and nonagricultural research expenditures, other domestic demand and supply shifters in the model include prices of competing fibers ($PPOLY_t$, $PRAYON_t$), prices of other factors in textile manufacturing ($DTEXW_t$, $DECI_t$), and per capita real disposable income (DPI_t). Proxies for the impact of the price of imports on domestic mill demand include foreign income ($FGDP_t$) and the world price of cotton ($WPCOT_t$). Other variables were entertained and initially included in the model (foreign textile wages, real exchange rate), but inclusion of these variables led to little change and/or improvement in the model. Also, there was some evidence to indicate that including these additional variables substantially increased the level of multicollinearity. This is not too surprising considering that wages are a high proportion of income. A regression of $FGDP_t$ on real foreign textile wages and the real exchange rate shows an R-squared above 80 percent, confirming that $FGDP_t$ is highly collinear with foreign textile wages and the exchange rate.

Our interest in this study is primarily in quantifying the impact of generic promotion and research on demand for cotton. One complication we have to address is the timing of these explanatory variables and allow for the possibility that their impact on consumption may be more complicated than simply contemporaneously (i.e., in the same period that they occur). That is, the effects of promotion and research on demand may be distributed over a number of months or even infinitely. Generally, models that allow for explanatory variables to affect the dependent variable over several periods are referred to as distributed lag models because the influence of the explanatory is distributed over a number of lagged values. The number of periods that these effects influence the independent variable, m, can be either finite or infinite.

Unfortunately, theory does not offer much guidance in determining the appropriate value for m; however, we do need to assume that the sum of the coefficients on the explanatory variables is finite to avoid the possibility of the expected value of the dependent variable being explosive. Thus, it is necessary to consider alternative lag lengths for both advertising and research to determine the "best" lag structure. With the correct lag length m* unknown, the number of regressors that must be included in the model is also unknown. If the researcher chooses an m other than m* ($m \neq m^*$) the parameter estimates of the model will either be biased or inefficient. It will be biased if $m < m^*$ because there are omitted variables, but is inefficient if $m > m^*$ due to overspecification of the model.

To complicate matters there is really no consensus on the appropriate criteria to use in selecting the best model. Possible candidates are the Akaike Information Criteria (AIC), Schwartz Bayesian Criteria (SBC), and the adjusted R-square (see Appendix C for details). Each of these criteria takes different forms and as a result does not necessarily imply the same ordering of preferred models. These alternative forms place different weights on factors such as number of observations used, number of parameters estimated, and how they take into account the in-sample fit of the model. No single criterion stands alone as the "preferred criterion," and each has known advantages and disadvantages under different scenarios. For instance the AIC criterion can lead to selecting too long of a lag length (Judge et al., 1988), whereas the SBC criterion is known to produce consistent estimates of the lag length under certain conditions. Geweke and Meese (1981) investigated the properties of the AIC and SBC and discovered that, as sample size becomes large, the probability that the lag length chosen will be less than the optimal lag length (i.e., $m < m^*$) vanishes. That is, the probability of underestimating the true lag length, thereby resulting in biased estimates, becomes zero as sample size becomes large. Furthermore, they also established that the probability that the lag length would be overestimated ($m > m^*$) as sample size becomes large, thereby making estimates inefficient, does not vanish for the AIC criterion but does for the SBC criterion. These large sample properties are useful properties to understand but are tempered by the fact that researchers are rarely fortunate enough to have large samples in practice, as is the case here, with a total of 180 observations that could be regarded as moderately large at best. Monte Carlo experiments by Geweke and Meese (1981) to investigate the small sample behavior of these different estimators revealed that, for samples greater than 100 observations, these estimators provide small sample results close to the theoretical asymptotic results (Judge et al., 1988). This is encouraging for the case at hand. With a sample size of 180, some confidence can be placed in the results provided by the above-mentioned criteria. They should do a decent job of identifying the appropriate m for explanatory variables that we suspect may have distributed lag effects. Thus, in selecting an optimal lag length the AIC, SBC, and adjusted R-square criterion were used.

Various challenges and trade-offs arise in selecting distributed lag models. As mentioned previously, sample size is critically important in the confidence one can place in the parameter estimates and the criteria used for selecting lag length. If m is large and only a limited sample of observed data is available, then we may not have enough observations to estimate all of the parameters. Furthermore, even if a large sample of observed data is available, as additional lags of explanatory variables are included in the model a high degree of multicollinarity can occur, which is detrimental to standard errors of the estimated coefficients. Typically, applied researchers address this problem by imposing restrictions on estimated parameters, thereby reducing the number of estimated coefficients. By imposing restrictions that fail to be rejected (i.e., are found to be consistent with the data) the in-sample fit of the model is not greatly adversely affected, but problems with degrees of freedom and multicollinearity are reduced. A final complicating facet of selecting the model is that arriving at a preferred model based on one criterion, or some combination of the criteria described above (i.e., AIC, SBC, or adjusted R-square), does not guarantee that the implied estimated economic effects (elasticities) in the preferred model make sense. That is, the researcher must combine both the statistical evidence about which model appears to fit the data best and accurately capture the distributed lag effects with prior beliefs from economic theory in arriving at the "preferred model."

Our selection of the best model was in the context of viewing the model as either a finite or infinite distributed lag model between mill consumption and promotion and research. Concerning the possibility of a finite distributed lag model and the potentially large number of lags involved, we considered different possible distributed lag models and decided that the Almon distributed lag model (without end-point restrictions imposed) would probably provide the greatest flexibility. We then embarked on grid search procedures in an attempt to find the best model. Concerning the possibility of an infinite distributed lag model, we employed a geometric lag model. In all cases of model selection across alternative specifications, we relied on statistical measures of AIC, SBC, and adjusted R-square and the implied estimated economic effects (elasticities) to compare competing models and arrive at a preferred model.

5.2.1 Model Selection Among Distributed Lag Models

The approach that most researchers recommend in a situation like this is to first search for the best lag length using unrestricted lags. Then once the maximum lag is determined, researchers use a sequential testing procedure to determine the lowest-order polynomial to impose on the maximum lag length (Greene, 1990). An alternative procedure, but one that is computationally expensive, is to search over different lag lengths and degrees of polynomial simultaneously. Both procedures were employed in this study.

For the first search we entertained the possibility that the explanatory variables for the price of cotton ($PCOTTON_t$), advertising ($SAGADV_t$), and nonagricultural research ($SAGNARES_t$) may have distributed lag effects. Using unrestricted lags, we conducted a search by estimating all combinations of lag lengths for price up to 13 lags (i.e., $PCOTTON_{t-m}$, where m = 0, 1, 2, …., 13), advertising up to 13 lags (i.e., ., $SAGADV_{t-m}$, where m = 0, 1, 2, …, 13), and research up to 60 lags (i.e.., $SAGNARES_{t-m}$, where m = 0, 1, 2, ….., 60). This search involved estimating a total of 11,956 alternative models (14x14x61=11,956). The maximum lag lengths were chosen based on the assumption that the impact of price and advertising would probably not last longer than a year and that the impact of research might have lags as long as 5 years. For each model the AIC, SBC, and adjusted R-square were calculated, and then models were sorted from best to worst for each of these criteria. A subset of the results of this grid search are shown in Table 5-1 where the top 25 models according to each criterion are displayed. The results of this grid search indicated lag lengths of 13 for price and advertising and 59 for research by the AIC criterion, but lag lengths of zero for price and advertising and

Table 5-1. Grid Search Using Unrestricted Lag Length Search

Rank	Model	AIC	Model	SBC	Model	Adj. R^2
1	p13a13r59	–6.3819	p00a00r03	–4.2574	p08a08r59	0.9271
2	p13a12r59	–6.3806	p01a00r03	–4.2427	p08a09r59	0.9243
3	p13a11r59	–6.3502	p00a00r02	–4.2330	p09a08r59	0.9242
4	p13a13r60	–6.3440	p00a00r04	–4.2305	p10a08r59	0.9238
5	p13a12r60	–6.3432	p00a01r03	–4.2285	p08a10r59	0.9219
6	p13a11r60	–6.3168	p00a06r00	–4.2260	p11a08r59	0.9217
7	p13a10r59	–6.2782	p00a00r01	–4.2218	p08a11r59	0.9212
8	p12a13r59	–6.2707	p00a07r00	–4.2197	p10a09r59	0.9212
9	p10a13r59	–6.2707	p00a00r00	–4.2192	p09a09r59	0.9211
10	p10a12r59	–6.2685	p01a00r04	–4.2168	p10a10r59	0.9203
11	p13a10r60	–6.2668	p01a00r02	–4.2145	p08a07r59	0.9194
12	p13a09r60	–6.2665	p02a00r03	–4.2138	p12a08r59	0.9191
13	p13a09r59	–6.2614	p01a01r03	–4.2136	p11a09r59	0.9188
14	p12a12r59	–6.2611	p01a00r00	–4.2120	p10a11r59	0.9188
15	p10a11r59	–6.2558	p00a00r05	–4.2112	p09a10r59	0.9186
16	p13a08r60	–6.2553	p00a02r03	–4.2104	p08a12r59	0.9180
17	p11a12r59	–6.2551	p00a05r00	–4.2091	p09a11r59	0.9174
18	p11a13r59	–6.2547	p00a08r00	–4.2086	p09a07r59	0.9172
19	p12a11r59	–6.2504	p01a06r00	–4.2085	p13a08r59	0.9171
20	p11a11r59	–6.2435	p00a01r00	–4.2073	p10a12r59	0.9167
21	p12a13r60	–6.2429	p00a02r00	–4.2061	p11a10r59	0.9165
22	p10a10r59	–6.2400	p01a07r00	–4.2044	p13a11r59	0.9165
23	p13a08r59	–6.2360	p00a01r02	–4.2044	p10a07r59	0.9164
24	p10a13r60	–6.2347	p00a06r01	–4.2017	p13a09r59	0.9161
25	p10a12r60	–6.2327	p00a01r04	–4.2014	p12a09r59	0.9160

Notes: Each model is denoted by a nine letter-digit name where p denotes $PCOTTON_t$, a denotes $SAGADV_t$, and r denotes $SAGNARES_t$. The two-digit number following each of these letters (either p, a, or r) denotes the choice of m (the lag length) of the corresponding explanatory variable. For example, p00a01r02 would represent a model that includes current price ($PCOTTON_t$), current and one period lagged of advertising ($SAGADV_t$ and $SAGADV_{t-k}$) and current and two periods lagged of research ($SAGNARES_t$, $SAGNARES_{t-1}$, and $SAGNARES_{t-2}$).

three for research by the SBC criterion. The rankings according to the criterion of adjusted R-square favor lag lengths of 8 for price and advertising and 59 for research.

