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"Machinery Has Completely Taken Over": The Diffusion of the Mechanical Cotton Picker, 1949–1964

The American South experienced abrupt and unexpected changes following World War II. Workers, especially African Americans, left the cotton fields; southern agriculture modernized; and new industries expanded. The Civil Rights Movement altered the social setting permanently. Mechanization of the cotton harvest proceeded rapidly; by 1970, the South's rural labor force had largely departed, leaving the landscape and social system barely recognizable to those who had observed it twenty years earlier.[1]

The spread of the mechanical cotton harvester is bound together with the South's social and political transformation and its economic convergence with the rest of the country. Alston and Ferrie argue that the adoption of the cotton picker caused the South's large rural labor force, with its attendant labor monitoring,

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1 The quotation in the title was spoken by Hughley M. Jones of Panola County, Mississippi, in *Goin' to Chicago,* a California Newsreel, produced by George King and Associates in 1994. After World War II, the South played a key role in income convergence. See Francesco Caselli and Wilbur John Coleman II, "The U.S. Structural Transformation and Regional Convergence: A Reinterpretation," *Journal of Political Economy,* CIX, (2001), 584–616; Kris Mitchener and Ian McLean, "U.S. Regional Growth and Convergence, 1880–1960, *Journal of Economic History* LIX, (1999), 1016–1042; Michelle Connolly, "Human Capital and Growth in the Postbellum South: A Separate but Unequal Story," *ibid.,* LXIV (2004), 363–399; Gavin Wright, *Old South, New South* (New York, 1986). On rural change, see Pete Daniel, *Breaking the Land: The Transformation of Cotton, Tobacco, and Rice Cultures since 1880* (Urbana, 1985); Jack Temple Kirby, *Rural Worlds Lost: The American South 1920–1960* (Baton Rouge, 1987).

and the incentives inherent in southern paternalism, to disappear. As a result, southern political leaders, in a move that had national, political implications, abandoned their resistance to welfare-state legislation that substituted for local paternalism. According to Wright, the emergence of the cotton picker was itself a response to the labor scarcity of World War II, further intensified by Federal legislation in the 1930s that had spurred out-migration by undermining the South's "separate" low-wage labor market.[2]

An examination of how the mechanical cotton picker spread across the South can illuminate such events as the "collapse" of southern equilibrium, the demise of southern paternalism, and the role of social institutions. The consequences of mechanical cotton harvesting have been widely studied, but the causes of the machine's diffusion have received less attention. "Institutions" are often blamed for the region's lagging development, although accounts have not always used a consistent definition of institutions, nor explained how they would have obstructed cotton-harvester diffusion. North uses the term *institutions* to mean "the humanly devised constraints that structure human interaction"—"formal constraints (e.g. rules, laws, constitutions), informal constraints (e.g. norms of behavior . . .), and their enforcement characteristics." This article, however, calls these phenomena "social institutions," in the sense of traditions, customs, or mores as embodied in laws and contracts, for the sake of consistency with the historical and political-science literature. The question is, Did any of the South's social institutions have the potential to retard the widespread adoption of the cotton picker?[3]

As it happened, southern social institutions did little to

2 On paternalism, see Lee Alston and Joseph Ferrie, *Southern Paternalism and the American Welfare State* (New York, 1999). In Wright's view, federal agricultural programs led to tenant displacement, and minimum wage laws reduced employment growth in labor-intensive industries ("The Economic Revolution in the American South," *Journal of Economic Perspectives,* I [1987], 161–178). See also Warren Whatley, "Labor for the Picking, the New Deal in the South," *Journal of Economic History,* XLIII (1983), 909–929. On schooling as a cause of migration, see Robert Margo, *Race and Schooling in the South, 1880–1950* (Chicago, 1990); on civil rights and economics, Wright, "The Civil Rights Revolution as Economic History," *Journal of Economic History,* LIX (1999), 267–289.

3 Acemoglu and James Robinson, *Persistence of Power, Elites and Institutions* (Cambridge, Mass., 2006), 49, credit the "collapse" of southern equilibrium to changes in incentives favoring previous political strategies. Douglass North, "Economic Performance Through Time," *American Economic Review,* LXXXIV (1994), 360. North's definition of *institution* distinguishes the concept from physical (and sometimes more transitory) manifestations, such as specific governments or their branches. Some economic historians prefer a more expansive definition—for example, Avner Grief, *Institutions and the Path to the Modern Economy* (New

impede the machine's diffusion once it was mass-produced, although some erosion of long-standing ones may have taken place before cotton-harvester diffusion began. Environmental advantages, along with a superior stock of human capital, fostered earlier diffusion of the mechanical harvester in the West than in the South. Despite the South's deficiency in human capital, southern social institutions had little effect on the cotton picker's acceptance once diffusion began.[4]

