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The Cotton Harvester in Retrospect:
Labor Displacement or Replacement?

Willis Peterson and Yoav Kislev

Department of Agricultural and Applied Economics

University of Minnesota
Institute of Agriculture, Forestry and Home Economics
St. Paul, Minnesota 55108

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I. The Problem

While the large scale substitution of capital for labor in U.S. agriculture is well known, the driving force behind this phenomenon is not obvious or agreed upon. In the recent economics literature the prevailing view seems to be that new mechanical technology has displaced or forced labor out of agriculture (See for example Day, 1967; Maier, 1969; Schmitz and Seckler, 1970). There is of course an alternative hypothesis, namely that rising wages in nonfarm occupations have drawn labor out of agriculture and new labor-saving technology was developed and adopted in order to replace the people who left farms in search of higher earning opportunities elsewhere. Under the first hypothesis labor is viewed as being pushed out of agriculture by a reduction in demand for its services while under the second, labor is pulled out by a decrease in supply.

The mechanization of cotton harvesting is viewed by many as one of the clearest examples of labor push, particularly in the Southern States. Cotton mechanization is regarded as the prime cause of the large social and economic changes that occurred in the South (Day, 1967). We therefore propose to use the mechanical cotton harvester as a test of the alternative hypothesis; namely, that labor exit was mainly due to increased real wages outside of agriculture and that machines were adopted in response to a reduction in labor supply.

The period of the analysis is 1949-1964, which covers most of the adoption process. In 1949 6 percent of the cotton was harvested mechanically;

this figure increased to 78 percent in 1964 and 100 percent in 1972.

The issue addressed is of more than academic interest. If labor has in fact been pushed out of agriculture then the research establishment along with farm machinery companies share responsibility for the social costs of the large scale migration of farm people. In this case a concern by government over job loss in agriculture and action to mitigate this process would be legitimate. On the other hand, if labor has been pulled out by higher earnings in nonfarm occupations, research institutions and machinery manufacturers can be viewed as responding to market forces. And public action to counteract these forces probably would harm society more than it would help.

II. Preliminary Evidence

In an earlier article in this journal, Richard Day (1967), using a recursive programming model found that unskilled labor in the Mississippi Delta was a "tight" or constraining resource in crop production during the 1940s but became a surplus input at current expected prices during the 1950s. He argued therefore that during the latter period migration out of the region "was induced more by a push than a pull effect." However Day attributed all the reduction in employment to lower machine prices and neglected to take into account the decrease in the real price of cotton and, as a result, in cotton acreage. As shown in Table 1 the real price of cotton (current prices deflated by the CPI) declined by about 15 percent from the first to the second half of the 1950s and cotton acreage decreased about 37 percent during this period. Since cotton was a relatively labor intensive crop compared to the ones that replaced it, particularly sorghum and soybeans, the total demand for farm labor should have decreased as

Table 1. *Cotton and Wage Statistics (1969 prices)

	Cotton			Wages		
Period	Price	**Acreage	Yield	Piece Rates	Hourly Rates	Mfg Wages
1949-53	$.501	24,499	285	$4.05	$ .89	$1.92
1954-58	.427	15,440	404	3.50	.94	2.25
1959-63	.401	15,168	464	3.30	.98	2.44
1964-68	.298	11,076	479	--	1.16	2.66

* See Appendix for definitions and data sources.

** 1000 acres.

Prices and wages deflated by the CPI, 1969 = 100.

a result. Moreover, Day greatly over estimated the role of mechanization in the later period of his analysis. His model suggested complete mechanization for 1957 (see his figure 2) while actually only 17 percent of the cotton was machine harvested in Mississippi in that year (USDA Stat. Bul. 417).