We note two striking features with respect to the results of this grid search: first, the stark contrast of preferred models depending on which criterion is used, with results spanning the range of possibilities, and second, regardless of criterion the lag lengths for price and advertising are found to be the same for the models that are ranked best for each criterion. Recall that the AIC criterion has the potential to overestimate lag length whereas this probability vanishes as the sample size gets large for the SBC criterion. First impressions of these results lead us to suspect that the AIC results may have overestimated the lag lengths. Similarly the large differences between the lag lengths estimated using the SBC and adjusted R-square also hints that the adjusted R-square criterion may have also overestimated the lag lengths. Closer inspection of the results from the models "p13a13r59" (price and advertising 13 months and research 59 months) and "p08a08r59" (price and advertising 8 months and research 59 months) reveals that this seems to be the case. Either none or only a few of the price lags are individually statistically significantly different from zero, and the sum of these lags is positive, implying an upward-sloping demand curve. In addition, the sum of the lags on advertising is also negative.

For the model that was ranked best by the SBC criterion, the "p00a00r03" (no lags on price and advertising and 3 lags on research), the results are much more promising with estimated coefficients on price and advertising and three of the four estimated coefficients on research being individually statistically significantly different from zero. In addition, the signs of these estimated effects are consistent with theory, including a downward-sloping demand curve and positive effects on demand from advertising and nonagricultural research. On the basis of the economics of the three models and by the consistency properties of the SBC criterion, our preference would be for the model with zero lags for price and advertising and 3 lags for research.

Next we entertained a more complex grid search where we allowed the lag lengths of advertising ($SAGADV_t$) and nonagricultural research ($SAGNARES_t$) to vary simultaneously with different polynomial degrees. Based on the previous grid search and some further investigation we decided not to allow the lag length and polynomial degree on price to vary further because it would complicate this search and we were content that including current price in the model adequately represented this relationship. The grid search over different combinations of lags and polynomial degrees for advertising and research was done by searching over lag lengths (m) up to 13 months for advertising and up to 48 months for research and polynomial degrees (d) from 1st up to 6th order. This search resulted in a total of 17,204 models being estimated. Again, for each model the AIC, SBC, and adjusted R-square were calculated and then sorted and a ranking of preferred models were ranked. The top 25 models according to each criterion appears in Table 5-2. According to both models that ranked best according to the AIC and SBC criterion, the appropriate lag length for advertising is 6 months and for research it is 40 months. Despite both criteria agreeing on lag length, they do not agree on the degree of polynomial for advertising—the AIC finds in favor of a 6th order whereas the SBC finds in favor of 1st order. The sixth order polynomial in advertising is ranked 15th according to the AIC. An F-test reveals that these two competing models are not statistically significantly different form each other. Based on this result we took a closer look at models with a 6-month, 1st order lag for promotion and a 40-month, 4th order lag for research (denoted by "a1-06r4-40" in Table 5-2). Although this model seems reasonable from the standpoint of lag length for research relative to promotion, it is inferior to the simpler model when statistical and economic considerations are factored into the equation. First, the polynomial restrictions are statistically rejected with a p-value of 0.01. Second, the results produce a positive, although statistically insignificant, effect of cotton price on mill consumption.

Given the economic and statistical considerations as a whole, our preference is for the simpler model. The long-run impacts of promotion and research are not too different in the model with long lags than in the model with shorter lags while the own-price effect in the simple model implies a downward-sloping demand curve and the own-price effect in the more complex model does not. In particular, the model with 13 lags on promotion and 40 lags on research indicates long-run promotion and research elasticities of

Table 5-2. Grid Search Using Almon Distributed Lag Models for Advertising and Research

Rank	Model	AIC	Model	SBC	Model	Adj. R^2
1	a6-06r4-40	–4.9991	a1-06r4-40	–4.4107	a6-08r4-05	0.8288
2	a6-06r5-40	–4.9954	a1-10r3-36	–4.3933	a5-06r5-07	0.8286
3	a5-06r4-40	–4.9920	a1-12r3-36	–4.3899	a5-06r4-08	0.8285
4	a4-05r4-40	–4.9909	a1-06r3-43	–4.3895	a6-08r3-04	0.8285
5	a4-05r5-40	–4.9908	a1-06r3-40	–4.3868	a4-05r3-04	0.8284
6	a6-06r4-47	–4.9884	a1-06r5-40	–4.3856	a4-05r4-05	0.8283
7	a5-05r5-40	–4.9871	a1-05r4-40	–4.3853	a6-08r3-03	0.8283
8	a5-06r4-47	–4.9854	a1-06r3-44	–4.3789	a5-06r3-04	0.8282
9	a4-05r4-44	–4.9852	a1-11r3-36	–4.3783	a6-08r5-07	0.8281
10	a5-06r5-40	–4.9852	a2-06r4-40	–4.3776	a5-06r6-08	0.8280
11	a5-05r4-40	–4.9845	a1-12r3-39	–4.3772	a5-06r4-05	0.8279
12	a4-05r4-47	–4.9836	a1-10r4-36	–4.3772	a6-08r4-04	0.8279
13	a6-06r6-40	–4.9815	a1-01r4-40	–4.3770	a5-06r3-03	0.8279
14	a6-06r4-44	–4.9809	a1-12r4-36	–4.3761	a5-06r4-07	0.8277
15	a1-06r4-40	–4.9781	a1-01r3-36	–4.3752	a5-06r5-08	0.8277
16	a4-05r6-40	–4.9771	a1-08r4-40	–4.3735	a6-06r4-08	0.8277
17	a5-05r4-44	–4.9756	a1-06r4-43	–4.3717	a6-08r5-06	0.8276
18	a5-06r4-44	–4.9748	a1-10r3-39	–4.3714	a4-05r3-03	0.8276
19	a6-08r4-47	–4.9742	a1-12r4-40	–4.3709	a6-06r5-07	0.8275
20	a1-06r5-40	–4.9739	a1-05r3-43	–4.3706	a6-08r5-05	0.8275
21	a6-06r5-47	–4.9737	a2-10r4-40	–4.3704	a5-06r6-07	0.8275
22	a5-05r6-40	–4.9733	a1-10r4-40	–4.3692	a4-05r4-04	0.8275
23	a5-05r4-47	–4.9730	a1-06r3-45	–4.3679	a5-06r5-09	0.8275
24	a4-05r5-44	–4.9715	a1-12r3-40	–4.3665	a6-08r6-08	0.8273
25	a5-06r6-40	–4.9714	a1-10r3-43	–4.3664	a5-06r4-04	0.8273

Notes: Each model is denoted by a nine letter-digit name where a denotes $SAGADV_t$ and r denotes $SAGNARES_t$. The first digit number following each of these letters denotes the choice polynomial degree (d) and the second two-digit number after the - denotes the lag length (m) for the corresponding explanatory variable. For example, a1-06r4-40 denotes a model that includes a first-order degree polynomial that includes six lags of advertising ($SAGADV_{t-k}$ where k=0,1, ...6) and a fourth-order polynomial that includes 40 lags of research ($SAGNARES_{t-k}$ where k=0,1,...40).

0.07 and 0.53, respectively. The model with zero lags on promotion and three lags on research suggests long-run promotion and research elasticities of 0.02 and 0.33.

The statistical results for no lags on promotion and three lags on research are shown in Table 5-3. The model was estimated by ordinary least-squares (OLS), OLS with correction for first-order autocorrelation in the error term, and two-stage least squares (2SLS) with correction for autocorrelation in the error term. With the exception of the effect of a change in the price of cotton, the results are very similar across the three models. It is especially encouraging that the three models show remarkable stability with respect to the relationship between mill consumption and promotion and research. In particular, the elasticity of advertising is estimated to be approximately 0.02 across all three models, and the long-run elasticity estimates of mill consumption with respect to research (the sum of current and lagged effects) range from 0.31 (model 2) to 0.35 (model 3).

Of the three models, the third model (2SLS) is the preferred model because of the endogeneity of price. Because first-order autocorrelation in the residuals was found in the model estimated by OLS, 2SLS were applied with correction for first-order correction for autocorrelation in the residuals. We used the two-step procedure developed by Hatanaka (1976). The procedure, which is more simply explained by Harvey (1991), consists of the following steps.

- Obtain a consistent estimate of rho by regressing the endogenous variables (which appear on the right-hand side of the equation) on all the predetermined and lagged predetermined models of the system.
- Use the quasi-differencing operator, (1-rho*L) (L lagged operator), to transform the model into a form where the error term is uncorrelated.
- Regress each one of the quasi-differenced endogenous variables (i.e., $w_{it} = z_{it}\text{-rho}^* z_{it-1}$) on all the predetermined and lagged predetermined variables of the model and use the predicted values of w_{it} as instruments for the quasi-differenced endogenous variables.
- Use these predicted values and quasi-differenced predetermined variables appearing on the right-hand side of the equation as instruments in instrumental variable estimation of the parameters (i.e., apply the GIVE estimator).