SOCIAL INSTITUTIONS AND THE SOUTH Wright argues that early in the twentieth century, the South exhibited features of a separate economy and that it did not share the same "resource environment" with the rest of the country. Typical of lagging economies, the South lacked an indigenous technological community that could adapt new technology to local conditions. The economic divergence of the South from the rest of the United States was the result of decisions that favored labor-intensive processes, thereby failing to spawn a cluster of engineers and other technical personnel to sustain technological change within the region. At root was a set of deliberate political decisions to withhold education from those who might otherwise have migrated from the region, and to prevent intervention by the federal government that would have undermined the South's separate low-wage economy. Thus was the South's institutional structure founded on historically prior policy that deliberately aimed at retaining a separate society.[5]

York, 2006)), 15–24—although usage in this literature tends to follow North more closely. See Daron Acemoglu and Simon Johnson, "Unbundling Institutions," *Journal of Political Economy,* CXIII (2005), 950.

4 The social consequences of cotton-picker diffusion include effects on wage convergence between the South and North, the civil rights movement, the migration of African Americans, and changes in racial economic inequality. See Wright, *Old South;* Daniel M. Johnson and Rex R. Campbell, *Black Migration in America* (Durham, N.C., 1981); Heinicke, "African-American Migration and Mechanized Cotton Harvesting, 1950–60," *Explorations in Economic History,* XXXI (1994) 501–520; *idem,* "One Step Forward: African-American Married Women in the South, 1950–1960," *Journal of Interdisciplinary History,* XXXI (2000), 43–62; Richard Day, "The Economics of Technological Change and the Demise of the Sharecropper," *American Economic Review,* LVII (1967), 427–449; Donald Holley, *The Second Great Emancipation: The Mechanical Cotton Picker, Black Migration, and How They Shaped the Modern South* (Fayetteville, 2000); Willis Peterson and Yoav Kislev, "The Cotton Harvester in Retrospect: Labor Displacement or Replacement?" *Journal of Economic History,* XLVI (1986), 199–216; Alston and Ferrie, *Southern Paternalism; idem,* "Paternalism in Agricultural Labor Contracts in the U.S. South: Implications for the Growth of the Welfare State," *American Economic Review,* LXXXIII (1993), 852–876.

5 Wright, "Economic Revolution,"164–171.

Street's contemporary work contains valuable insights about the beginning of the diffusion process: "[F]or at least the period since the advent of the tractor the stultifying effect of Southern social and economic institutions has been a greater factor than the existence of technical difficulties in explaining the slow rate of progress in the mechanization of cotton production and the lag in the general rationalization of Southern agriculture as well." If such institutions were central, however, exactly which of those that were in place after World War II could have slowed the diffusion of the cotton harvester and how would they have operated?[6]

Southern paternalism is one such social institution that entailed an extensive network of relationships and expected interactions on the part of landowners and workers; it served to lower the transactions costs of agricultural labor by providing incentives for workers to increase labor effort and by preserving stability and the social hierarchy. Landowners possessed much greater political power than tenants and wage workers; yet, at least some of the paternalistic landowners felt obligated to provide employment for their workers.[7]

Another characteristic southern social institution that could have inhibited economic development was racial discrimination, although the effects on cotton-harvester diffusion would have been indirect. Racial discrimination was expressed through numerous constraints on behavior, sustained by "Jim Crow" laws and periodic violence against blacks. Although a measurable, quantitative counterpart to these widely documented qualitative features is difficult to find, substandard schooling—the result of, say, discriminatory funding policies regarding the education of blacks—is a relevant pattern that provides measurable outcomes. By obstructing access to education and lowering educational quality, the institution of racial discrimination might have inhibited the diffusion of new technology by reducing learning-by-doing, the development of technological skills and complementary investment.[8]

6 James Street, *The New Revolution in the Cotton Economy* (Chapel Hill, 1957), 34. The focus of this article is on diffusion, but institutions may well have blunted the incentive to invent the machine.

7 Alston and Ferrie, *Southern Paternalism*. See Holley, *Second Great Emancipation,* 77, for the view of mechanization as ending small-scale farming in the South.

8 Connelly, "Human Capital," argues that racial discrimination in schooling undermined

Scholars have identified the major insitutions that could have impeded the diffusion of the mechanical cotton harvester: paternalism, racial discrimination, and a less clearly defined attachment to tradition. Although they endured into the 1950s, certain features may already have been on the wane when cotton-harvest mechanization began, having been undermined by the federal government's programs during the New Deal era and by the outmigration during World War II. The extent to which institutional constraints loosened is illuminated by this study.[9]

TIMING AND SPEED OF MECHANICAL COTTON HARVESTER ADOPTION In 1948, International Harvester began commercial production of "spindle" picking machines that simulated hand harvesting by rotating moistened, barbed spindles through the cotton plant and pulling the bolls from their bur. After decades of work to perfect the harvester, other manufacturers soon marketed one-row and two-row machines, either as tractor-mounted or self-propelled units.[10]

