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progress report on COTTON PRODUCTION RESPONSE

with Special Application to the Southeast

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CONTENTS

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PROGRESS REPORT ON

COTTON PRODUCTION RESPONSE

With Special Application to the Southeast

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SUMMARY AND CONCLUSIONS

From 1943 to 1950, acreage allotments on cotton were not in effect, but contrary to expectations, the acreage of cotton decreased. The effect of the drain of manpower on the acreage of cotton in the Southeast during this period was studied. The outflow of labor for military service and in response to nonfarm employment opportunities does not explain the decrease in acreage before 1949. Large underemployment on cotton farms in the Southeast before that year probably explains why the outflow of labor did not affect the acreage of cotton. Substitution of hay and peanuts (and perhaps pasture) for cotton acreage in response to relative changes in price provides a more adequate explanation of changes in cotton acreage before 1949. The data indicate, however, that after 1949 the effect of off-farm work on cotton acreage assumed increasing importance.

As a check on the results obtained for World War II and the postwar years and to expand the implications of these results, tentative acreage-response functions for cotton were constructed for the years from 1905 to 1932. A function was constructed for each of three regions: The Southeast, the Mississippi Delta, and the Southwest. For each region, the annual acreage of cotton was expressed as a function of the annual price of average cotton, the annual average prices of several substitute crops, and the trend in the acreage of cotton. A greater part of the change in acreage of cotton is explained by the estimates derived from these relations than by functions that attempt to explain the total acreage of cotton in the United States as a function of the average United States price of cotton. That is, by breaking down the total acreage of cotton in the United States into three regions and by expressing acreage in each region as a function of the economic forces that apply in that region, the ability to explain changes in the total acreage of cotton in the country as a whole is increased.

1/ At the time this publication was prepared, the author was on the staff of the Farm Economics Research Division, Agricultural Research Service.

The tentative results are not entirely satisfactory, but they do point up the need for more precise formulations of acreage and production response. Progress in this direction apparently demands a more economically meaningful subdivision of geographic regions and a set of acreage and yield response functions that will take into account the different economic forces in each region. The importance of potential substitutes, size and type of operation, conditions in the factor markets, and so on, differ among regions. The study reported here suggests that by taking these differences into account, improved quantitative knowledge of supply response in the United States as a whole can be obtained. Consequently, economic farm policy can be strengthened.

INTRODUCTION

In recent years, the problems of production response for agricultural commodities have been increasingly recognized. The importance of greater knowledge of these problems in the formulation of agricultural policies designed to influence production is clear. The more that is known about the factors that determine the levels of production the better are the chances of formulating programs with which to satisfy the goals set. The different forces that may influence the acreage devoted to a particular crop can be enumerated as can the systematic and random forces that determine yield per acre. From this knowledge, in some instances, probable qualitative judgments as to the direction production will take under assumed conditions can be made, but little quantitative information as to the relative importance of these various influences is available. Casual observation may produce misleading conclusions. Often, it cannot distinguish between forces that actually operated at some period of time and those that were not in operation.

Cotton provides an example. When acreage allotments and marketing quotas on cotton are not in effect, comparative freedom is given to purely economic incentives. What result should be expected? The removal of restrictions during World War II provides a laboratory in which the behavior of cotton farmers under conditions that changed with respect to acreage restrictions (relative to the previous years) and other factors can be observed. A detailed examination of the production of cotton during this period should yield a notable contribution to the knowledge of the relative importance of forces operating in the product and input markets.

To reduce the problem to manageable proportions, the study reported here was confined primarily to changes in cotton acreage in the Southeast. 2/ But this was not the only criterion for limiting the study to that area. Most of the speculation concerning causal influences is centered on

2/ The Southeastern States included in the study were North Carolina, South Carolina, Georgia, Alabama, and Florida.

this region. It will be seen that the conclusions drawn from the study in the Southeast have wider applicability. Certain general implications emerge for the construction of aggregate supply functions. The first section of this report summarizes the situation in the United States as a whole and in the Southeast during World War II years. The second examines the most popular hypothesis advanced to explain changes in cotton acreage in the Southeast, and the third provides an alternative explanation. The fourth section expands the alternative explanation by pursuing the implications of changes during the war for the general problem of supply response.

COTTON ACREAGE AND PRODUCTION DURING WORLD WAR II

In order to stimulate wartime production, acreage allotments and marketing quotas were removed from cotton in 1943; they were not reinstated until 1950. Contrary to expectations, the acreage and production of cotton not only failed to respond to the removal of restrictions; they decreased relative to previous years for the United States as a whole and for each of the three major cotton-growing regions - the Southeast, the Mississippi Delta, and the Southwest. Table 1 summarizes the situation for the United States and the Southeast.

In column 2 are shown the ratios of average prices received by farmers for cotton to support prices for the United States. In all except one of the war and postwar years, prices received exceeded support prices. In columns 3 and 6, planted acreages as of July 1 are taken as representative of acreage decisions by cotton growers. These estimates differ from harvested acreages by the extent of acreage abandonment. For both the United States and the Southeast, the average percentage of abandonment for the period covered in the table was small (about 2 to 3 percent of planted acreage); the annual percentages showed no trend; and year-to-year differences were negligible.

In order to eliminate the influence of weather and other erratic elements, the trend value of yield per planted acre is shown in columns 4 and 7. The trend value also eliminates any systematic or planned annual variations in yield caused by more or less intensive use of inputs other than land. The amount of commercial fertilizer used per acre on cotton from 1928 to 1950 showed a general upward trend but no radical difference in the rate of change during war years relative to prewar years. 3/ The average rate of increase in amount of fertilizer used per acre in the United States from 1933 to 1938 was approximately 4 percent per year. From 1943 to 1947, it was about 4 percent. The largest rate of increase over a previous year was 17 percent in 1933 while the largest war year, 1943, showed a 7-percent increase. The Southeastern State that showed the most rapid rate of increase in use of fertilizer during the war was Alabama. The prewar average was 7 percent and the wartime average 7 percent. The largest single prewar year

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3/ United States Agricultural Marketing Service, Statistics on Cotton and Related Data, U. S. Dept. Agr. Statis. Bul. 99, June 1951, Pages 99 and 102.

Table 1.- Cotton acreage, yield per acre, and prices, United States and the Southeast, 1935-50

Year	Ratio of U. S. average price received to support price	United States			Southeast 1/				
		Planted cotton acres July 1	Trend value of yield per planted acre 2/	Planned cotton output 3/	Planted cotton acres July 1	Trend value of yield per planted acre 2/	Actual yield per planted acre	Planned cotton output 3/	Actual cotton output
(1)	(2)	(3)	(4)	(5)=(3)(4)	(6)	(7)	(8)	(9)=(6)(7)	(10)
		Mil. acres	Pounds	Mil. lbs.	Mil. acres	Pounds	Pounds	Mil. lbs.	Mil. lbs.
1935-----	1.11	28.06	211.0	5,921	6.82	254.6	243.8	1,736	1,663
1936-----	4/	30.63	216.4	6,628	7.11	257.2	248.0	1,829	1,763
1937-----	.93	34.09	221.8	7,561	8.32	259.8	287.1	2,162	2,389
1938-----	1.03	25.02	227.2	5,685	6.37	262.4	225.6	1,671	1,437
1939-----	1.04	24.68	232.6	5,741	6.16	265.0	236.6	1,632	1,457
1940-----	1.10	24.87	238.0	5,919	6.20	267.6	272.3	1,659	1,688
1941-----	1.19	23.13	243.4	5,630	5.77	270.2	198.8	1,559	1,147
1942-----	1.11	23.30	248.8	5,797	5.53	272.8	279.7	1,509	1,547
1943-----	1.07	21.90	254.2	5,567	5.28	275.4	282.8	1,454	1,493
1944-----	.99	19.96	259.6	5,182	4.60	278.0	354.8	1,279	1,632
1945-----	1.08	17.53	265.0	4,645	4.22	280.6	307.0	1,184	1,296
1946-----	1.43	18.16	270.4	4,910	4.35	283.2	278.0	1,232	1,209
1947-----	1.20	21.56	275.8	5,946	4.55	285.8	284.6	1,300	1,295
1948-----	1.06	23.25	281.2	6,538	4.83	288.4	349.2	1,393	1,687
1949-----	1.05	27.91	286.6	7,999	5.68	291.0	210.7	1,653	1,197
1950-----	1.43	18.63	292.0	5,440	3.89	293.6	205.3	1,142	799

1/ The Southeast includes North Carolina, South Carolina, Florida, Georgia, and Alabama.
2/ Value of a linear trend fitted to actual data on yield per acre.
3/ Number of planted cotton acres multiplied by the trend value of yield per acre.
4/ Prices not supported.