Table 5-3. Regression Results for the Monthly Per Capita Mill Demand for U.S. Cotton, 1986-2000

Independent Variable	OLS			First-Order Autocorrelation			2SLS & First-Order Autocorrelation		
	Parms.	t-values	Elast.	Parms.	t-values	Elast.	Parms.	t-values	Elast.
CONSTANT$_t$	1.97714	2.27		2.26220	2.17		1.75181	2.07	
M1$_t$	0.24005	7.19		0.23910	8.23		0.23720	7.57	
M2$_t$	0.15837	4.74		0.15725	4.83		0.15811	4.64	
M3$_t$	0.32105	9.60		0.32054	9.59		0.32788	9.43	
M4$_t$	0.22697	6.86		0.22504	6.72		0.22650	6.49	
M5$_t$	0.30343	9.06		0.29989	8.81		0.32037	8.99	
M6$_t$	0.25450	7.54		0.25163	7.32		0.27420	7.59	
M7$_t$	0.10311	3.10		0.09812	2.91		0.11965	3.38	
M8$_t$	0.36200	11.05		0.35981	10.89		0.36604	10.74	
M9$_t$	0.28302	8.54		0.28263	8.47		0.28398	8.23	
M10$_t$	0.34242	10.41		0.34239	10.69		0.33890	10.10	
M11$_t$	0.19263	5.88		0.19252	6.78		0.18853	6.15	
PCOTTON$_t$	–0.00434	–2.52	–0.165	–0.00265	–1.35	–0.101	–0.01089	–3.21	–0.413
PPOLY$_t$	–0.00434	–2.43	–0.156	–0.00371	–1.64	–0.133	–0.00361	–1.65	–0.129
PRAYON$_t$	0.00284	1.99	0.149	0.00205	1.15	0.107	0.00261	1.50	0.137
DTEXWAGE$_t$	–0.19959	–1.67	–0.687	–0.24807	–1.70	–0.859	–0.13169	–0.87	–0.453
WPCOTTON$_t$	0.00710	4.17	0.240	0.00548	2.71	0.186	0.01264	4.08	0.427
DECI$_t$	–0.00683	–2.43	–0.243	–0.00713	–2.16	–0.255	–0.00723	–2.14	–0.256
DPI$_t$	–15866.9	–0.23	–0.144	–27662.2	–0.37	–0.253	–67879.7	–0.87	–0.616
FGDP$_t$	3.20E-05	0.47	0.164	5.80E-05	0.76	0.295	0.000061	0.79	0.309
SAGADV$_t$	2.04E-08	1.93	0.022	1.57E-08	1.58	0.017	2.12E-08	2.00	0.023
SAGNARES$_t$	4.90E-07	4.55	0.145	4.68E-07	4.61	0.139	5.12E-07	4.72	0.152
SAGNARES$_{t-1}$	4.29E-08	0.42	0.013	2.91E-08	0.28	0.009	7.30E-08	0.68	0.022
SAGNARES$_{t-2}$	2.64E-07	2.67	0.078	2.52E-07	2.62	0.075	2.79E-07	2.75	0.083
SAGNARES$_{t-3}$	3.21E-07	3.10	0.095	2.97E-07	3.06	0.088	3.16E-07	3.06	0.094
rho				0.26845	3.32		0.19303	2.62	
N	177			177			176		
R^2	0.8453			0.8550			0.7990		
R^2-bar	0.8208			0.8310			0.7671		
DW	1.5199			2.1243			2.0318		
SSE	1.2064			1.3020			1.2413		
AIC	–4.7060			–4.7600			–4.67023		
SBC	–4.2574			–4.2935			–4.21988		

The estimates from applying the two-step 2SLS procedure are shown in the third model in Table 5-3. Overall, the results seem quite reasonable and suggest a strong and significant impact of promotion and research on mill consumption of cotton. There is significant seasonality in mill consumption as indicated by the statistically significant monthly dummy variables. The own-price elasticity of demand for cotton is –0.4, which is close to estimates of about –0.3 by Lowenstein (1952), Wohlgenant (1986), and Waugh (1964). It is somewhat smaller than the estimate of –0.6 by Shui, Beghin, and Wohlgenant (1993). However, the estimate of own-price elasticity of demand is larger than Capps et al. (1997), where researchers estimated an elasticity of demand of –0.16. One significant difference between this study and the Capps et al. (1997) study is the assumption in their study that price affects consumption only after a 13-month lag. When we included the 13-month lagged price variable in our model (in addition to current price), we found no statistically significant impact of lagged price. We take these results to strongly suggest that mill consumption and the raw fiber price are contemporaneously determined.

Consistent with the Capps et al. (1997) study, we find that the empirical results suggest that polyester is a complement with cotton and that rayon is a substitute. However, much more in accordance with theory, we find the cross-elasticities of –0.13 and 0.14 are much smaller than the own-price effect.

in the U.S.! market!

As expected, textile wages and energy costs exert a negative influence on mill consumption. While the impact of foreign GDP on consumption is positive as expected, the impact of U.S. disposable income on consumption is negative. However, U.S. disposable income is statistically insignificant, suggesting it is highly correlated with the wage variable.

The world price of cotton variable (WPCOTTON), represented by the A index, also has a large and significant effect on cotton mill use. This variable is a strong indicator of the cost of imported cotton products. Higher world cotton prices raise the cost of producing cotton in foreign countries, which translates into higher prices of cotton products imported and higher U.S. mill consumption of cotton. It is important also to recognize that, because the U.S. is not a small country in international trade of cotton, feedback effects may exist from changes in the U.S. cotton

Evidence? ... Some of this is found in Hudson & Ethridge, Agr. Econ., June 99, & JAAE, Apr. 2000.

price on the world cotton price. Therefore, in the simulations of the impact of promotion and research on returns to cotton producers this feedback effect needs to be considered.

Several diagnostic tests were performed on the model. The model was re-estimated using just the last 5 years of data (1996 through 2000) because the cotton checkoff program is being evaluated over this time period. A change in the structure from the previous years to the most recent years might indicate concern about the validity of the statistical model over the entire sample (1986 through 2000) used to evaluate the impact of the checkoff program over the past 5 years. The results for the most recent 5 years show changes in some of the coefficients, but by the Chow test we fail to reject the null hypothesis that the structure in the last 5 years is any different than over the previous 10 years. We also examined the recursive residuals to see if there was any strong indication that the structure was changing over time. Again, although we observe changes in the coefficients over time, there seems little evidence that the structure has changed in significant ways over time.

The model was also re-estimated to include the square roots of promotion and research as explanatory variables to test to see if the linear model adequately models the relationship between mill consumption and promotion and research. Again, the results indicate failure to reject the simple linear model with zero linear lags on promotion and three linear lags on research.

5.3 EXPORT DEMAND FOR U.S. COTTON

The export demand for U.S. cotton is specified as a partially reduced-form equation in which exports of U.S. cotton are modeled as a function of the price of domestic cotton, prices of substitute fibers, and demand and supply shifters of foreign-produced textile products. These demand and supply shifters will influence the amount of U.S. cotton that foreign mills will choose to purchase. In addition, a variety of export specifications including advertising and nonagricultural research were estimated. However, neither advertising nor research seems to have a significant effect on export demand in our preferred model. This result may be because data specifically related to foreign promotion and transfer of research results were not available at a monthly level. Thus, total monthly advertising and nonagricultural research were included in these specifications even though the majority of this expenditure is focused on the domestic market. If Program expenditures on domestic and foreign activities changed at the same rate over time, this would not be a problem, but that is not necessarily the case. It is possible that more disaggregated data would reveal Program impacts on exports, but for the current model, no Program expenditures are included in the export demand equation.

This demand equation was estimated using monthly data over the period from January 1986 through December 2000, which provides a total of 180 observations. The model was estimated in linear form[6] using the following variables:

$M_{i,t}$	=	monthly dummy variables (Mi=1 for ith month, 0 otherwise) for i=1,...,11 where December is the reference month
$EXPORTS_t$	=	U.S. exports of raw cotton (thousands of bales)
$PCOTTON_t$	=	U.S. real raw fiber equivalent price of cotton (cents/lb)
$PPOLY_t$	=	U.S. real raw fiber equivalent price of polyester (cents/lb)
$FTEXWAGE_t$	=	real foreign manufacturing wage ($/hour)
$WPCOTTON_t$	=	real A Index of the world cotton price (cents/lb)
$DECI_t$	=	U.S. real energy cost index, used as a proxy for foreign energy costs
$FGDP_t$	=	foreign real GDP for OECD countries other than U.S. (billions of $)
$ROWSTK_t$	=	foreign cotton stocks (pounds)
$EXPORTS_{t-1}$	=	lagged U.S. exports of raw cotton (thousands of bales)
rho	=	first-order autocorrelation parameter value

All of the variables denominated in dollar terms (PCOTTON, PPOLY, FTEXWAGE, WPCOTTON, DECI, and FGDP) were deflated using the CPI for all items, 1982-84 = 100.

[6]Other specifications were also estimated, including double-log and semi-log models, but the linear model cannot be rejected based on the results from any of the models that we estimated. In other words, the linear model is at least as good as any alternative models that we tried. Therefore, we chose to use the linear model due to its relative simplicity.

The foreign supply and demand shifters included in the model include prices of competing fibers in the foreign fiber market (PPOLY, WPCOTTON), prices of other factors affecting foreign textile manufacturing demand for U.S. cotton (FTEXWAGE, DECI, ROWSTK), and foreign income (FGDP). The real exchange rate, promotion, and nonagricultural research were initially included as well, but inclusion of these variables did not lead to significant improvement in the model.

It appears that WPCOTTON is a much better indicator of export demand for cotton than a more general exchange rate. Also, we performed a grid search over lags and degrees of polynomial distributed lags on advertising and nonagricultural research similar to the one performed for the domestic demand model. As in the domestic demand model, the preferred models using AIC and SBC criteria generally suggested very short lags. Before inclusion of a lagged dependent variable or correction for autocorrelation, research is marginally significant, but advertising is not. Advertising was generally found to have a negative, but insignificant effect on export demand across the models ranking highest in the grid search. It is possible that this results from high levels of advertising increasing domestic demand (where the majority of advertising is taking place) such that less cotton is available for exports, although the price variables should be capturing this effect. When either lagged exports or a correction for autocorrelation in the error term is added, then the significance of research disappears. When advertising is dropped from the equation, the model preferred by a grid search over research lags and polynomial degrees is a first order polynomial with one lag. However, the parameters on research in this preferred specification are insignificant. As mentioned above, the lack of significance for advertising and research on export demand may result from using total promotion and nonagricultural research expenditures rather than expenditures specific to the export markets. Nonetheless, given the results derived from available data, both advertising and research were dropped from the preferred export demand model.

not significant

no such term!