In a study focused more specifically on the adoption of the mechanical cotton picker Maier (1969) argued that the picker must have displaced labor because piece rates (in current dollars) for hand picking of cotton remained relatively constant over the period of adoption. In fact as shown in Table 1 piece rates in real terms declined substantially during the 1950s and early 1960s. This observation, which may be taken to support the labor push hypothesis, is, however, inconsistent with the fact that the October hourly earnings in the 16 major cotton states increased in real terms over the period (Table 1). Surely the labor in picking cotton and other types of farm work was highly substitutable. The most likely explanation for the divergence between the piece and hourly rates is that even though piece rates declined, the hourly earnings of cotton pickers increased along with the earnings of other agricultural labor because of the increase in cotton yields: 68 percent over the 20 year period. While it may take more time to pick an acre of cotton yielding 400 pounds than one with half the yield, it is not likely to take twice as long. Dragging the bag of cotton along the row was a rather substantial part of the time and effort involved in picking cotton. The important figure determining the supply of labor by cotton pickers was their hourly or time rate earnings, not the piece rate, although the latter affected the former, of course. There are no official earnings figures for piece rate work but special surveys by the U.S. Dept. of Agriculture, Statistical Reporting Service, reveal that piece rate workers earn up to 50 percent more on an hourly basis than other hired farm workers.[1/] The evidence also suggests that migratory workers who are paid largely on a piece rate basis on the average earn as much or more than other agricultural workers on an annual basis.[2/] Thus it is questionable that the decline in real piece rates for picking cotton meant that actual earnings of cotton pickers also declined. This in turn calls into question the wage rate test of the push hypothesis.

III. The Model

We propose the following simple model of the farm labor market for picking cotton as a more direct test of the two alternative hypotheses.

(1) $Q^d = a + bW_c + cP + dM + eY + u_1$ demand

(2) $Q^s = \alpha + \beta W_c + \gamma W_m + \delta B + u_2$ supply

(3) $Q^d = Q^s$ equilibrium

where: Q^d, Q^s = quantity of labor demanded, or supplied, for hand picking of cotton

W_c = hourly wages of cotton picking labor

P = price of cotton in year t-1

M = hourly cost of machine picking of cotton

Y = cotton yields

W_m = hourly wages in manufacturing

B = number of Braceros admitted during the cotton harvesting season.

A detailed description of the variables along with the data sources is presented in the Appendix. The model is fitted in log linear form to pooled time series - cross section state level observations for 12 of the major cotton producing states encompassing the 1949-1964 period (N = 192).[3/] Although not designated above, state dummies are included in the empirical estimation of the model. All monetary values are deflated by the CPI, 1969 = 100.

In the labor supply equation manufacturing wage rates in each state are used as a proxy for the opportunity cost of picking cotton. Labor can of course choose other employment or migrate between states but own-state manufacturing wage rates should provide a lower bound of this opportunity cost. The number of workers admitted under the Bracero program during the cotton harvest season between 1952 and 1964 is considered a supply shifter in addition to manufacturing wages.

IV. The Main Results

The results of estimating the cotton picking labor demand and supply functions are presented in Table 2. The equations were estimated in log form, and the coefficients are elasticities.[4/] Except for the coefficient on machinery price all the 2SLS coefficients are significant and have the expected signs. The findings indicate very elastic labor supply and demand functions as should be expected in cases in which substitutes are readily available -- machinery on the demand side and nonfarm employment on the supply side. While the machine price elasticity in the demand equation is positive, indicating a push effect does exist, it is small relative to the pull effect of manufacturing wages in the supply equation.

A better picture of the relative impacts of the exogenous variables on cotton picking wages and employment is obtained by solving for W_c in in equations (1) and (2) to obtain (4).

*Table 2. Regression Results

A. Labor Demand

Ind. Var.	OLS	2SLS
Price of labor	-2.80 (-4.73)	-11.1 (-5.35)
Price of cotton	3.10 (10.2)	2.57 (5.59)
Price of machines	1.21 (4.83)	.419 (1.03)
Cotton Yields	.34 (1.91)	1.53 (4.08)
R^2	.845	.727

B. Labor Supply

Ind. Var.	OLS	2SLS
Price of labor	-.442 (-.77)	4.74 (2.24)
Mfg. wages	-4.64 (-13.3)	-6.91 (-7.11)
Braceros	.270 (8.74)	.305 (7.68)
R^2	.864	.814

* Figures in parentheses are t-ratios. State dummies and intercepts are not shown.

$$(4) \quad W_c = \frac{1}{b-\beta} [(\alpha-a) + \gamma W_m + \delta B - cP - dM - eY]$$

The results of using equation (4) to calculate the partial and total effects of the changes in the exogenous variables of the model are presented in Table 3. For example, the real price of cotton declined on the average by 1.90 percent per annum during the 1949-1964 period; this shifted the demand for labor to the left at an annual rate of 4.88 percent. Assuming no change in supply, equilibrium wage was reduced, due to the change in price of cotton by 0.31 percent annually and the equilibrium quantity of labor employed decreased by 1.47 percent per year.