CCC Price Support Statistical Handbook, U. S. Dept. Agr. Washington, D. C., November 1956 (Mimeographed); Statistics on Cotton and Related Data 1920-1956, U. S. Dept. Agr. Statis. Bul. 99, Feb. 1957.

was 1933 with an 18-percent increase, while the largest war year, 1943, showed a 13-percent increase over the previous year. These data indicate that use of fertilizer per acre in the Southeast probably did not respond generally to the removal of output restrictions. There may have been response in some areas, but quantitatively, it was small. 4/

An index of man-hours used per acre in production of cotton shows a decline during the war and postwar years, of which more is said later. Mechanized cotton picking did not become important until 1948, and then it was adopted only gradually in the Southeast. Even today, it is not significant in this region. Substitution of tractors for mules in tillage operations shows no marked deviation from the upward trend during this period. Hence, with these minor qualifications in mind, the trend value of yield per acre was taken as an estimate of intended yield. Columns 5 and 9 were derived by multiplying the number of planted acres by the trend value of yield per acre. Finally, for comparison, actual yields and production are shown in columns 8 and 10.

Examination of table 1 reveals that with the removal of acreage allotments and marketing quotas, the drop in acreage and planned output that occurred lasted until 1948. The expansion of acreage in 1949 was probably due partly to the expectation of a return to production restrictions in 1950, which was reflected in the sharp decline in acreage and production in that year. There was a pronounced linear trend in yields for both the United States and the Southeast. This trend is indicative of the upward trend in the use of fertilizer per acre, and the general shift in cotton cropland from East to West, where, because of soil conditions, irrigation, and so on, the yield per acre is considerably higher. The shift in growing location explains partly the slower rate of increase in yields in the Southeast relative to the United States as a whole. As actual yields fluctuate around the trend during the war and postwar years, it was assumed, on the basis of the information shown above, that any systematic deviations from the trend were negligible. Changes in production were thereby attributed primarily to changes in acreage. As a result, changes in acreage rather than changes in production are discussed in the rest of this report.

EFFECT OF LABOR SUPPLY ON ACREAGE

The explanation of the wartime decline in cotton acreage that has been rather widely accepted runs in terms of the outflow of labor from cotton farming during World War II. Although this hypothesis as such has not

4/ These data refer to number of pounds of fertilizer mix. There has been a steady growth in the concentration of available nutrients in each pound of mix. There is no reason to assume, however, that this influences year-to-year yield variations from trend.

appeared in print 5/, it is commonly assumed that with the outbreak of war, greater alternative income opportunities, together with compulsory military service, drew workers from production of cotton. Nonfarm employment opportunities expanded, especially in the Southeast, where cotton is a labor-intensive crop and where wages for cotton labor were very low relative to nonfarm wages. The decline in cotton acreage (and perhaps a switch to less labor-intensive crops) is assumed to have been caused by the alleged decrease in the labor supply.

It is difficult to measure labor outflow from cotton production on the basis of existing data. Whether one is concerned with the national, State, or local level, the ideal measure of labor outflow is the change in the number of labor units (preferably hours) actually applied to production of cotton. Unfortunately, data organized in such a way as to yield this measure are rare.

The data cited by Street 6/ as rough indicators of this outflow are: (1) Farm-employment figures by Census-of-Agriculture regions; (2) farm versus nonfarm wage rates by regions, and wages for cotton picking versus nonfarm wage rates by regions; and (3) net off-farm migration figures and men withdrawn from farms for military service by regions. Comparisons are made between successive census years.

The limitations on these data, however, cast doubt as to their accuracy as indicators of the relevant decrease in labor supply: (1) The data are presented for changes over 5-year periods; movements between census years are omitted; (2) wage differentials refer only to the hired labor force; (3) in farm-employment figures, farm operators and hired workers are counted as employed if they spent one or more hours at farmwork during the census week, and members of the operator's household doing unpaid farmwork are counted if they put in 15 hours or more; (4) migration and selective service data are available for geographic regions only, and there is no assurance of a relation of proportionality between off-farm migration (including military service) by area and migration from cotton farming; (5) even if net migration figures were available for movements of persons out of cotton farming, they would not necessarily imply an equivalent decrease in the number of persons actually working in the production of cotton. Wives, children, or elderly males may substitute for adult male workers who migrate. This would be particularly true of small farms operated by sharecroppers. Exchange of labor services among farmers may lead to more efficient use of a given amount of available labor in an area. It implies that the number of persons on cotton farms cannot be taken as an accurate measure of the number of persons working in cotton production.

5/ See Street, James H., The "Labor Vacuum" and Cotton Mechanization, Jour. Farm Econ. 35: 381-397, 1953, for reference to this hypothesis (page 381).
6/ Ibid., pp. 382-390.

Even more important, the relevant measure of a change in the quantity of labor supplied is the change in the number of hours of labor used in cotton production rather than a change in the number of persons working in cotton production. Of those who actually work in cotton, some may work as much as 50 hours a week; others may work only 20.

An attempt was made in the study to obtain a more accurate and more economically meaningful estimate of the change in labor supply. The effect of changes in the labor supply on cotton acreage was also examined.

Cotton is grown under diverse soil, climatic, and technological conditions in different regions. Because of these differences and because references to nonfarm employment opportunities are usually concerned with the Southeast, interest here is centered on that region. In attempting to discover the source of changes in cotton acreage in this region, however, more general implications arose with respect to the construction of aggregate supply functions.

We have seen that the relevant measure of a change in the quantity of labor supplied is the change in number of hours, and that changes in number of persons on cotton farms may not reflect changes in hours.

Figure 1 shows the annual rates of change in a 4-State index of labor hours used in cotton production from 1935 to 1955. Data for South Carolina, Georgia, Alabama, and Florida were included. Figure 1 shows also the annual rates of change in 3-State indexes of farm employment and farm population. 7/ As Florida produces less than 1 percent of all cotton produced in the region, it was omitted in order to provide comparability of data. A close correlation between changes in acreage and changes in labor hours used may be observed. But labor hours show a substantial degree of variation that is independent of variations in farm employment or population. If the "pull" on farm labor influenced the acreage of cotton, changes in labor hours (and acreage) would be expected to vary with changes in farm employment, farm population, or both.

The reason for the independence of fluctuations in labor hours is suggested in figure 2. In order to test the hypothesis that the migration of

7/ The index of labor hours was computed from unpublished estimates of labor requirements for cotton production by the Farm Economics Research Division, Agricultural Research Service, U. S. Dept. of Agriculture. Estimates from 1951 to 1955 are preliminary. The farm-employment index was made available by the Agricultural Estimates Division, Agricultural Marketing Service, U. S. Dept. of Agriculture, from unpublished data. The unrevised 3-State index was revised by an index for the South Atlantic region as a whole. The Farm Population data were taken from "Farm Population, Annual Estimates by States, Major Geographic Divisions, and Regions, 1920-50 and for the United States, 1910-50," U. S. Agr. Marketing Serv., Washington, D. C., November 1956, table 2.