(e.g.) Then research affects supply.

The results of the estimation of the preferred model are shown in Table 5-4. The model was estimated by OLS and 2SLS. The results are generally quite similar across the models. The results agree fairly well with other studies of the cotton market. There is

Table 5-4. Regression Results for Monthly Export Demand for U.S. Cotton, 1986-2000

Independent Variable	OLS			2SLS & First-Order Autocorrelation		
	Parms.	t-values	Elast.	Parms.	t-values	Elast.
CONSTANTt	361.930	0.84		338.440	0.77	
$M1_t$	−149.761	−2.70		−153.243	−2.70	
$M2_t$	−124.293	−2.30		−120.853	−2.20	
$M3_t$	−71.837	−1.32		−74.392	−1.36	
$M4_t$	−260.092	−4.71		−263.555	−4.74	
$M5_t$	−274.309	−5.10		−275.322	−5.07	
$M6_t$	−286.276	−5.31		−285.608	−5.25	
$M7_t$	−279.346	−5.19		−277.163	−5.12	
$M8_t$	−307.754	−5.74		−306.221	−5.68	
$M9_t$	−360.646	−6.65		−358.869	−6.58	
$M10_t$	−256.853	−4.63		−253.844	−4.55	
$M11_t$	−83.386	−1.53		−81.071	−1.46	
$EXPORTS_{t-1}$	0.583	8.93	0.583	0.601	9.27	0.601
$PCOTTON_t$	−6.008	−2.27	−0.618	−6.757	−1.98	−0.692
$PPOLY_t$	0.670	0.27	0.065	0.748	0.31	0.072
$WPCOTTON_t$	6.711	2.48	0.678	7.266	2.23	0.732
$DECI_t$	−1.270	−0.43	−0.122	−0.389	−0.13	−0.037
$FGDP_t$	0.021	0.68	0.285	0.016	0.52	0.211
$ROWSTK_t$	−5.640E-0	−0.86	−0.154	−3.790E-0	−0.57	−0.103
rho				0.07600	−0.53	
N	179			178		
R^2	0.7415			0.7540		
R^2-bar	0.7154			0.7290		
DW	1.9500			1.8939		
SSE	3331071.4			3332785.1		
AIC	10.0437			10.0510		
SBC	10.3820			10.3906		

significant seasonality to U.S. cotton exports as indicated by the highly significant monthly dummy variables. The seasonal pattern of exports is quite different than that of mill consumption and it is also much more variable. While domestic mill consumption is fairly smooth over time and typically hits its lowest point in December, exports jump around much more during the course of a year and usually are close to their peak in December. The export demand elasticity for cotton is about –0.7, which is just below the lower end of the range estimated for the export demand elasticity by Duffy, Wohlgenant, and Richardson (1990) and is more elastic than domestic demand, as we would expect. The price of polyester has a positive coefficient, as expected, but it is very insignificant. The effect of lagged exports is highly significant. It seems that the major factors contributing to export demand are the domestic cotton price, the world cotton price, seasonality, and partial adjustment of exports over time to these and other unobserved trade shocks, with none of the other variables having a very important role. The price elasticity for the world price of cotton is around 0.7, suggesting that foreign cotton and U.S. cotton are substitutes for one another, and that U.S. export demand is fairly sensitive to the world cotton price. As mentioned in the previous section, because the U.S. cannot be considered a small country in terms of cotton production, changes in the U.S. cotton price may influence the world cotton price. It may be important to consider this effect when simulating the impact of changes in U.S. cotton price on export demand.

The energy cost index, foreign GDP, and foreign cotton stock variables all have the expected signs but are insignificant. The foreign manufacturing wage (used as a proxy for the foreign textile wage) was included in alternative model specifications, but it was insignificant and seems to be highly correlated with foreign GDP, so it was dropped.

To check for stability of the parameter estimates over time, the model was reestimated for 1996 through 2000, which is the period of emphasis for this study. The Chow test fails to reject the null hypothesis of no structural change in export demand over the last 5 years.

Although the DW statistic is reported, it is not relevant for this model because of inclusion of a lagged dependent variable. The

Durbin-h statistic is often suggested in this case, but as Harvey (1991) points out, this statistic is not very reliable in small samples. Instead, what is recommended is the LM test, which is a test of rho = 0 by estimating an auxiliary regression in which the estimated residuals are regressed on the lagged residuals and all the explanatory variables appearing on the right-hand side of the regression equation. A simple t-test on the lagged residual variable is then performed to determine if autocorrelation in the residuals is present.

An LM test on the model residuals reveals the presence of autocorrelation, but adding an autocorrelation parameter did not significantly reduce this problem. When the model was estimated using 2SLS and a first order autocorrelation correction, the rho parameter is insignificant and autocorrelation is still present. We will revisit this issue prior to the final draft.

5.4 DOMESTIC SUPPLY OF RAW U.S. COTTON

The domestic supply of raw U.S. cotton was modeled at the annual level because the planting decision is made on an annual basis. Although there may be some response of production to changes in price after planting (e.g., higher abandonment at low price), it is likely to be relatively small. The supply of cotton is modeled as a function of expected cotton price, an index of farm input prices, the deviation of yield from its trend, lagged CI agricultural expenditures, and lagged production (because there may be lags in full adjustment of production to changes in market conditions). <*It would probably be preferable to estimate supply as a function of total agricultural research on cotton including USDA and State Agricultural Experiment Station (SAES) expenditures, among others collected by USDA, but the data series currently available is too short (1986-1999) to reliably estimate the function because there are very few degrees of freedom (the research series for CI spending does not include that many points either, but it is 6 years longer). Assuming USDA provides this information for an additional 13 years as they have committed to, we will revisit this supply function estimation. As it is, the results seem pretty reasonable, but there may be some overstatement of the impacts of CI-funded research.*>

The supply function was estimated using data from 1981 through 2000, a total of 20 observations. A linear model was estimated incorporating the following variables:

$PROD_t$	=	annual U.S. cotton production (millions of bales)
$FPCOTTON_t$	=	cotton futures price averaged over planting months (cents/lb)
$PINPUT_{t-1}$	=	index of prices paid by farmers for inputs (1991=100)
$DYIELD_t$	=	deviation of yield from long-run quadratic trend (lbs/acre)
$CIAG_{t-3}$	=	CI Agricultural Research Expenditures ($)
$PROD_{t-1}$	=	lagged annual U.S. cotton production (millions of bales)

All variables denominated in dollars were deflated by the CPI for all items, 1982-84=100.

More complex supply function specifications were considered, but the data are inadequate to add much complexity beyond the current model. The results of this relatively simple model do appear reasonable, however. Table 5-5 provides the results of the estimation for the model estimated with OLS both with and without correction for autocorrelation. Although rho is insignificant, an LM test on model residuals reveals that the autocorrelation present in the OLS model is removed following its addition. The price elasticity of supply is about 0.58, which is in the range of supply elasticities in the literature. Duffy and Wohlgenant (1991) use a short-run supply elasticity for cotton of 0.3, while Duffy, Shalishali, and Kinnucan (1994) report a value of 0.92 for the cotton supply elasticity.

As expected, the price index of farm inputs has a negative impact on cotton production. This index is included in the model with one lag to reflect expectations of prices at planting time based on the previous year's production costs. The elasticity of supply with respect to this price index is –2.1, suggesting a large responsiveness of cotton supply to increases in production costs. This value seems fairly large but was stable across numerous specifications of the supply function. Lagged production has a positive and significant effect on current period supply, reflecting the incomplete

Table 5-5. Regression Results for Annual Supply of U.S. Cotton, 1981-2000

Independent Variable	OLS			First-Order Autocorrelation		
	Parms.	t-values	Elast.	Parms.	t-values	Elast.
$CONSTANT_t$	33.43562	5.05		33.41958	4.84	
$PROD_{t-1}$	0.20357	1.48	0.202	0.18238	1.30	0.181
$FPCOTTON_t$	13.44521	4.01	0.621	12.63957	3.60	0.584
$PINDEX_{t-1}$	–37.49300	–4.98	–2.167	–36.54780	–4.54	–2.112
$DYIELD_t$	0.02032	4.35	0.000	0.02120	5.31	0.000
$CIAG_{t-3}$	0.00003	1.45	0.046	0.00003	1.22	0.049
rho				3.39E-01	1.07	
N	17			17		
R^2	0.8829			0.8941		
R^2-bar	0.8297			0.8306		
DW	1.4124			2.0248		
SSE	13.1375			11.8795		
AIC	0.4481			0.4651		
SBC	0.7422			0.8082		

adjustment that occurs in one year. In addition, the deviation of yield from a quadratic trend was included to capture the effects of random events such as weather and insect infestations that cause yield to jump around considerably from year to year. The coefficient on this term is very significant statistically, but the elasticity of production at the means is small because the mean of the deviations is almost zero.

The effects of CI research were captured using a 3-year lag on research expenditures. This was the lag length that consistently provided the best results in terms of fit and theoretically correct signs across several different model specifications. Presumably, the effect of this research is to allow cotton production using fewer inputs per unit of output. In this way, the costs of production per unit could fall even if input costs rise because fewer units of input are necessary. Agricultural research on cotton may also lead to improvements in yield such that more output is realized from the same quantity of inputs. Either of these types of changes is expected to increase the supply of cotton, other things being equal. The elasticity of CI agricultural research is fairly small, about 0.05, implying that a 10 percent increase in CI agricultural research expenditures will lead to a 0.5 percent increase in supply.