Compared to the negative impact on wages and employment of the decline in the real price of cotton, the effect of the delcine in the real price of the mechanical cotton harvesting services was relatively small. Moreove- the negative effect of both these factors was exactly offset by the positive impact of cotton yields. Consequently the model indicates no net shift in labor demand over the period; the decline in the supply of labor due to higher wages in other occupations explains 100 percent of the wage and employment changes over the period.

Of course the role of mechanization varied between states. As shown in Table 4 mechanical harvesting was adopted earlier and reached saturation sooner in the high wage states such as California than in states such as Alabama where labor was relatively cheap. As expected machine harvesting costs per hour did not vary much between states but declined over time as the supply of machines increased.

It should be recognized that the relative price changes observed during the 1949-1964 period do not tell the entire story. The largest gains in farm wages occurred during World War II. Between 1940 and 1946 real farm wages in the U.S. more than doubled. However farmers could not begin to

Table 3. Model Application

		Change in variable	Horizontal Shift in function	Changes in Equilibrium Values of wages	Changes in Equilibrium Values of labor employed
		(1)	(2)	(3)	(4)
Demand					
Price of cotton	P	-1.90	-4.88	-0.31	-1.47
Price of machinery	M	-2.09	-.88	-0.06	-0.28
Cotton Yield	Y	3.85	5.89	0.37	1.75
Total Demand				0	0
Supply					
Wages in manufacturing	W_m	2.28	-15.75	0.99	-10.99

Note:

Column (1) Annual rate of change; the value of r estimated in the regression log x(t) = a + rt + s + u for each variable x. s is a set of state dummies.

(2) Col. (1) times the corresponding coefficient in Table 2.

(3) Col. (2) times 1/(b-β) times the sign of the corresponding coefficient in equation (4).

(4) Col. (3) times the elasticity of supply (4.74) for demand shifts and the elasticity of demand (-11.1) for the shift in supply.

Table 4. Cotton Harvesting Methods and Prices
California and Alabama
(constant 1969 prices)

	1949	1964
I. Percent Harvested by Machine		
Alabama	0	67
California	13	97
II. Manufacturing Wage Rates per Hour		
Alabama	$ 1.75	$ 2.55
California	2.46	3.48
III. Agricultural Wage Rates per Hour		
Alabama	$ .62	$ .81
California	1.40	1.60
IV. Machine Harvester Cost per Hour [a/]		
Alabama	$29.92	$21.06
California	29.32	20.37

a/ Two-row low drum and high drum models.

adopt mechanical harvestors until after the war when peacetime production resumed. It is likely that the wartime wage increases by themselves were enough to tip the scale in favor of mechanical harvesting. Afterall mechanical cotton harvestors did not just come on the scene in the late 1940s. The first mule drawn picker was produced nearly 100 years earlier in 1850 (Street). Self propelled, tractor drawn, and tractor mounted machines appeared in the 1920s. Granted the early machines no doubt were less efficient than later models. By the late 1940s over 1800 patents had been issued on the mechanical cotton harvestor. If the relative price of farm labor had risen before World War II to its post-war level it is hard to believe that the machines would not have been brought into widespread use. Before the war it was just cheaper to use labor rather than machines to pick cotton.