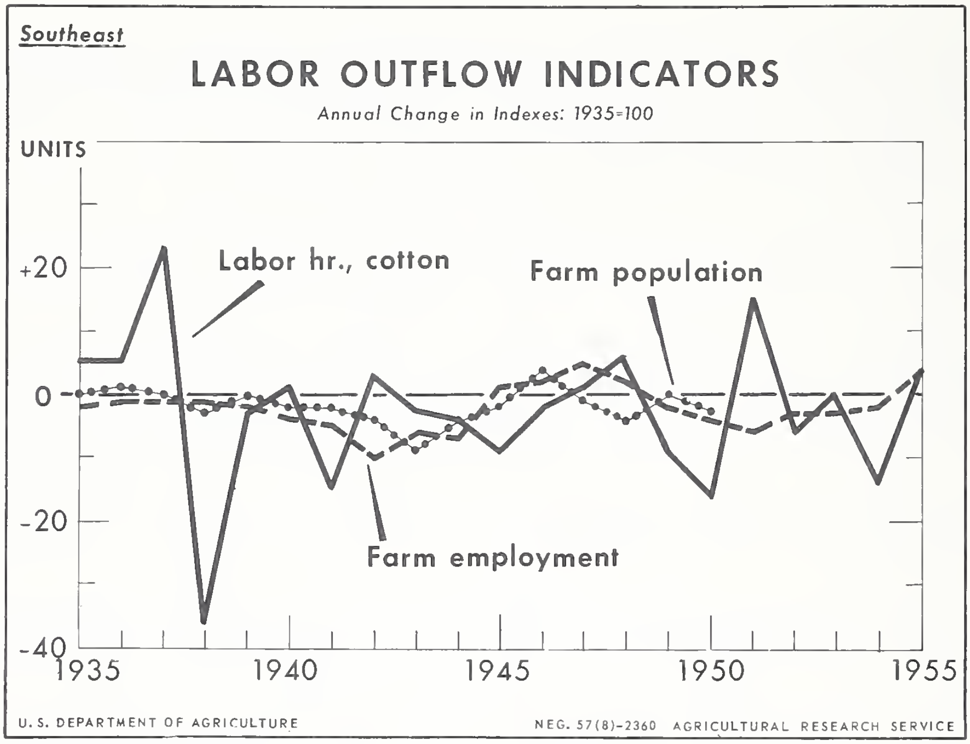

Figure 1

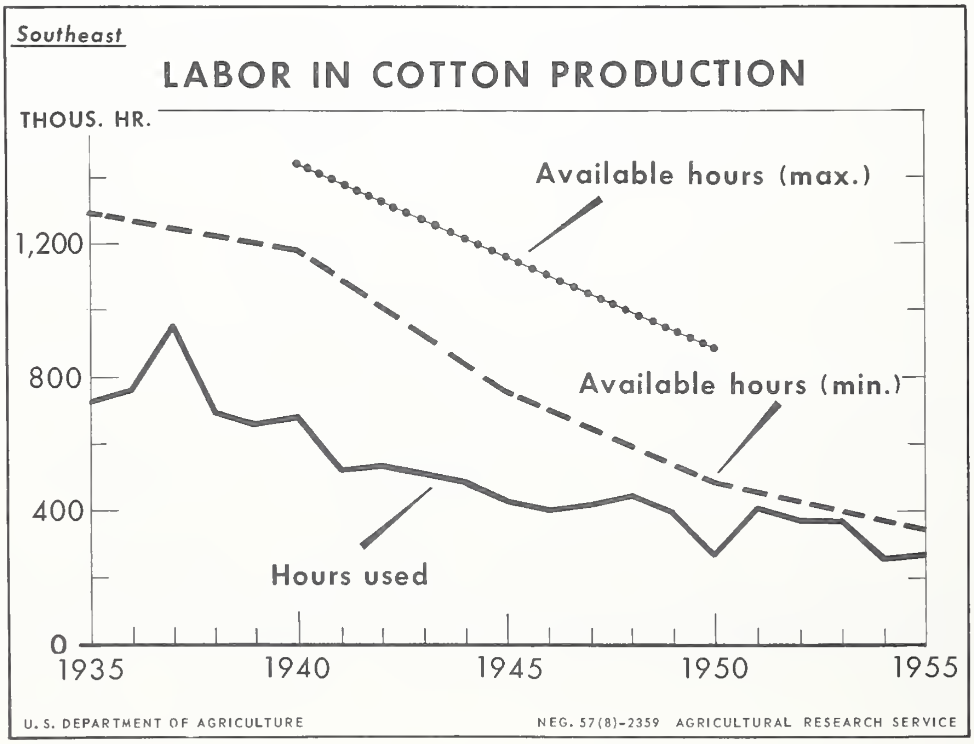

Figure 2

labor is the cause of the decrease in acreage, two estimates of labor supply are utilized - the number of labor hours used in cotton production and the number available for use. An attempt was made to construct an estimate of labor hours available for cotton production on the assumption that if the number of hours actually used and the number of hours available are approximately equal, a reduction in the number of hours available during the war period can be considered the cause of the reduction in cotton acreage. But if the number of hours used in cotton production is significantly smaller than the number of hours available for use, there is a "surplus" that can be removed without affecting cotton acreage. In the latter instance, hours of labor input can be varied independently of migrations of persons from cotton farms because of greater income possibilities or military service. Figure 2 depicts the number of labor hours used in cotton production annually and the minimal and maximal estimates of hours available for cotton production for the four States mentioned. The way in which these estimates of available hours were derived is explained in detail below. The minimal estimate is for Census-of-Agriculture years and the maximal estimate is for Census-of-Population years. Although the measures of available hours are necessarily crude, the conclusions that may be drawn with confidence are significant.

The fundamental problem involved in estimating the number of hours available springs from the way in which census data are organized. As no farm is solely a producer of cotton, the number of persons on "cotton farms" cannot be taken as an exact measure of the number of persons who work in cotton. There is also the problem of converting number of persons to number of hours. The minimal estimate of available hours is obtained from three sources of labor on cotton farms - hired workers, farm operators, and unpaid members of the operator's family who worked 15 hours or more during the census week. The Census of Agriculture enumerates the number of persons in each of these categories, by type of farm by States. 8/ The planting, hoeing, and chopping season stretches from March or April to June or July, depending on location. The picking season begins in early September, reaches a high point in October or November, and trails off into December and January. Data on number of hours used indicate that preharvest labor re-requirements slightly exceed harvest requirements. For each census year in

8/ The Census-of-Agriculture classifications are not strictly comparable throughout the entire period 1935-54. The number of persons in each category of labor is classified by type of farm, that is, type of commodity produced. In 1945 and prior census years, cotton farms are included in the category "all field crops." The number of cotton farms is estimated from a linear extrapolation of the trend of the proportion that cotton farms are of all field-crop farms. Also, prior to 1945, the type of farm is defined on the basis of "major source of income." In 1945 and later years, it is defined on the basis of "Fifty percent or more of the value of all farm products sold." This lack of comparability leads to weaknesses in the estimates for census years prior to 1945, but the differences should not be great enough to alter the basic conclusions.

which the census week occurred in January or March, seasonal adjustments in numbers of hired and family workers were based on monthly farm-employment figures for the South Atlantic region.

Hired workers are divided into regular workers (150 days or more of work) and seasonal workers (less than 150 days of work). Both are counted as full-time workers during the cotton planting and picking seasons. Each full-time hired worker is assumed to be available for 50 hours of labor per week for 10 weeks in the preharvest season and 10 weeks in the harvest season. 9/ Operators are divided into those available for full-time cotton work during the peak seasons (50 hours a week) and those available for part-time work (30 hours a week). Full-time operators are estimated as follows: Operators who worked one or more hours on the cotton farm minus the number who worked 100 days or more off the farm minus the number of operators 65 years of age or over. This division implies that those operators who worked 100 or more days off the farm are available for neither preharvest nor harvest work, and that those who worked less than 100 days off the farm are available on a full-time basis for both. Members of the operator's family are included as part-time workers and assigned 30 available hours per week for 20 weeks.

This approximation (the sum of these available hours) underestimates the "true" number of hours available for these reasons: (1) The data are reported for cotton farms, and a cotton farm is defined as one for which cotton amounted to 50 percent or more of the value of all farm products sold. Included in the labor hours actually used are hours expended on cotton on farms for which the crop amounted to less than 50 percent of the value of farm products sold; (2) some family workers will have worked less than 15 hours per week and so are not included in the census data; (3) it is likely that some farmers who worked 100 days or more off the farm were available for some preharvest or harvest labor; (4) the amount of labor expended on cotton picking in December and January, although it is relatively small, is not included; (5) some labor in the surrounding locality may have been available but not hired because of the availability of unpaid family labor.

The measure of hours available tends to be overestimated because of the necessity of devoting hours to farmwork other than cotton picking, even during the peak cotton-picking months. Farm chores and the care of livestock and other crops take time that should be subtracted from the estimate of available hours for cotton production. The magnitude of this time is uncertain and difficult, if not impossible, to approximate from available data. The net effect is probably in the direction of an underestimate. The number of factors that contribute to an underestimate is greater than the number that contribute to an overestimate. Some of them, such as (1) and (5), are likely to carry more weight separately than any single factor that makes for an overestimate.

9/ Economists who are familiar with cotton production in the Southeast believe that this is a reasonable minimal estimate of average annual hired labor availability.

The maximal estimate is taken from the Census of Population for 1940 and 1950, the 2 census years included in the period studied. To facilitate comparison, a straight line connects these two observations in figure 2. It is not intended to imply that the trend is actually linear. This maximal estimate consists of hired seasonal workers plus the farm population 15 years of age or over in these counties for which 20 percent or more of the harvested acreage is devoted to cotton. All males between the ages of 20 and 64 are considered to be full-time workers (on the basis of the preceding definitions). Part-time workers include all females 15 years old or over plus all males 65 years of age or over. The "true" number of available hours probably lies between these two estimates and closer to the minimal estimate.

Figure 2 indicates that, at least prior to 1948, the number of labor hours available greatly exceeded the number used. Although the estimate of number of hours available is admittedly rough, it is unreasonable to suppose that so large a difference can be accounted for by errors in the estimate of number of hours available. During the 1930's, there was considerable under-employment on farms. There can be no doubt that the wartime expansion of nonfarm employment and income opportunities drew available labor hours from cotton production in the Southeast. But the number of available hours, especially in the earlier part of the period, apparently exceeded those actually used to such an extent that the pull did not exert sufficient pressure on labor availability to explain the decrease in cotton acreage.