5.5 IMPORT SUPPLY OF COTTON PRODUCTS

Importers of cotton products are also subject to the checkoff fee so it is important to know whether they benefit from the checkoff program. Conceptually, demand for textiles (containing cotton) can be viewed as demand for domestically produced and imported textiles. Because the U.S. exports as well as imports textiles, it is important to develop a model that does not double-count quantities sold. Most of the cotton coming into the U.S. from other countries is apparel or intermediate products made into apparel. The bulk of cotton products exported to other countries returns to the U.S. in apparel product form. Therefore, it is reasonable to view net imports of textiles containing cotton as the relevant quantity variable to evaluate.

Producers' surplus to importers can be measured by the area above the supply curve and between the prices with and without the checkoff program. Provided the right variables are included in the supply equation, this area will measure quasi-rents to cotton importers. Unfortunately, we don't have data on prices of intermediate products shipped into the U.S., which is what we ideally would want to measure the price of inputs to importers. However, we can use the world price of cotton (the "A" index) and other input prices (e.g., foreign textile wages, energy costs) as proxies for the cost of imported cotton. If the technology producing these intermediate products from cotton fiber approximates constant returns to scale, then using these input prices as proxies for the price of intermediate textile products will allow us still to make valid inferences about the profitability of market middlemen downstream from producers of intermediate goods. There still is a question, however, of whose quasi-rents we are measuring. That is, the cause of an upward-sloping supply curve could be fixity in capital so that the owners of the capital stock—which would not necessarily be cotton importers—could be the ones receiving the rents. This suggests that our estimates at best only indicate whether

I contend that this connection is very weak cotton importers benefit from the checkoff program and that we focus on the more limited question of *whether* cotton importers benefit than by how much. Therefore, in the remainder of this section, we focus on the nature of the supply function of imported cotton by attempting to estimate the supply elasticity of importers. On the one hand, if we find the supply is upward-sloping, then we can conclude that importers likely benefit from the Program, because if that is the case then there will be positive rents associated with the Program. On the other hand, if supply is flat, then importers will not gain from the Program.

Cotton importers' supply behavior was estimated with quarterly time series data over the time period 1990 through 2000, a total of 44 observations. The model was estimated with all continuous variables transformed into natural logarithms so that the estimated coefficients are elasticities. The following variables (in logarithms) were used in the model:

$PIMPORTS_t$	=	real Fisher index of 100 percent cotton apparel products (1982-84, deflated by CPI for all items),
$QIMPORTS_t$	=	net imports of products containing cotton (pounds of raw-cotton equivalent),
$DECI_t$	=	U.S. real energy cost index (1982-84=100),
$FTEXWAGE_t$	=	real foreign textile wages ($/hours),
$WPCOTTON_t$	=	real A index of world cotton price (cents/lb).

The model was estimated in price dependent, rather than quantity dependent, form because of the belief that the supply elasticity is probably large and therefore price is nearly exogenous with respect to changes in own quantity. Also, some experimentation occurred with selecting explanatory variables. Quarterly dummies were not found to be singly or jointly significant and were therefore not included in the final estimated models. Different lag structures on quantity and price were evaluated as well, and it appears that both lagged price of imports and lagged quantity of net imports should be included as explanatory variables. Finally, the restriction that the sum of the price elasticities of input prices equal unity was imposed on the model. This restriction comes from the property that the cost function is homogenous of degree one in input prices. Therefore, we would expect the marginal cost function, which is the inverse supply function, also to be homogeneous of degree one in input prices. The restriction was tested and was not rejected statistically.

The results are shown in Table 5-6 for two models, one estimated by OLS and the other estimated by 2SLS. The results are very similar and indicate significant impacts of current and lagged net imports on the price of imports. While the current quantity variable is negative, the sum of the current and lagged quantity are positive and are consistent in indicating that the supply curve of importers is upward sloping in the long run. Indeed, an estimate of the long-run elasticity can be derived by summing the two quantity variables and dividing by 1 minus the coefficient on $PIMPORTS_{t-1}$. For the OLS results, the estimated long-run elasticity of price with respect to quantity is 0.24. For the 2SLS results, the estimated long-run elasticity of price with respect to quantity is 0.14. Long-run supply elasticities are obtained by taking the inverses of these elasticities of prices with respect to quantities. For the OLS model, the long-run elasticity of importers is estimated to be 4.2; for the 2SLS model, the long-run elasticity of importers is estimated to be 7.1. While the exact magnitude of the elasticity is hard to determine, the statistical results clearly indicate that the supply curve of importers is upward sloping, suggesting that importers have benefited from the checkoff program.

Application of the LM test to the OLS model yielded a t-statistic of –0.66, which is well below the cut-off point for either a 5 percent or 10 percent significance level. Therefore, there does not appear to be any evidence of autocorrelation in the residuals.

5.6 CONCLUSIONS

The models of domestic mill demand, export demand, domestic supply, and import supply all provide fairly good fits to the data and generate theoretically reasonable parameter estimates. In general, the parameter estimates have the expected signs or have "wrong" signs but are insignificant. Based on our models, it appears that both promotion and nonagricultural research increase domestic mill demand for cotton, while agricultural research leads to an increase in the domestic supply of cotton. However, there was no evidence for effects of promotion or research on the export demand equation.

Table 5-6. Econometric Results for Aggregate Quarterly Supply of Cotton Textile Importers, 1990-2000

Independent Variable	OLS		2SLS	
	Parms.	t-values	Parms.	t-values
$Constant_t$	–6.6249	–4.816	–4.3479	–3.224
$PIMPORTS_{t-1}$	0.4550	3.138	0.4503	3.512
$QIMPORTS_t$	–0.1591	–2.073	–0.1853	–2.143
$QIMPORTS_{t-1}$	0.2908	3.721	0.2634	3.186
$WPCOTTON_t$	-0.3955×10^{-1}	–0.4362	-0.8119×10^{-2}	-0.939×10^{-1}
$DECI_t$	0.8986	4.906	0.7756	3.988
$FTEXWAGE_t$	0.1406	0.644	0.2325	—
R^2	0.5977		0.6345	
R^2-bar	0.5402		0.5851	
DW	1.9450		1.9799	
SSE	0.23182		0.25676	

These parameter estimates are used in the following section to generate estimates of the net benefits and benefit-cost ratios associated with Program expenditures. The parameters that allow us to make these calculations are the advertising and research parameters and corresponding elasticities as well as the supply and demand price elasticities. While we have found strong evidence for positive supply and demand shifts resulting from Program expenditures, it still remains to examine the benefits to producers relative to Program costs to ensure that producers are benefiting overall as a result of the cotton Program.

6 Returns to the Cotton Program

In this section, we use the estimated parameters from the previous section to estimate both the total and marginal benefits of Program expenditures. Estimation of the total net benefits (and average benefit-cost ratio) involves setting Program expenditures to zero and simulating market conditions. To generate estimates of the marginal benefits, we simulated the cotton market assuming a 1 percent increase in expenditures relative to actual historical levels for promotion, nonagricultural research, and agricultural research individually.

The econometric results presented in the previous section allow us to estimate the change in the quantity of cotton sold that has resulted from Program expenditures, holding prices (and all other variables) constant. The estimated coefficients on promotion and nonagricultural research reveal the increase in farm-level demand expected for each dollar in Program expenditure on those activities. Multiplying these coefficients by the actual Program expenditures in each month reveals the extent to which the supply and demand curves were shifted in that month as a result of promotion or research. In addition, the coefficient for agricultural research is a measure of the shift in the supply curve that results from a dollar of expenditure on agricultural research activities. To simulate the market without Program expenditures, we simply need to set those expenditures to zero and observe what the supply and demand curves would look like. The simulated equilibrium without the Program provides the information necessary to calculate the net returns to producers.

6.1 RATE OF RETURN CALCULATIONS

The returns to the groups served by the Cotton Program, domestic producers and importers, are estimated using two separate sets of models. Using our econometrically estimated equations from Section 5, we can simulate the prices and quantities that would have prevailed without the Program and calculate the change in producer surplus resulting from the Program. While the econometric results indicated that generic advertising and research have each had positive effects on the quantity demanded and agricultural research has had a positive effect on the quantity supplied, the important result to cotton producers is the impact on producer surplus.

To measure the effect of the Program on domestic producers, we simulated the model for several different scenarios. First, the past was replicated with actual, inflation-adjusted research and advertising expenditures. Then, the model was simulated with zero Program expenditures, and for combinations of marginal changes in individual categories of expenditures (promotion only, nonagricultural research only, agricultural research only, demand-side effects only).

The change in price received by producers expected to result from a marginal change in Program expenditures is estimated using:

$$EP = \frac{s_1\beta_1 EA + s_1\beta_2 ENAR + (1-s_1)\beta_3 EA + (1-s_1)\beta_4 ENAR - \beta_5 EAR}{e - s_1\eta - (1-s_1)\eta_x} \qquad (6.1)$$

where E in front of a variable denotes a proportional change in that variable; s_1 is the share of domestic cotton production sold domestically; e is the estimated supply elasticity; η is the estimated domestic demand elasticity; η_x is the estimated export demand elasticity; P^S is the price received by domestic producers;[1] A is advertising expenditures; NR is nonagricultural research expenditures; AR is agricultural expenditures; and β_{AE}, β_{NRD}, β_{NRE}, and β_{AR} are the domestic advertising elasticity, export advertising elasticity, domestic nonagricultural research elasticity, export nonagricultural research elasticity, and agricultural research

[1] Note that this price is generally not the same as the price paid by demanders because of gaps created by the assessment by U.S. government subsidies to buyers of U.S. cotton and government support payments to producers.

elasticity, respectively. For details on the derivation of this equation, see Appendix D.