V. Concluding Remarks.

The evidence presented in this study is consistent with the hypothesis that cotton harvesting labor was in large part pulled out of agriculture by higher wages in nonfarm occupations rather than displaced by new machine technology. While it is hazardous to generalize these results to all of agriculture, they should at least prompt one to question the popular assumption that farmers have been "tractored off of farms", in effect losing their jobs to machines. Of course, it will always be possible to find individuals who lost their jobs to machines; we do not deny that such cases exist. But our results imply that such cases are the exception rather than the rule, and that the main force behind the reduction in number of farm people has been the increase in the opportunity cost of farm labor rather than the introduction of new machines. Therefore it would appear to be a mistake for government to actively discourage the development of mechanical technology with the objective of saving jobs in agriculture.

Appendix

Construction of Variables and Data Sources.

Price of Labor: Hourly wage of hired farm labor during October (without room and board) in each of the 12 cotton producing states. The wage rate data are from the various issues of Farm Labor. Piece rates for picking cotton are from USDA Stat. Bul. 417. "Statistics on Cotton and Related Data."

Price of Cotton: Price per pound of cotton received by farmers in each of the 12 states in year t-1 of the regression. Source: USDA Stat. Bul. 417 and 617, "Statistics on Cotton and Related Data."

Yields of Cotton: Measured as pounds of cotton per harvested acre in each of the 12 states over the 1949-64 period. Source: USDA Stat. Bul. 417 and 617, "Statistics on Cotton and Related Data."

Quantity of labor to pick cotton. There are no official statistics on this variable. We assumed that cotton pickers earned on the average the same hourly wage rates as other hired farm workers in these 12 states during the month of October. By dividing the hourly wage rate (W_c) by the piece rate (P_c) we obtain the pounds of cotton picked per hour. Dividing this figure into total pounds of cotton picked by hand (Q_c x H), where Q_c is quantity of cotton produced per state and H is the percent of cotton acreage harvested by hand), equals the total hours of labor utilized to pick cotton in each state in each year (Q_1). $Q_1 = (Q_c \times H) W_c/P_c$.

Wage rates in manufacturing: Hourly earnings of production workers in manufacturing in each of the 12 states over the 1949-64 period. State figures for 1949 are not available. The 1949 figures were estimated by assuming each state increased by the national average percentage increase between 1949 and 1950. Source: Statistical Abstract, corresponding years.

Cotton acreage: Thousands of harvested acres in the United States. Source: USDA Stat. Bul. 417 and 617.

Price of machines: Dollars per hour. These figures were obtained from (Maier, 1969), and were constructed from synthetic engineering data. The figures were originally constructed on a cost per hour basis but presented on a cost per unit of cotton. The costs were converted back to an hourly basis by multiplying the cost per pound of cotton lint times yield per acre times performance rates (hours required per acre) for two-row machines (Maier, Tables 13, 30, and 31). In order to cost equal size and capacity machines all costs are for two-row low and high drum models. Two-row machines were not available in 1949 and 1950. In order to obtain the costs of a constant capacity machine, the 1951 performance rates were utilized in constructing the hourly costs for 1949 and 1950. As far as quality is concerned Maier concludes after an extensive review of the technical literature that "the overall design and operation of mechanical pickers are essentially unchanged since these machines were first used experimentally in the late 1930s and became commercially available in the late 1940s" (Maier, p. 76).

Braceros: Peak employment of Mexican nationals admitted under P.L. 78 when the peak occurred during the cotton harvest season. Source: Maier, Table 12, Appendix D.

Footnotes

* University of Minnesota, St. Paul, and Hebrew University, Rehovot, Israel respectively. We are indebted to Vernon Ruttan for comments on an earlier draft of the paper.

1/ U.S. Dept. of Agriculture, "Major Statistical Series of the U.S. Dept. of Agriculture," Ag. Handbook No. 365, Vol. 7, Nov. 1969, P. 12

2/ ibid.

3/ The states are Ala., Ariz., Ark., Calif., Ga., La., Miss., Mo., NM., NC., SC., and Tenn. Texas and Oklahoma are omitted because of a lack of data on the prices for machine harvesting (see appendix).

4/ The equations also were estimated in linear arithmetic form. The results were similer except that the machine price coefficient was the wrong sign (negative) in both the OLS and 2SLS equations. Also the R^2s were lower in the arithmetic functions.

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