Manufacturing employment is the chief alternative to farm employment in the Southeast. A correlation has been found between decreases in farm population and increases in manufacturing employment by States from 1939 to 1955 (the correlation coefficient is 0.68). Nevertheless, no significant correlation could be found between cotton acreage by States and (1) manufacturing employment, (2) total nonfarm employment, or (3) manufacturing employment plus military inductions by States. If relations between cotton acreage and movements of labor out of cotton farming are taken as indicative of the effect of changes in the labor supply on changes in acreage, the picture is little better. When the data are broken down into census economic areas within States, no relation is evident between changes in farm population and changes in acreage. Also, for State economic areas, the percentage decrease in the acreage of cotton has been compared with the percentage increase in number of operators who spent 100 days or more in off-farm work, and here the relation is somewhat better. From 1935 to 1954, the rates of change are measured from one census year to the next. Figures 3 to 6 show four scatter diagrams relating the percentage changes in number of cotton farmers who spent 100 days or more on off-farm work and the percentage changes in cotton acreage by State economic areas. Although the correlation improved steadily with time, no statistically significant correlation appears prior to 1949-54. For this period, the correlation coefficient is 0.55, which for 32 observations is significant at the 1-percent level. Furthermore, of the 32 economic areas, 11 show an increase in off-farm work of 8 percent or greater and 9 show an increase of 3 percent or less. With 3 exceptions, the areas that show a change of 8 percent or more in off-farm work