Given the change in price estimated using Eq. (6.1), the change in producer surplus can be calculated by the following equation:

$$\Delta PS = P_0^S Q_0(EP - K)(1 + 0.5\ EQ) - \frac{1}{1 - \frac{e}{s_1\eta + (1-s_1)\eta_x}} \bullet T \qquad (6.2)$$

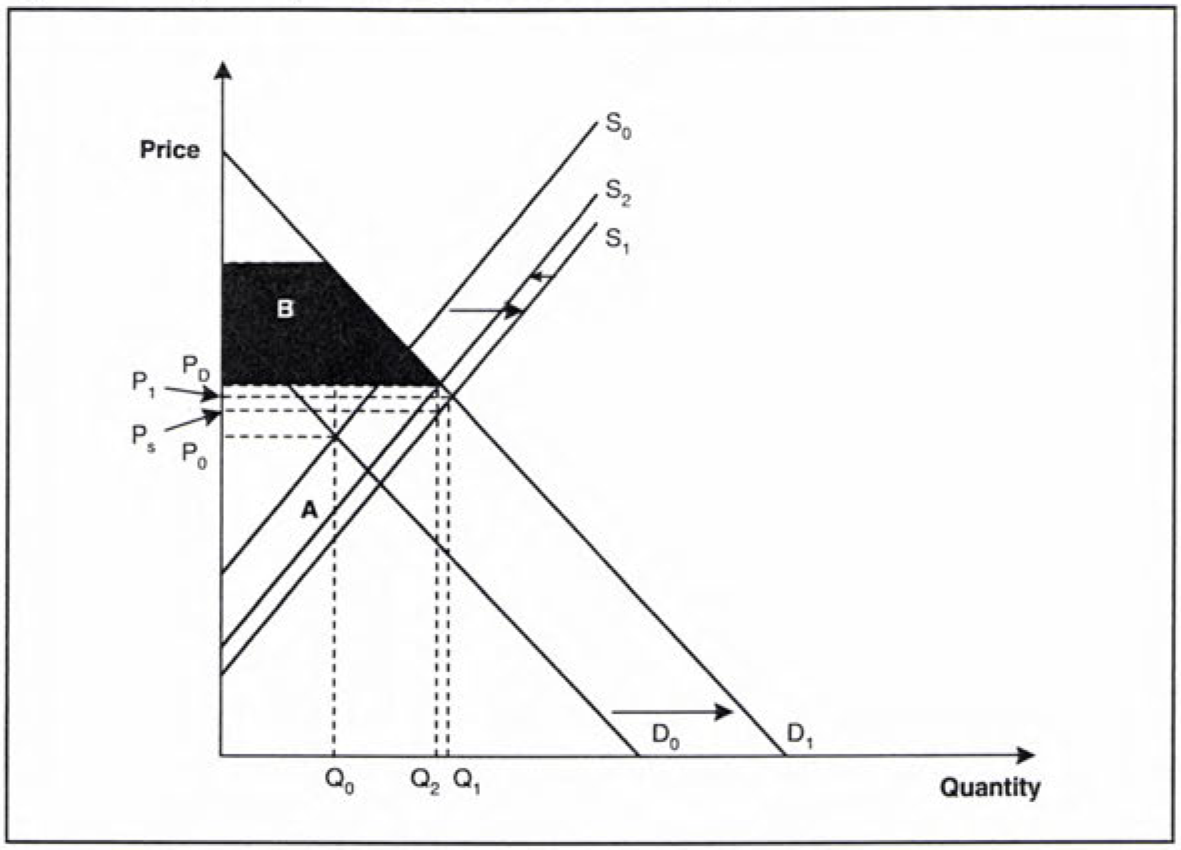
where a subscript of 0 denotes baseline conditions, E denotes a proportionate change in a variable, K is the proportionate downward shift of the supply curve, and T is the assessment collected from domestic producers. This formula will generate estimates of the change in returns that producers would have experienced at different levels of expenditure by the Cotton Program.

6.1.1 Cotton Producers

Figure 6-1 shows the hypothesized impact of the Program on the domestic cotton industry modeled at the farm level. Both supply and demand are shifted by Program activities. In addition, there is a supply shift resulting from the assessment collected from producers. It is expected that the net effects of Program activities have been to shift the demand curve outward from D_0 to D_1 and the supply curve outward from S_0 to S_1. The collection of the assessment, which is assumed for simplicity to operate like a per-unit excise tax, causes a shift in supply from S_1 to S_2. It is important to recognize that both producers and consumers pay a portion of the tax in this case. The portion that each pays is known as their tax incidence. The reason that producers' incidence is less than the full amount of the tax is that they are able to pass on part of the cost to consumers through higher prices for cotton. This graph shows that the assessment causes a gap between the price paid by buyers, P_D, and the price received by sellers, P_S. Note that relative to P_1 (the price after demand and supply shifts, but before inclusion of the assessment), buyers pay a higher price and sellers receive a lower price when the assessment is added.

Assuming that the horizontal shift in demand is larger than the horizontal shift in supply, both price and quantity would be

Figure 6-1. Program Impacts on Domestic Cotton Industry



expected to increase as a result of the Program. Assuming the same absolute increase in demand and supply at all quantities, Figure 6-1 can also be used to indicate changes in welfare resulting from the Cotton Program. Area A represents gains in producer surplus, while Area B represents gains in consumer surplus. The distribution of total net gains among producers and consumers depends on the relative price elasticities of supply and demand.

Table 6-1 summarizes the impacts on domestic producers that have resulted from Program activities over the period from 1986 through 2000 as well as from 1986 through 1995 and 1996 through 2000.

These estimates were obtained using Eqs. (6.1) and (6.2) and our point estimates of demand and supply parameters. The upper half of the table refers to estimates using 0 percent to compound the benefits over time, while the lower half uses a 3 percent compounding rate to reflect preferences for benefits sooner rather

Table 6-1. Benefits and Costs of the Cotton Research and Promotion Program (millions of constant [2000] dollars)

	1986-1995	1996-2000	1986-2000
0 Percent Compounding			
Average benefits, costs:			
Present Value, Net Producer Benefits	21,005.2	13,608.7	34,614.0
Present Value, Producer Cost Incidence	280.3	124.2	404.5
Producer Benefits/Producer Costs	**74.9**	**109.6**	**85.6**
3 Percent Compounding			
Average benefits, costs:			
Present Value, Net Producer Benefits	17,493.4	9,304.2	26,797.6
Present Value, Producer Cost Incidence	238.8	84.9	323.7
Producer Benefits/Producer Costs	**73.3**	**109.6**	**82.8**

than later. Basically, this is because those benefits could have been invested, and it is assumed that they would have earned a 3 percent real rate of return. Because there is little difference between the results, we will focus on the case with 0 percent compounding.

The results of the simulation indicate that the total net benefits to domestic producers resulting from the Cotton Program have been $34.6 billion over the 1986 through 2000 period. Over this same period, the share of assessments on domestic producers paid by domestic producers was $404.5 million. Thus, producer surplus was increased by an average of $85.60 for each dollar of assessments paid. Over the last 5 years, total net benefits have been $13.6 billion. The ratio of net benefits to producer costs over this time period is 109.6 to 1. The benefit-cost ratios indicate that the benefits were more than sufficient to cover Program expenditures for each period analyzed. The estimated return to producers from this program is extremely large and has gotten larger in more recent years (mainly because advertising and research elasticities have become larger in recent years).

Table 6-2 provides estimates of the marginal return to each of the three major components of the Cotton Program: promotion, nonagricultural research, and agricultural research.[2] These results reveal that increasing expenditures on any of the three program activities would have benefits greater than the costs, but these results suggest that nonagricultural research has, by far, the highest return. This is followed by agricultural research and finally by promotion.

6.1.2 Cotton Importers

As mentioned in Section 5.5, the emphasis for the cotton importers is primarily whether they are receiving positive benefits or not, rather than the level of benefits. This is because of the difficulty in separating out the producer surplus gains that are flowing to the cotton importers as opposed to other groups in the marketing chain. If we assume that the price received by importers increased by the same percentage as the farm-level price due to the Program, then we can get a rough estimate of the gains on the import side of the market. *<We're planning on returning to this issue later>*

6.1.3 Aggregate Welfare Measures

In addition to the impacts on producers, there is some interest from society's perspective in the impacts of Program activity on consumers. *<We're planning on returning to this issue later>*

6.1.4 Sensitivity Analysis

The estimates of rates of return included in Sections 6.1.1 through 6.1.3 are based on point estimates of the parameters. Because these estimates are unlikely to be exactly correct, the measures of net benefits should also be thought of as estimates rather than exact measurements. Generally, studies that measure the demand response to advertising calculate and report point estimates of benefits to producers and do not report the precision with which this point estimate is measured. For example, a researcher may report that the ROI for a particular advertising effort is 10 to 1. It

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[2]These results were calculated by estimating the change in producer surplus for a 1 percent change in the relevant program activity. The cost of each was estimated as the producer incidence of a 1 percent increase with real expenditures on the relevant activity, without including associated administrative costs.

Table 6-2. Marginal Benefits and Costs Associated with a 1 Percent Increase in Expenditures on Individual Components of the Cotton Research and Promotion Program (millions of constant [2000] dollars)

	1986-1995	1996-2000	1986-2000
0 Percent Compounding			
Marginal benefits, costs:			
Present Value, Net Producer Benefits, Promotion	9.1	6.8	15.9
Present Value, Net Producer Benefits, NonAg Research	187.2	103.1	290.4
Present Value, Net Producer Benefits, Both Demand Shifts	196.4	109.9	306.3
Present Value, Net Producer Benefits, Ag Research	27.1	36.6	63.7
Present Value, Producer Cost Incidence, Promotion	1.5	1.2	2.7
Present Value, Producer Cost Incidence, NonAg Research	0.5	0.3	0.7
Present Value, Producer Cost Incidence, Both Demand Shifts	1.9	1.5	3.4
Present Value, Producer Cost Incidence, Ag Research	0.2	0.2	0.3
Producer Benefits/Producer Costs, Promotion	**6.2**	**5.7**	**6.0**
Producer Benefits/Producer Costs, NonAg Research	**402.8**	**373.5**	**391.9**
Producer Benefits/Producer Costs, Both Demand Shifts	**101.4**	**75.0**	**90.0**
Producer Benefits/Producer Costs, Ag Research	**171.7**	**191.0**	**182.3**
3 Percent Compounding			
Marginal benefits, costs:			
Present Value, Net Producer Benefits, Promotion	7.6	4.6	12.2
Present Value, Net Producer Benefits, NonAg Research	155.4	70.6	226.1
Present Value, Net Producer Benefits, Both Demand Shifts	163.0	75.3	238.3
Present Value, Net Producer Benefits, Ag Research	23.0	24.9	47.9
Present Value, Producer Cost Incidence, Promotion	1.2	0.8	2.0
Present Value, Producer Cost Incidence, NonAg Research	0.4	0.2	0.6
Present Value, Producer Cost Incidence, Both Demand Shifts	1.6	1.0	2.6
Present Value, Producer Cost Incidence, Ag Research	0.1	0.1	0.2
Producer Benefits/Producer Costs, Promotion	**6.2**	**5.7**	**6.0**
Producer Benefits/Producer Costs, NonAg Research	**400.2**	**374.4**	**391.8**
Producer Benefits/Producer Costs, Both Demand Shifts	**100.8**	**75.2**	**91.0**
Producer Benefits/Producer Costs, Ag Research	**179.4**	**190.0**	**184.8**

would also be informative to report how precisely this ROI was measured. That is, a researcher could also calculate and report a confidence interval around this ROI, allowing lower and upper bounds to accompany this estimate, thus providing important additional information. For example, it would be helpful to know whether these lower and upper bounds include zero, indicating whether this estimate of the ROI is statistically significantly different from zero. Moreover, testing whether a particular welfare estimate is statistically significant may not be as informative as taking an additional step of calculating the probability that a particular welfare measure change is greater than zero. For example, reporting "the best estimate of the ROI is 10 to 1, but we cannot be confident that this estimate is statistically significantly different from zero," is not as informative as "the precision with which the ROI can be measured indicates that we can be 75 percent certain that the ROI ratio is greater than 1, and the best estimate of this ROI is 10 to 1."

In an effort to measure the demand response to advertising, researchers estimate the "true" underlying demand function by choosing a demand model and incorporating advertising into the model, which hopefully does a decent job of measuring the impact advertising has had on the "true" underlying demand function. Let the vector of estimated coefficients for the demand model be denoted by $\hat{\beta}$. Accompanying these estimated coefficients are measures of their precision. Let the variance-covariance matrix that characterizes the underlying probability distribution of these point estimates be denoted by $\hat{\Sigma}$. Hypothesis tests concerning the statistical significance of the advertising on demand can be performed using the information contained in $\hat{\beta}$ and $\hat{\Sigma}$. That is, we can test whether advertising has had a statistically significant effect on demand. If there has indeed been a statistically significant effect on demand, then it is informative to calculate the magnitude of this impact. Magnitude of impact can be determined by calculating advertising elasticities of demand ($\hat{\omega}$), which are functions (sometimes nonlinear depending on the choice of functional form) of the estimated coefficients $\hat{\beta}$ and the observed data X (i.e., $\omega = \omega(\hat{\beta}, X)$). The question that remains is how we can calculate measures of precision for the $\hat{\omega}$ using the information contained in $\hat{\Sigma}$. Similarly, the precision of simulated producer welfare measures from advertising (ΔZ) obtained using the estimated advertising elasticities ($\hat{\omega}$) will also depend on information contained in $\hat{\Sigma}$.

Because these relationships can be nonlinear, deriving a measure of precision for estimated values of $\hat{\omega}$ and ΔZ from information contained in $\hat{\Sigma}$ is not necessarily straightforward. One approach to addressing this problem is to linearize the functions. This approach was proposed by Klein (1953), and adopted by Griffin and Gregory (1976), for example. Krinsky and Robb (1991) raised questions about the appropriateness of the linear approximation and compared this approach with two alternative techniques. One alternative technique uses bootstrapping (see Green, Hahn, and Rocke [1987] for an illustration), and the other uses a simulation technique, with many random draws taken from the multivariate normal distribution with mean $\hat{\beta}$ and variance-covariance matrix $\hat{\Sigma}$ (see Krinsky and Robb [1986, 1990]). Both techniques generate empirical distributions for the elasticities and, based on the Krinsky and Robb (1991) comparison, produce results that are similar to those from the linear approximation. Similar findings were reported by Dorfman, Kling, and Sexton (1990), who compared six alternative techniques for constructing confidence intervals for elasticities: three bootstrap-based approaches, a linear approximation approach, and approaches proposed by Fieller (1954) and Scheffé (1970). In their application, with very simple forms for single-equation demand models, five of these techniques worked reasonably well, producing comparable results, while the method suggested by Scheffé did not. Concerning implementation, however, Krinsky and Robb (1991) make some persuasive arguments for preferring the simulation approach, pointing out that the linearization approach may be inappropriate when elasticity formulas are complex, and that the bootstrap is very computer-intensive, requiring models to be re-estimated repeatedly.

The problem of how to evaluate precision of estimates also arises for the estimates of advertising welfare measures (ΔZ). The issues are essentially the same, because the welfare changes are also nonlinear functions of the estimated $\hat{\beta}$ and the observed data X (i.e., $\Delta Z = \Delta Z[\hat{\beta},X]$). Although the functional relationship between ΔZ and $\hat{\beta}$ is complicated, to obtain measures of precision for ΔZ from what we know about the precision of $\hat{\beta}$ is no different, in principle, from obtaining measures of precision for elasticities. Piggott (1997) showed how this can be done using a simulation technique similar to Krinsky and Robb (1991) where a large number of draws, say N, would be taken from $\hat{\beta} = N(\hat{\beta}, \hat{\Sigma})$. Each draw would then be used to calculate the implied price elasticities of demand and advertising elasticities, which would be used to solve an equilibrium displacement model of a simulated change in advertising and to calculate the implied changes in welfare. In carrying out this approach, restrictions from theory may also be imposed (such as curvature) by checking the feasibility of the estimated price and advertising elasticities at each iteration. If N were sufficiently large, stable estimates would be obtained of the mean and standard deviation of the implied changes in welfare (ΔZ), and a confidence interval could be placed around each element of the estimated ΔZ. If the confidence interval does not include the value zero, then the hypothesis that the particular estimate of ΔZ is not different from zero can be rejected. Furthermore, if N is sufficiently large, then the sample of estimates of the implied changes in welfare can be used to calculate the probability that the welfare measures will be greater than a particular value of interest.

To evaluate the precision of our benefit and cost measures, we conducted random draws taken from the multivariate normal distribution with mean $\hat{\beta}$ and variance-covariance matrix $\hat{\Sigma}$, as mentioned above. This type of simulation is commonly known as Monte Carlo simulation. Using what we know about the joint probability distribution of estimation errors for the estimated parameters, we can generate random draws of parameter values and calculate the welfare measure associated with each draw. This sampling process mimics the variability present in the estimated coefficients and can be interpreted as repeating the process of generating our data with new draws on the error terms in the estimated equations, and re-estimating the parameters.

If we generate estimates of the welfare measures at each draw from the probability distribution of the estimated parameters, we can generate an empirical approximation of the underlying probability distribution for the welfare measures. This empirical version of the distribution can then be used to assign measures of precision to the point estimates of changes in welfare. Estimates of welfare impacts resulting from the Program can then be reported with accompanying confidence intervals. The width of these intervals then provides a measure of confidence about whether the returns are positive. Although point estimates of welfare measures are useful, they are much more informative when accompanied by measures of precision.

Measures of precision for each of the welfare measure were generated by drawing values at random from the estimated distribution of the parameters. The resulting drawn parameters were then used to conduct the simulations of the cotton market without the Program and to evaluate accompanying welfare impacts. This process was repeated for 10,000 random draws of parameter estimates.

<These results will be added for the final draft.>

6.2 CONCLUSIONS FROM RATE OF RETURN ESTIMATES

To determine the average rate of return (and total net benefits) associated with the Program, we needed to simulate what the market for cotton would look like if the Program had not existed. This is done by setting Program expenditures (and assessments) equal to zero and using our model results to simulate supply and demand under this condition. We perform this simulation for both the domestic raw cotton market and the import market to measure producer surplus to both domestic producers and importers. Producer and consumer surplus are then compared with and without the Program.

We find that the returns to this Program have been quite large. This follows from the relatively high estimated elasticities of demand response to promotion and nonagricultural research, and the elasticity of supply response to agricultural research.

Another interesting question is whether the rate of return on advertising and research differ. If so, this implies that a reallocation of expenditures towards the area with a relatively higher return would improve net returns to producers. Thus, rates of return are calculated separately for promotion, nonagricultural research, and agricultural research to address this issue. Our results indicate that, although it would pay to increase all three activities, it appears that reallocation towards nonagricultural research would provide the largest return.

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Appendix A: Examples of Work in Progress at Cotton Incorporated for the Development of New Technologies (CI, 2001)

- **Production**
  - ✓ Research on COTMAN™ (a computer-based decision aid) is ongoing. In 2001, there will be four multistate projects looking at refining insecticide-termination rules under high yield situations, irrigation termination, UNR application, in addition to refining the heat unit accumulation procedure used by COTMAN.
  - ✓ A practical assay kit for detection of *N. fresenii* in aphids (Agdia), which will reduce cost and pesticide use.
  - ✓ A more efficient attractant system (bait) for boll weevil traps used in the eradication program (McKibben).
  - ✓ Development of an assay system to rapidly screen germplasm for resistance to feeding by lygus bugs (Teuber).
  - ✓ Development of transgenic insects (autocidial gene) for management of pink bollworm (Miller).
  - ✓ Identify proteins with modes of action similar to *Bt* against aphids and lygus, primarily for use in developing transgenic varieties (Federrici, 2002).
  - ✓ Economic evaluation of UNRC, precision farming, *Bt, Bt-II,* and other new technologies.
  - ✓ Through support of improved software for cotton farm record-keeping, we are establishing a package that will meet business and regulatory needs on farms.
  - ✓ Use of oligomer synthesis to track fiber development—research to understand the biochemical pathway of cellulose synthesis in cotton fiber—fundamental science, huge upside potential—essential for efficient use of biotechnology for fiber improvement.
  - ✓ Breeding to improve transgenic varieties—weed and insect control.
  - ✓ Methods of comparative evaluation of transgenic varieties under field-production conditions because Official Variety Tests are inapplicable—See May et al. (2000) and the Crop Sci. Society Symposium (2001) and our 2001 Agronomic Systems test (AR, GA, TX).
  - ✓ Economic evaluation of herbicide-resistant, transgenic systems—the 1997-1999 Regional Project, report in preparation.
  - ✓ Evaluation of new lay-by herbicides so producers encounter fewest possible problems with new compounds—several products, chiefly from Valent and DowAgro Sciences.
  - ✓ Nematology—research to find ways to manage the reniform nematode, an increasing pest of cotton.
  - ✓ Host-plant-resistance breeding against reniform nematodes by using sources outside of *Gossypium hirsutum*—*G. bardadense* and *G. longicalyx,* for example.