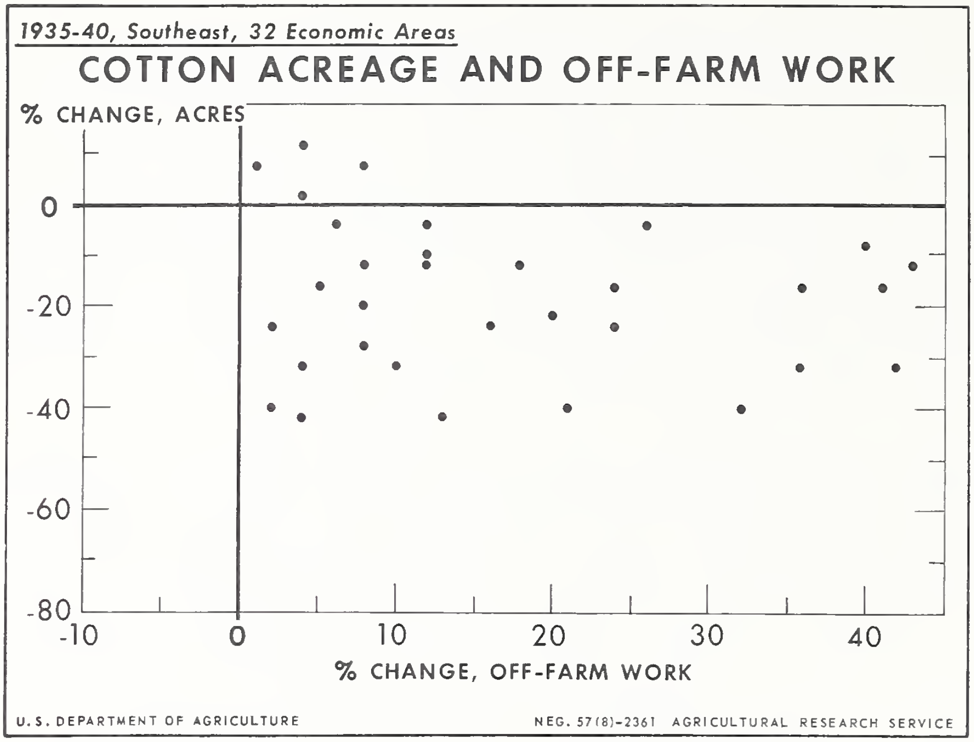

Figure 3

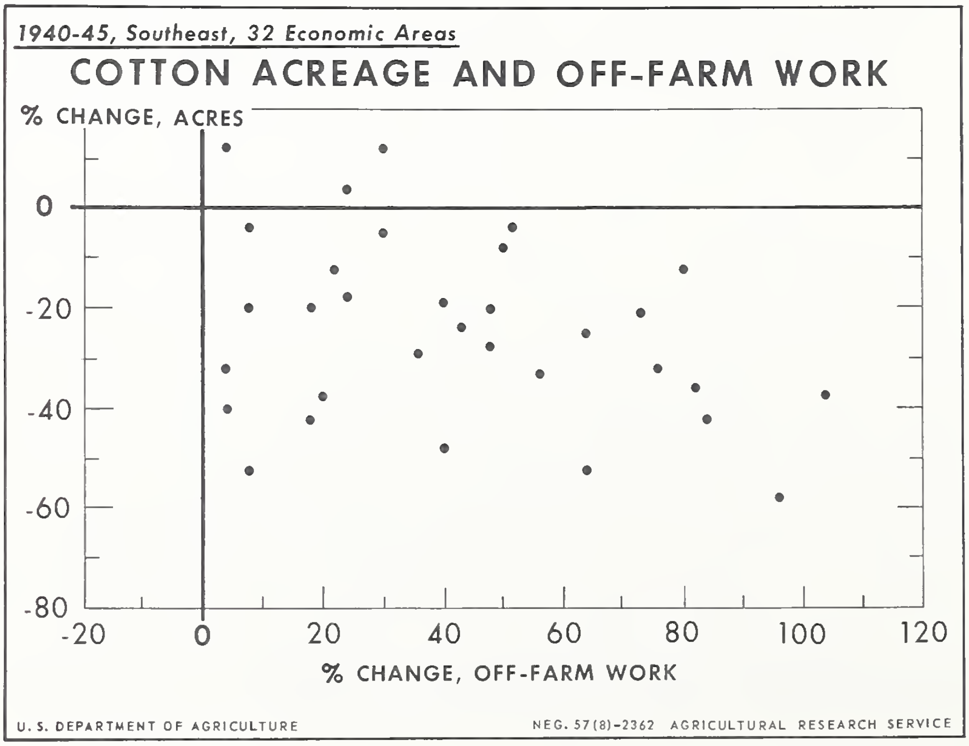

Figure 4

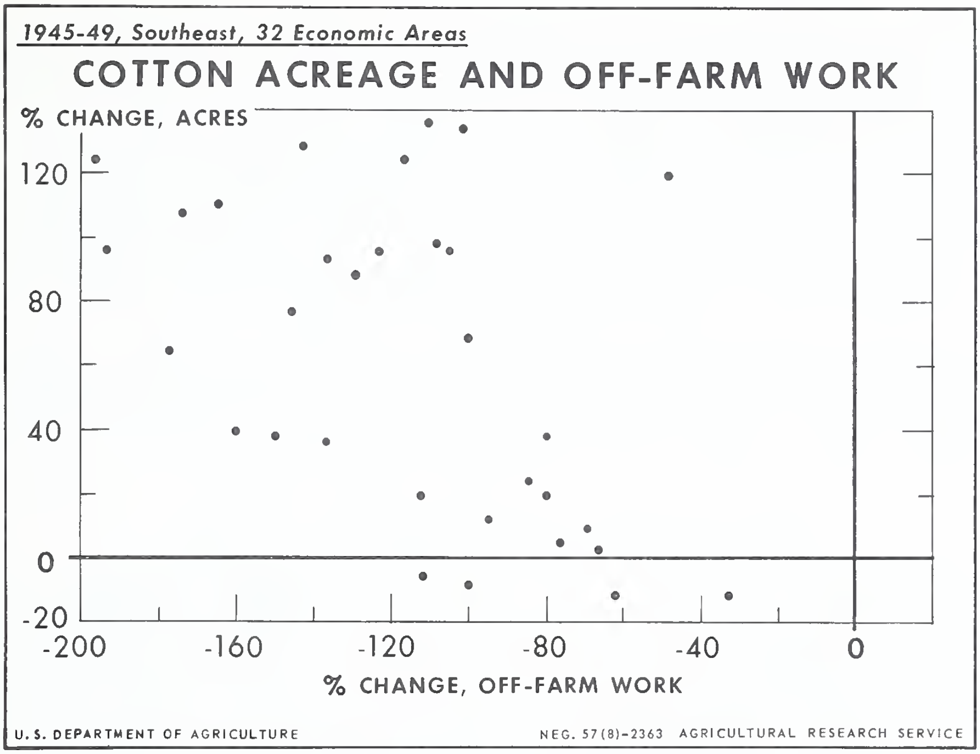

Figure 5

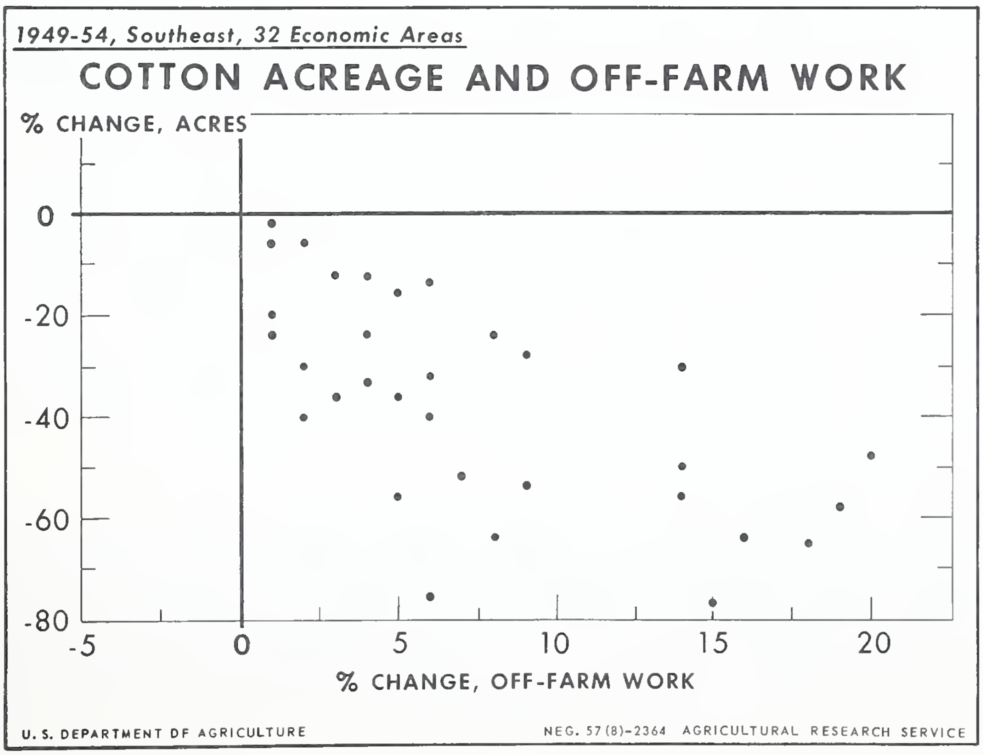

Figure 6

also show the smallest average yield per acre in 1949; with 2 exceptions the areas that show a change of 3 percent or less in off-farm work show the largest average yield per acre in 1949. More accurate data on income, size of farm, and ownership position are not available. 10/ The lack of adequate data limits the precision of conclusions that can be drawn from the analysis in this section of the report. However, the evidence suggests that labor outflow had little effect on changes in cotton acreage during the prewar period, when there was considerable underemployment of farm labor in the region. But beginning in the later stages of World War II, the effect of labor outflow on cotton acreage became increasingly apparent. Moreover, if present trends in migration and off-farm work in the Southeast continue, labor outflow will probably have a more pronounced effect on cotton acreage in the near future, subject to modifications imposed by price supports.

CROP SUBSTITUTION IN RESPONSE TO PRICE

The response of crop acreage to relative prices provides a more adequate explanation of the behavior of cotton acreage from 1943 to 1948. Price supports were in effect during World War II and the immediate postwar years, but prices of most crops exceeded support prices. On the average, prices received for cotton were 14 percent greater than support prices for the period 1941-48. When price supports are in effect, choice of the relevant price expectation that enters output decisions must be more or less arbitrary.

Given the conditions of a free market, that is, a market in which prices are not influenced by a central authority, it is plausible to formulate a price-expectation function for farmers. Then the expected prices by which acreage decisions are partly determined can be functionally related to several past prices, past acreage, or other relevant economic variables. When price supports are in effect, however, there are no obvious criteria for choosing the relevant price to which acreage should be related. Equally cogent arguments can be advanced for choosing the current support price, a lagged support price, price received lagged one year, or the current price received. We shall assume that the expected price determining harvested acreage is approximately equal to the actual price received by farmers (harvested acreage related to price lagged one year does not yield notable quantitative differences in the conclusions). The choice of actual current prices received is justified on the ground that they exceeded the support prices in each year except 1944.

10/ Some further evidence of the growing effect of labor outflow on cotton acreage is provided by the experience in the Piedmont in 1949. The Piedmont is an area of heavy industrialization as well as an important cotton-growing area. Cotton acreage in the Piedmont behaved much as acreage in the other southern areas during World War II. In 1949, however, when cotton acreage expanded in all other areas, the expansion in the Piedmont was negligible. This may well have been due to a labor shortage in cotton production.

Given the expanding demand conditions that prevailed from 1941 to 1948 and changes in the support price, it is plausible to assume that farmers expected actual prices to exceed continuously the support prices. Wartime requirements for cotton introduced a greater element of certainty with respect to military and civilian demands for cotton. These continuous upward shifts in demand, together with changes in the support price, which lagged behind increases in market prices, provided a basis for expectations with respect to changes in the actual market prices. Therefore, it is likely that the prices expected by farmers more closely approximated the current actual prices than either the support or the lagged actual prices.

If relative prices were the dominant force operating on acreage decisions, we should observe that the percentage of total cropland devoted to cotton is negatively correlated with the ratio of the price of a substitute crop to the price of cotton. We must observe also that the percentage of cropland devoted to the substitute crop is positively correlated with this price ratio. For each of our 5 Southeastern States, the acreage harvested for the 9 most important crops was tabulated. These crops are cotton, wheat, corn, oats, soybeans, cowpeas, hay, tobacco, and peanuts. In terms of cropland harvested, corn and hay were found to be important potential substitutes throughout most of the region; peanuts are especially important in Georgia and Florida and tobacco in North Carolina. From annual State data, simple correlations were run between the ratios of harvested cotton acres to total acres harvested for all 9 crops and the ratios of prices received for potential substitutes to the prices received for cotton. Correlations were also run between the ratios of acreages of potential substitutes to total acres and the corresponding ratios of prices of substitutes to cotton prices. 11/ The correlation coefficients for each State are shown in table 2 for the prewar years (when acreage restrictions were in effect) and for the war and postwar years when allotments and quotas were absent.

11/ The presence of pronounced trends in the acreages of cotton and potential substitutes might seriously weaken confidence in the correlations. Opposite trend movements in cotton acreage and acreage of potential substitutes might have occurred in the absence of relative price changes. If these trends are not slight, the series should be adjusted to remove their influence. There is a decreasing linear trend in cotton acreage in the Southeast (see Section V). The trends in acreage of potential substitutes are much smaller than in the case of cotton. When acreages are expressed as percentages of total cropland, the trend component of changes in acreage is significantly reduced. The shortness of the series, the existence of acreage restrictions prior to World War II, and the conditions of the war period may also lead researchers to question the importance of trend movements during the period studied. In order to test further the importance of trend, correlations were run between annual rates of change in relative prices and annual rates of change in acreages. The correlation coefficients are statistically significant at the 5-percent level; they do not differ appreciably from those obtained in table 2.

Table 2.- Indicators of changes in cotton acreage in response to relative prices 1/

Items correlated	Period 2/	Correlation coefficients
Alabama:		
Price of corn and acreage of:		
Corn	1933-41	-.25
	1942-48	+.22
Cotton	1933-41	+.22
	1942-48	-.23
Price of hay and acreage of:		
Hay 3/	1933-41	+.20
	1942-48	+.80
Cotton	1933-41	-.16
	1942-48	-.77
Georgia:		
Price of corn and acreage of:		
Corn	1933-40	-.13
	1941-48	+.46
Cotton	1933-40	+.11
	1941-48	-.39
Price of hay and acreage of:		
Hay 3/	1933-40	+.27
	1941-48	+.92
Cotton	1933-40	-.21
	1941-48	-.78
Price of peanuts and acreage of:		
Peanuts	1933-40	+.33
	1941-48	+.84
Cotton	1933-40	-.47
	1941-48	-.91
Florida:		
Price of corn and acreage of:		
Corn	1933-41	+.02
	1942-48	-.01
Cotton	1933-41	-.06
	1942-48	-.08
Price of peanuts and acreage of:		
Peanuts	1933-41	-.12
	1942-48	+.82
Cotton	1933-41	-.14
	1942-48	-.81

-Continued

Table 2.- Indicators of changes in cotton acreage in response to relative prices 1/ -Continued

Items correlated	Period 2/	Correlation coefficients
South Carolina:		
Price of corn and acreage of:		
Corn	1933-41	+.18
	1942-48	+.51
Cotton	1933-41	+.34
	1942-48	-.68
North Carolina:		
Price of corn and acreage of:		
Corn	1933-40	-.42
	1941-48	-.57
Cotton	1933-40	+.06
	1941-48	-.39
Price of tobacco and acreage of: 2/		
Tobacco	1933-40	-.24
	4/ 1941-48	+.77
Cotton	1933-40	+.13
	4/ 1941-48	-.79
Price of hay and acreage of:		
Hay 3/	1933-40	+.20
	1941-48	+.92
Cotton	1933-40	-.44
	1941-48	-.87

1/ Prices deflated by price of cotton. Acreage figures are harvested acreages of particular crops as percentages of total harvested acreages of all principal crops.

2/ Choice of period to be covered was dictated partly by factual information and partly by formation of scatter diagrams relating acreage and price received, which indicate that substitution began in Georgia and North Carolina in 1941 and in the other States in 1942. Another reason for starting with 1941 for these 2 States is the lower degree of underemployment and the underplanting of cotton, peanuts, and, in some instances, tobacco, relative to total cropland. Somewhat higher correlation coefficients were obtained by omitting the 1942 observations in Florida, South Carolina, and Alabama.

3/ Excludes alfalfa, clover-timothy, and lespedeza, which are not subject to year-to-year variations. In Georgia and Alabama, excludes peanuts for hay in 1944-48 because significant part of acreage is hogged-off - information not available on peanuts for hay before 1944.

4/ 1947 omitted because it shows as extreme deviation in scatter diagram.

Agricultural Statistics, U. S. Dept. Agr. (annual), and unpublished data in the U. S. Agricultural Marketing Service.

Table 2 indicates that before 1941 there was little response of acreage percentages to price ratios. No doubt this was due to the restriction programs. Except for the corn-cotton relation in Florida and North Carolina, the signs of all the coefficients reflect crop substitutions during the years 1942 to 1948. Nevertheless, the values of the coefficients for corn are very small, except possibly in South Carolina. Hay and peanuts are the strongest substitutes for cotton in the Southeast, with correlation coefficients in the neighborhood of 0.8 and 0.9. The correlation for tobacco is somewhat weaker; the explanation probably lies in the geographic separation of growing areas within the State, the different types of fixed inputs required for tobacco, and other factors that contribute to lags in response. The phenomenal rise in the price of livestock during World War II apparently accounts for the switch from cotton to hay. From 1940 to 1950, there was a correlation between annual average prices received by farmers for meat animals and acreage of hay in the Southeast (the coefficient is 0.81) and between annual average prices received for dairy products and hay in this region (the coefficient is 0.76). Since 1940 the number of livestock on farms in the Southeast has increased steadily. 12/ If the data were available on an annual basis, one might expect to find that there was also a substitution of cropland devoted to pasture for cotton acreage. Census-of-Agriculture data for 1940, 1945, and 1950 indicate that cropland in pasture has increased continuously in the southeastern cotton-growing States. The shortage of fats and oils in the United States during World War II and the consequent high price of peanuts probably accounts for the substitution of peanuts for cotton in Georgia and Florida. The patriotic appeal for increased output may have helped also.

Care must be taken in interpreting the correlation coefficients for the World War II and postwar periods. The samples from which they were calculated consist of either 7 or 8 observations, and it is easy for sampling errors to distort the picture. Statistical tests for the reliability of the correlation coefficients were applied. The coefficient for cotton and corn in South Carolina should be rejected as unreliable on statistical grounds (it does not differ significantly from zero). The coefficients found for hay, peanuts, and tobacco are clearly acceptable. 13/ The degree of confidence placed in the estimates must be based upon both economic logic and the statistical properties of the estimates. Although the sample is smaller than

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12/ U. S. Bureau of Agricultural Economics. Will More Forage Pay? U. S. Dept. Agr. Misc. Pub. 702, November 1949.

13/ The t test for small samples was used to test the statistical significance of the coefficients. Coefficients for corn and cotton in South Carolina were found to be not significant at the 5-percent level. The others are clearly significant. For all correlations except that between corn and cotton in South Carolina, this is equivalent to the statement that we reject the hypothesis that the "true" correlation coefficient is zero, that is, that there is no correlation in the population. By choosing the 5-percent level of significance, we reject the hypothesis that there is no correlation because the probability that the divergence between the empirical results and the hypothesis is due to chance is less than 5 percent.

most samples with which economists work, sufficient reasons are drawn from economic theory to support the conclusions regarding crop substitution. If a larger sample were available, however, it would enable us to be more decisive about the conclusions. Acreage allotments were placed on cotton in 1950 but were removed again from 1951 to 1953. This does not help in the case of peanuts because peanut acreage was under allotment during this period. For hay, the other important substitute, we do obtain three more observations that are free from acreage restrictions. The results obtained from the introduction of these additional observations can only be described as inconclusive. For North Carolina, the reliability of the correlation was increased; for Alabama the results were mixed; and for Georgia the correlation was weakened somewhat. 14/ It is questionable whether data taken from this period can be considered as uninfluenced by acreage restrictions. There was little assurance that the absence of allotments would be more than a year or two in duration. The basic conditions that affected farmers' expectations with respect to restrictions probably differed from those existing during World War II. The way in which this short-term removal of allotments affected farmers' expectations is uncertain.

To obtain an idea of the absolute change in cotton acreage in response to prices of substitute crops, cross elasticities were computed. Acreage of cotton is not expressed here as a percentage of total cropland. When two crops are substitutes in production, their price cross elasticities of supply are negative. 15/ If the cross elasticity of cotton acreage with respect to relative prices of other crops is negative, its value gives a measure of the percentage change in cotton acreage in response to the percentage change in the price of substitute crops relative to the price of cotton.

Cross elasticities of the harvested acreage of cotton with respect to the prices of hay, peanuts, tobacco, and corn, each deflated by the price of cotton for the war and postwar years covered in table 2, were computed at the

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14/ The correlation coefficients for hay acreage and relative prices and cotton acreage and relative prices are both approximately unchanged in North Carolina. With three more observations, this increases the value of t by increasing the degrees of freedom. For Alabama, the correlation between the acreage and the price of hay does not change significantly, but the coefficient between the acreage and the price of cotton is reduced by about 0.10. Both correlations are weakened for Georgia. The coefficient between the acreage and the price of hay decreases by about 0.08 and between the acreage and the price of cotton by about 0.13.

15/ The cross elasticity of a commodity x with respect to the price of another commodity y is defined as the percentage change in the supply of x with respect to a percentage change in the price of y relative to the price of all other commodities.

mean values of prices and acreages from multiple linear regressions as follows:

Crops	Elasticities
Hay:	
Alabama	-.84
Georgia	-.47
North Carolina	-.64
Peanuts:	
Georgia	-.31
Florida	-1.54
Tobacco:	
North Carolina	-.22
Corn:	
South Carolina	-.09

Simple linear regressions on the deflated prices of hay, peanuts, and corn were used for Alabama, Florida, and South Carolina, respectively. For Georgia and North Carolina, multiple linear regressions of cotton acreage on the prices of two substitute crops were used. The statistical properties of these latter regressions must be taken into account in interpreting the results. Multicollinearity was found to exist in the regression for North Carolina when the deflated prices of hay and tobacco were used as explanatory variables. Although this means that the separate influences of the two explanatory variables cannot be ascertained (the coefficients that satisfy the relation are not uniquely determined), the signs of the coefficients are still relevant. Therefore, they were included in the tabulation above. They must be interpreted with this reservation on their numerical values.

The negative elasticities give further evidence of substitution, but the degree of substitution is relatively weak between cotton and tobacco and between cotton and corn. This corresponds with the evidence in table 2.

The data presented in table 2 and the tabulation above support strongly the hypothesis that the dominant force operating to decrease the acreage of cotton when restrictions were removed is to be found in the substitution of hay and peanuts (and perhaps pasture) for cotton during this period. Changes in inputs and in relative prices of inputs also need to be considered in any analysis of the substitution of other crops for cotton. The increase in the relative price of labor, for example, may have affected the decrease in cotton acreage in two ways. In the first place, the profitability of cotton production relative to production of substitute crops was reduced. The price of labor increased more than the prices of other inputs. Also, the quantity of labor used per acre is much greater for cotton than for crops such as hay and peanuts. Second, when changes in labor input are solely the result of changes on the supply side of the labor market (rather than changes in the demand for labor in response to relative crop prices), then changes in the price of labor may be considered as another index of labor availability. As the supply of labor decreased, especially in recent years, the substitution of other crops for cotton may have represented partly a shift from labor-intensive to labor-extensive enterprises. The effects of changes in the wage rate of labor and changes in other costs on the profitability of cotton production relative to other crops need to be explored further.

In the section that follows, the general implications of crop substitution for the construction of aggregate supply functions are discussed. In particular, an attempt is made to measure the influence of prices of substitutes on the acreage of cotton in the preallotment period.

IMPLICATIONS FOR AGGREGATE SUPPLY FUNCTIONS

Recent writings in agricultural economics have emphasized our lack of knowledge of aggregate supply response. 16/ Most writers have not questioned the adequacy of our quantitative knowledge of supply response for individual products. Instead, they have stressed the shortcomings in our knowledge concerning changes in the supply of farm products as a whole. The factors connected with technological change and input-output relationships have received primary attention.