- ✓ Seed and fiber promoters—produced and now testing a number of gene-expression promoters at Texas Tech University.
- ✓ Defoliation—study of genes involved in leaf drop in cotton—two genes in the pathway are described at Auburn University, with continuing work needed.
- ✓ Single Sequence Repeat (SSR) development and fiber-gene discovery—multiple SSRs and subsequent gene retrieval—ongoing at Alabama State University.
- ✓ Fiber specific promoters and genes—discovery of fiber expansion genes ongoing at University of California.
- ✓ SSRs for use as genetic markers—produced over 200 SSRs, over 3,000 ESTs (DNA sequences that produce useful traits), and multiple, associated genes—Texas A&M.
- ✓ Development of a new method to measure lint density and production on seeds—Brookhaven National Laboratory.
- ✓ Cotton stickiness (caused by constituent plant sugars, insect honeydew, seed fragments or fiber waxes) is a sporadic problem with U.S. cotton, particularly cottons grown in dry climates that have late season populations of whiteflies and aphids. CI continues to sponsor research.

➤ **Processing**

- ✓ Projects are under way to use scanning and image capture techniques to eliminate technician measurement of samples used in shrinkage and appearance evaluations.
- ✓ A new version of MILLNet EFS® software has been undertaken. This version is designed to take full advantage of PC-based Windows Client/Server architecture and uses Microsoft's SQL database. This version, named MILLNet32, is needed because computer networks used by the industry have matured in recent years and tasks have become dispersed, and many users, in diverse locations, need access to the same data files. MILLNet32 is also designed to be a complete corporate-wide mill cotton management system that has the potential to help mills acquire exactly the cotton they need for a specific end product and processing machinery at the lowest possible cost and yet produce product that consistently meets their customers' specifications. This project is now in beta evaluation at Avondale Mills and the general release is scheduled for the end of August 2001.
- ✓ The development of functional finishes offers the chance for cotton to compete in an area where synthetics have become the majority. These chemistries include water repellant, soil release, odor absorbing finishes, UV protection, antimicrobial finishes, and scents.
- ✓ The development of 100 percent cotton recreational performance apparel has begun to allow cotton to compete

in areas where moisture management is critical. These products should be breathable, fast drying, and, in some cases, water repellent.

- ✓ New technology for reducing flammability includes developing new molecules that make cotton fabrics less flammable; using existing chemistry with new application techniques; and applying technology from the plastics industry to cotton.
- ✓ Comfort assessment technology is critical for CI to continue to differentiate cotton from synthetics that claim to be "cotton-like" and more comfortable than cotton. Instruments and technology systems are being evaluated in-house and outside CI that can accurately show the comfort of cotton fabrics relative to synthetic fabrics.
- ✓ Murata MVS (vortex) air jet spinning. CI's process and end product developments are playing a central role in the decision of textile manufacturers to install these machines.
- ✓ CI is playing an important role in demonstrating to the textile industry the economics and yarn potential of compact spinning systems.
- ✓ Continuing demonstration to the yarn spinning industry of the importance of fiber quality on the processing efficiency and quality of yarn product.
- ✓ Seamless knitting has become a fast mover in the underwear business. The ability to eliminate seams in the garments and to reduce the cut-and-sew steps is critical. CI will pursue this technology for outerwear items such as golf and tennis shirts.
- ✓ CI is developing the Engineered Wovens Program, which is a modeling system for woven fabrics. This technology will allow a manufacturer of woven fabrics to predict the performance of a new weaving set-up without having to weave the fabric. This process will shorten the development costs and time by reducing the number of samples required to process from weaving through dyeing and finishing to meet specifications.
- ✓ CI will continue to work on bio-polishing and dyeing as well as bio-preparation and dyeing. The goal is to combine bio-polishing, bio-preparation, and dyeing in the same bath, which will offer great cost savings and better fabric hand performance.
- ✓ Low temperature bleaching is being investigated with the supplier of the technology. This system will offer savings in energy and time. Work is also beginning on a system with another textile chemistry supplier, which will result in less rinsing after preparation offering savings in water and energy costs.
- ✓ CI has purchased a digital printing system with CAD/CAM properties to develop the ability to apply different colorants

and the necessary delivery systems. The gain will be greater flexibility, unlimited pattern and color combinations, and cost savings.

- ✓ CI is investigating minimum application methods (foam and sprays) to apply conventional chemistries or dyes. These systems use less water and therefore less energy and offer the ability to apply different chemistries on both sides of a fabric.
- ✓ In-house development is continuing of an economical cotton and wood pulp blend for airlaid nonwovens fabrics implementation.
- ✓ Barnhardt Manufacturing has installed a continuous bleaching line that CI developed. This process will deliver a cleaner and more open fiber for use in spunlace fabrics. Barnhardt is currently the largest supplier of kier-bleached staple fiber in the U.S. The addition of this continuous line will allow Barnhardt to compete at a higher fiber quality. CI will assist them in this endeavor.
- ✓ Work is continuing on patented airlaid technology from M&J Fibretech in Denmark with specific interest in the production of cotton airlaid, absorbent cores, disposable wipes, and components for hygiene products.
- ✓ Ongoing work is targeted to the expanded development of cotton spunlace (hydro-entanglement) for multiple wiping applications including short- and long-life end uses.

Appendix C:
Grid Search Details

The Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBC), and Adjusted R-square are computed as follows:

$$AIC = -2\ln L + 2k$$

$$SBC = -2\ln L + \ln T\, k$$

$$Adj\, \mathrm{R}^2 = 1 - \left[\frac{(T-1)}{(T-K)}(1-R^2 \right]$$

where L is the value of the likelihood function evaluated at the parameter estimates, T is the number of observations, and m is the number of estimated parameters, R^2 is the standard R-square. However, assuming a Gaussian process (as we have done here) the AIC and SBC criterions reduce to

$$AIC = \ln \sigma^2 + \frac{2k}{T}$$

$$SBC = \ln \sigma^2 + \frac{k \ln T}{T}$$

where σ^2 is the estimated variance of the error term.

[Put some figures in here of the grid search results]

Appendix D: Calculating Program Returns

ESTIMATING CHANGES IN PRICES

To estimate the change in cotton price taking place as a result of the cotton Program, the cotton market was modeled using a series of equations representing supply, demand, and market clearing relationships. The endogenous variables of the model are proportional changes in quantities of cotton sold domestically (EQ_{cd}), cotton sold on the export market (EQ_{cx}), cotton supplied by producers (EQ_s), and farm-level cotton prices (EP). Fixed values are assumed for all input costs, for domestic and export market shares, and for elasticities of supply and demand.

$$EQ_{cd} = \eta EP + \beta_1 EA + \beta_2 ENAR \qquad (D.1)$$

$$EQ_{cx} = \eta_x EP^D + \beta_3 EA + \beta_4 ENAR \qquad (D.2)$$

$$EQ_s = eEP + \beta_5 EAR \qquad (D.3)$$

where EA, ENAR, and EAR denote proportional changes in advertising, nonagricultural research, and agricultural research expenditures, respectively; η is the price elasticity for domestic demand; η_x is the price elasticity for export demand; e is the price elasticity for domestic supply; β_1 through β_4 are domestic and export demand elasticities with respect to advertising or nonagricultural research; and β_5 is the supply elasticity with respect to agricultural research.

The proportionate change in quantity supplied equals the weighted change in quantity demanded:

$$EQ_s = s_1 EQ_{cd} + (1 - s_1) EQ_{cx} \qquad (D.4)$$

where s_1 is the share of domestic production used by domestic mills. Substituting for the change in quantities yields

$$eEP + \beta_5 EAR = s_1(\eta EP + \beta_1 EA + \beta_2 ENAR) + (1 - s_1)(\eta_x EP + \beta_3 EA + \beta_4 ENAR)$$

Rearranging this expression gives us an equation for the proportionate change in price:

$$EP = \frac{s_1\beta_1 EA + s_1\beta_2 ENAR + (1-s_1)\beta_3 EA + (1-s_1)\beta_4 ENAR - \beta_5 EAR}{e - s_1\eta - (1-s_1)\eta_x} \qquad (D.5)$$

Now, Eq. (D.5) can be used to calculate the changes in price and quantity necessary to generate estimates of changes in producer surplus. Following Lemieux and Wohlgenant (1989), the change in producer surplus can be calculated using

$$\Delta PS = P_0^s Q_0(EP - K)(1 + 0.5\, EQ) \qquad (D.6)$$

where K is the proportionate downward shift in the supply curve resulting from agricultural research expenditures.

Augmenting Eq. (D.6) to include the effects of the assessment on producer surplus yields:

$$\Delta PS = P_0^s Q_0(EP - K)(1 + 0.5\, EQ) - \frac{1}{1 - \dfrac{e}{s_1\eta + (1-s_1)\eta_x}} \bullet T \qquad (D.7)$$

where T is the assessment collected from domestic producers. Only a portion of the assessment falls on producers; the rest is passed on to consumers through higher prices. The proportion paid by consumers and producers depends on their relative price elasticities. Eqs. (D.5) and (D.7) are used in Section 6 to generate estimates of the changes in producer surplus resulting from changes in Program expenditures.