The conclusions reached in the study reported here suggest that too much existing quantitative knowledge as to the response of individual commodities may have been assumed. The few known attempts to construct geographically aggregated supply functions for single commodities for the United States have used average United States data on acreage, production, prices, and so on. 17/ Furthermore, few workers have included the prices of

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16/ Cf. Schultz, T. W., Reflections on Agricultural Production, Output and Supply, Jour. Farm Econ. 38: 748-762 (1956). Johnson, G. L., Some Facts and Notions About the Supply Function for Agriculture, unpublished paper presented at the Conference on Adjusting Commercial Agriculture to Economic Growth, Chicago, Ill., March 18-19, 1957.

17/ See Nerlove, M., Estimates of the Elasticities of Supply of Selected Agricultural Commodities, Jour. Farm Econ. 38: 496-509. (1956).

other outputs or of inputs in their investigations. This type of averaging may lead to results that are accurate enough for some products. However, many crops are grown over wide areas, within which technological conditions, soils and climate, alternative crops, wage rates, and so on, differ enough to produce different production responses in different locations. As these differences are masked by average figures for the United States as a whole, it is likely that the quantitative predictions these data yield are unreliable.

These considerations imply that a more fruitful approach to the problem of supply response can be found in more micro-economic research (other than studies of individual farms). The total United States supply could then be built up from several functions - one for each geographic region containing the variables relevant to that region. Ideally, each region would be defined in terms of homogeneity of crop substitutes, type of operation, controlled inputs, climate and soil, technology, and so on. 18/

As a special case, it may be acceptable to define one region which includes all United States acreage devoted to a particular crop, that is, the region would be the United States as a whole. To do so, it would be necessary that the fundamental conditions that affect production be approximately the same in separate geographic locations. This is basically the problem of defining the extent of the markets for inputs and output. Substitute crops, the stage of technological advancement, and the nature of the labor market must be similar enough to justify the use of average United States data on prices, wages, and so on. For cotton, at least 10 economically defined regions would be required. Of course, data must be available by economic regions, and our present geographic classifications prevent the realization of this ideal. 19/ In addition, as planned output is the product of planned acreages and planned yield per acre, a completely adequate supply function should include a yield-response component for each region. In future years, the withdrawal of labor from cotton production will probably become more important. Its influence might be summarized in the wage rates for hired labor and estimates of returns to "unpaid" labor and management. Other factors that operate in the input markets may also affect output markedly. Here again, the effects in various regions may show significant quantitative differences.

As an initial step in the direction of regional aggregation, a tentative cotton acreage-response function for the United States has been

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18/ A possible complementary technique of research where it would be possible to measure more accurately changes in profitability might be analysis of typical farms representative of the important production situations in the area. These representative situations could be weighted on the basis of their relative importance in aggregating for the region.

19/ The 1954 Census of Agriculture contains a special report entitled "Cotton Producers and Cotton Production," Vol. III, Part 9, Chapter II, in which data on cotton are classified by 10 subregions.

constructed for the period 1905-32 (prior to price supports). Only under very restrictive assumptions as to the behavior of planned yields can it be considered as an approximation to the supply function. The acreage of cotton in the United States has been divided into three geographic categories. 20/ In each of the three regions the acreage of cotton is expressed as a function of the expected price of cotton, the expected prices of selected substitute crops, and trend. The introduction of time into the multiple regression equation is equivalent to measuring the set of other variables as deviations from linear time trends. An estimate of total acreage for the United States can be obtained by adding the estimated acreage in each of the three regions.

By this formulation, the acreages of cotton on July 1 in each region are approximated from observations on estimated expected prices in the region and a trend variable. The expected prices of each crop are assumed to depend upon two past prices; they are computed from J. R. Hicks' elasticity of price expectation. 21/ This is equivalent to the assumption that the expected percentage change in price in the current year relative to the price in the preceding year is proportional to the percentage change in price last year relative to the price 2 years ago. (See Appendix.) In estimating expected prices from knowledge of 2 past prices, price lagged 1 year is weighted more heavily than price lagged 2 years. The past prices are season average prices received by producers. For each State, they are weighted by the acreage in the State and deflated by an index of prices received for all farm products. The choice of potential substitute crops was determined by the number of acres devoted to various crops in each State. Measured in terms of acreage harvested, the important potential substitutes in the Southeast are corn, hay, tobacco, and peanuts. Corn and hay are potential substitutes in the Delta region and corn, wheat, and oats in the Southwest. In the Southwest, substitute crops in California, Arizona, and New Mexico were ignored because these States produced less than 3 percent of all cotton produced in the region. Grain sorghums were important in Texas and Oklahoma but they had to be omitted because the series on acreage and price did not go back beyond 1918. In general, the Delta and the Southwest are more homogeneous than the Southeast with respect to substitute crops grown in various areas within the region.

20/ The Southeast includes North Carolina, South Carolina, Georgia, Alabama, and Florida. The Delta consists of Louisiana, Mississippi, Arkansas, Tennessee, and Missouri. The Southwest includes Texas, Oklahoma, California, Arizona, and New Mexico after 1921.

21/ Let $\dot{P}_t$ represent the expected price in year t and P_t the actual price. The elasticity of price expectation, α , is defined as:

$$\frac{\dot{P}_t - P_{(t-1)}}{P_{(t-1)}} = \alpha \frac{P_{(t-1)} - P_{(t-2)}}{P_{(t-2)}}$$

where α is a constant. $\dot{P}_t$ is estimated from this relation after α has been determined by least squares from the relation $\log P_{(t-1)} = \alpha \log P_{(t-2)} + \log k$, where k is a constant.

The acreage-response function is assumed to be approximately linear in each region. The following relations were found for the regions indicated. The partial regression coefficient for the expected price of oats does not differ significantly from zero, and it was omitted from the equations. Figures in the parentheses are standard errors of the regression coefficients. 22/

$$(1)\quad X_e = 12.02 + \underset{(\pm .097)}{.29\dot{P}_c} - \underset{(\pm .019)}{.05\,\dot{P}_r} - \underset{(\pm .009)}{.02\,\dot{P}_t} - \underset{(\pm .020)}{.10\,\dot{P}_p} - \underset{(\pm .058)}{.13\,t}$$

$$R^2 = .79$$

$$(2)\quad X_d = 6.37 + \underset{(\pm .080)}{.25\dot{P}_c} - \underset{(\pm .031)}{.06\,\dot{P}_r} + \underset{(\pm .087)}{.16\,t}$$

$$R^2 = .84$$

$$(3)\quad X_w = 11.76 + \underset{(\pm .151)}{.48\,\dot{P}_c} - \underset{(\pm .014)}{.03\,\dot{P}_r} - \underset{(\pm .031)}{.07\,\dot{P}_w} + \underset{(\pm .111)}{.17\,t}$$

$$R^2 = .73$$

X_e, X_d, and X_w are the estimated planted acreages on July 1 for the Southeast, the Delta, and the Southwest, respectively, measured in millions of acres. $\dot{P}_c$, $\dot{P}_r$, $\dot{P}_t$, $\dot{P}_p$, and $\dot{P}_w$ are the expected prices in cents per unit of cotton, corn, tobacco, peanuts, and wheat in each region. Each expected price was computed by the method outlined previously. The trend variable is represented by t.

Comparison of the numerical values of the coefficients in each equation indicates the relative importance of the variables in determining the acreage of cotton on July 1. For the period covered by the data, the relatively small values of the coefficients of prices of substitute crops

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22/ The standard errors have the following interpretations: Assuming a normal distribution of sample coefficients from a large number of samples, the chances are approximately 68 in 100 that the computed coefficient lies within one standard error of the "true" or population coefficient. The chances are approximately 95 in 100 that it lies within two standard errors of the population coefficient. Using R. Frisch's bunch maps, no definite multicollinearity could be estimated among the explanatory variables. However, for the expected prices of corn and wheat in the Southwest, the conclusions that can be drawn from the bunch maps are uncertain. To test for the presence of autocorrelation in the residuals, the ratio of the mean square successive difference to the variance was used. The hyothesis of no significant autocorrelation cannot be rejected.

suggest that substitution of other crops for cotton occurred only when relatively large changes in price were expected for the substitutes. The comparatively weak multiple correlation coefficient (R) in the Southwest is probably due to the omission of grain sorghums.

These results may be compared with those obtained by writers who have used average data for the United States as a whole and have not included the prices of substitutes in their estimation procedures. Nerlove 23/ expresses cotton acreage as a function of the expected price of cotton and trend. The expected price is a weighted average of several past prices. Earlier investigations commonly used cotton price lagged 1 year as the explanatory variable. The price elasticity of acreage of cotton with respect to the expected price of cotton is a measure of the percentage change in the acreage of cotton that would accompany a given percentage change in its expected price, all other expected prices remaining constant. Nerlove estimates the price elasticity of supply (acreage) as 0.67 as compared with approximately 0.20 derived by previous writers using price lagged 1 year. Our estimates of price elasticity lie between these two. For the Southeast, the Delta and the Southwest, the price elasticities are 0.33, 0.31, and 0.37, respectively. They were derived from equations (1), (2), and (3) at the mean values of expected cotton prices and acreages. It is questionable whether a simple linear aggregation of the three acreage-response functions is appropriate.

For comparison purposes, however, a supply function for the United States which is a linear sum of (1), (2), and (3) has a price elasticity of approximately one. (See Appendix.) The percentage of the total variation in cotton acreage attributed to the explanatory variables (reflected in the value of R^2) is 0.59 for price lagged one year and trend and 0.74 for Nerlove's expected price and trend. Equations (1), (2), and (3) show R^2 values of 0.79, 0.84, and 0.73 respectively. The trend variable summarizes the systematic forces affecting acreage that were not included independently

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23/ Nerlove, *op. cit.*, pp. 501. More exactly, the Nerlove formulation assumes that decision-makers revise the price they expect in the coming year in proportion to the error made in predicting price in the current year. That is,

$$P^*_t - P^*_{(t-1)} = \beta (P_{(t-1)} - P^*_{(t-1)}), \quad 0 < \beta < 1,$$

where P^*_t and $P^*_{(t-1)}$ are expected prices in year t and t-1, respectively, $P_{(t-1)}$ is the actual price in year t-1 and β is a constant. This equation is a first order difference equation in expected price, the solution of which is

$$P^*_t = \beta P_{(t-1)} + (1-\beta) \beta P_{(t-2)} + (1-\beta)^2 \beta P_{(t-3)} + \cdots\cdots$$

That is, expected price can be expressed as a weighted moving average of past prices, where the number of past prices to be included is determined by the data.

in the equation. A reduction in its coefficient reduces our "ignorance" about the separate influence of these forces. The trend coefficients in (1), (2), and (3) are slightly less than those obtained by Nerlove. He finds a trend coefficient of 0.18 as compared with a trend coefficient of 0.48 in the relation using prices lagged 1 year.

The preliminary geographic breakdown into three regions shows some improvement in our ability to explain changes in cotton acreage. The results are not entirely satisfactory but the tentative nature of these quantitative estimates must be emphasized. They do point up the need for more precise formulations of acreage and production response.

Putting aside the problems of total production and yield response, more exact criteria for an acreage-response function are required. Progress in this direction may demand a more economically meaningful subdivision of geographic regions. This is indicated by the number of prices included in the acreage function for the Southeast. Peanuts, for example, are not grown throughout the Southeast. The influence of the expected price of peanuts on the acreage of cotton is greater in Georgia and Florida than in the Carolinas. The importance of tobacco as a potential substitute for cotton differs in various States of the Southeast. There is a similar situation in Texas. Cotton is grown in the Black Prairie, the High Plains, and the southern coastal areas. The relative importance of substitutes differs among these areas. They differ also through time. In the Delta in recent years, the acreage devoted to soybeans for beans has expanded. In Texas and Oklahoma, hybrid grain sorghums have been developed.

A closely related consideration is the criterion for choice of potential substitutes. The basis used here is the magnitude of land devoted to a crop. Although small in land coverage, truck crops probably play a more important role as a substitute for cotton than is indicated by number of acres alone. Probably, type and size of operation should receive some weight in the choice of substitutes in different regions. In addition, a more appropriate price-expectation function may be called for. Changes in demand and supply in the markets for factors of production have not been taken into account in our model. Only continued research and consistent empirical success will enable researchers to choose between alternative formulations. Some simplification in choice of variables and classification of data is always required. In any research, some variables must be omitted. The problem reduces to choosing the most important variables and relegating the rest to the role of random disturbances. In the geographic breakdown of production response, probably a less-than-perfect classification must be accepted in order to make the problem manageable.

The results obtained for the years from 1905 to 1932 suggest that prices of substitute crops partly explain changes in cotton acreage. The World War II experience indicates that under appropriate conditions, cotton farmers respond significantly to relative price changes. If our concern is with future years and future economic farm policy, improved quantitative knowledge about the relative importance of the several factors that influence acreage and production will be valuable. Quantitative estimates are more meaningful for rational planning than either casual empirical observations or *a priori* qualitative inferences.

APPENDIX

The Derivation of Expected Price

Assume that the price in period t-1 is an exponential function of the price in period t-2. Then

(4) $$P_{(t-1)} = k\, P^{\alpha}_{(t-2)},$$

where k and α are constants. Expressing this relationship in logarithmic form,

(4) becomes

(5) $$\log P_{(t-1)} = \alpha \log P_{(t-2)} + \log K.$$

The elasticity of any variable y with respect to another variable x is the ratio of the percentage change in y to the percentage change in x. More exactly, it is the first differential of y over y divided by the first differential of x over x. This may be expressed as $\frac{dy}{dx} \cdot \frac{x}{y}$. Following this definition, we have for (5)

(6) $$\frac{d\, P_{(t-1)}}{P_{(t-1)}} = \alpha \frac{d\, P_{(t-2)}}{P_{(t-2)}}$$

or

(7) $$\frac{\dfrac{d\, P_{(t-1)}}{P_{(t-1)}}}{\dfrac{d\, P_{(t-2)}}{P_{(t-2)}}} = \alpha$$

where α is the constant elasticity. α can be estimated by least-squares techniques. We can approximate $d\, P_{(t-1)}$ and $d\, P_{(t-2)}$ by taking first differences. Then (6) becomes

(7) $$\frac{\dot{P}_t - P_{(t-1)}}{P_{(t-1)}} = \alpha \frac{P_{(t-1)} - P_{(t-2)}}{P_{(t-2)}}.$$

We have substituted the expected price in period t, $\dot{P}_t$, for the actual price, which is unknown in period t. However, the past prices, $P_{(t-1)}$ and $P_{(t-2)}$, are known. α has also been estimated. Solving for $\dot{P}_t$, we have

$$(8) \qquad \dot{P}_t = \alpha \frac{P^2_{(t-1)}}{P_{(t-2)}} + (1-\alpha) P_{(t-1)}$$

It may be seen from this relation that $P_{(t-1)}$ carries more weight in the determination of $\dot{P}_t$ than does $P_{(t-2)}$.

Derivation of the Elasticity of the Acreage-Response Function for the United States as a Whole

It was mentioned earlier that the elasticity of cotton acreage with respect to the price of cotton for the United States as a whole was computed from a linear sum of the three regional acreage-response functions. This aggregation gives the following acreage-response function for the United States as a whole:

$$(9) \qquad X_u = X_e + X_d + X_w = 30.15 + 1.02\, \dot{P}_c - .14\, \dot{P}_r - .02\, \dot{P}_t - .10\, P_p - .07\, \dot{P}_w + .20\, t.$$

X_u is total acreage for the United States as a whole. The other variables have been defined in the main body of the study. From this relation, the elasticity of total United States cotton acreage with respect to the average price of cotton is derived as follows:

$$(10) \qquad \frac{dX_u}{dP_c} \cdot \frac{\bar{\dot{P}}_c}{\bar{X}_u} = (1.02)\,(.97) = .99,$$

in which $\bar{X}_u$ and $\bar{\dot{P}}_c$ are the arithmetic means of cotton acreage and weighted prices in each region.

This naive summation procedure assumes that the parameters in the aggregate acreage-response function for the United States as a whole are simple unweighted sums of the corresponding parameters in the regional equations. From a mathematical (and an economic) viewpoint, this assumption is untenable. Only a few brief comments on aggregation in economic models can be included here. 24/ In general, the intercept in the United States

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24/ See Theil, H., Linear Aggregation of Economic Relations (Amsterdam, North-Holland Publishing Company, 1954) for a complete discussion of the problems of aggregation.

response function depends not only on the corresponding intercepts in the regional functions but also upon other slope parameters (coefficients) in the regional equations. The slope parameters in the function for the United States as a whole depend not only on the corresponding slope parameters in regional equations but also upon the other slope parameters in the regional equations. Finally, both the intercept and the slope parameters in the United States function may depend upon the values of the variables in the regional equations. The problem may be expressed somewhat differently: Weights enter into the summation process but are ignored in the naive method of simple summation. The weights in the summation of regional intercepts, for example, are related to the slope parameters in the regional equations. Under certain conditions, these weights are zero; when this occurs simple unweighted addition of the intercepts is acceptable. It is doubtful, however, that these conditions are met in the case of cotton.

The problems involved in the aggregation process render the estimated elasticity of total United States acreage with respect to the price of cotton (0.99) untenable. The elasticity is probably smaller. The suggestions advanced in pages 28 to 29 of this report must take into account a more sophisticated method of aggregation, which requires a comprehensive study of acreage response for cotton.

Agriculture - Washington