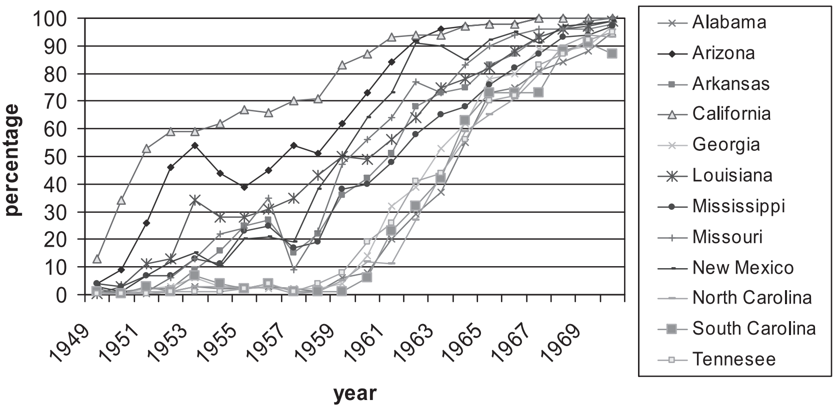
Figure 1 displays the speed of adoption of the mechanical cotton picker as well as the distinctive West-to-East pattern of picker diffusion. Growers in the western states of California and Arizona adopted the machine first, followed by those in the Delta states (Missouri, Mississippi, Louisiana, and Arkansas) and then the Southeast (North Carolina, South Carolina, Alabama, and Georgia). Mechanical harvester diffusion can be characterized numeri-

human-capital formation of both African Americans and whites in the South. Street, *New Revolution,* 238, asserts that the South was more "tradition bound" than the West. Moses Musoke and Alan Olmstead, "The Rise of the Cotton Industry in California: A Comparative Perspective," *Journal of Economic History,* XLII (1982), 385–412, cite capital-market imperfections and numerous other factors. On institutions and cotton-seed quality, see Paul Rhode and Olmstead, "Hog-Round Marketing, Seed Quality, and Government Policy: Institutional Change in U.S. Cotton Production, 1920–60," *ibid.,* LXIII (2003), 447–488.

9 Wright, *Old South.* Alston, "The Wright Interpretation of Southern U.S. Economic Development: A Review Essay of *Old South, New South* by Gavin Wright," *Agricultural History,* LXI (1987), 65–67, questions the relative strength of the New Deal vs. outmigration. Musoke and Olmstead, "Rise of the Cotton Industry," argue for the importance of environmental conditions in determining cotton mechanization. Whatley, "A History of Mechanization in the Cotton South: Institutional Hypothesis," *Quarterly Journal of Economics* (1985), 1191–1215, focuses on share tenancy, although his argument applies mainly to invention. On the New Deal, see Bruce Schulman, *From Cotton Belt to Sunbelt: Federal Policy, Economic Development, and the Transformation of the South, 1938–1980* (New York, 1991).

10 For detail about invention, see Holley, *Second Great Emancipation* 93–158; Street, *New Revolution,* 104–127.

Fig. 1 Cotton Harvested by Machine



SOURCE United States Department of Agriculture, *Statistics on Cotton and Related Data 1920–1973* (Washington, D.C., 1974, 218).

cally by two measures—year of initial adoption and speed of adoption. The year by which 10 percent of the state's cotton was machine-harvested can be regarded as the time of initial adoption.[11]

The average western state reached the 10 percent threshold by 1951, the average Delta state by 1953, and the average southeastern state by 1960 (see Table 1). The fact that the within-South lag in early adoption (between the Delta states and the Southeast) was greater than that between the West and the Delta casts doubt on the argument that social institutions were primarily responsible for delaying southern adoption of the mechanical picker; the social conditions that characterized the South existed in both the Delta states and in the Southeast.[12]

11 Maier, "Economic Analysis," uses the 10% figure to designate the initial adoption of the cotton harvester. Zvi Griliches, "Hybrid Corn: An Exploration in the Economics of Technological Change," *Econometrica,* XXV (1957), 501–522, also uses 10% of the "ceiling acreage" on which hybrid corn was planted to denote when the experimental stage for this innovation was passed.

12 Note that differential rates of adoption by state based on a 20% mechanization rate showed a longer delay of the Delta relative to the West and a smaller lag within the South than the 10% threshold implies. For the 20% threshold, the lag is about equal between the West and the Delta, as well as between the Delta and the Southeast (four years). The speed of diffusion, however, is best suited to addressing this question. At least one Delta state experienced initial adoption before a western state (Louisiana vs. New Mexico); the ordering is preserved at 20% mechanization.

After reaching 10 percent of the United States' cotton harvesting market in 1951, diffusion unfolded rapidly; about sixteen years elapsed between the time when 10 percent and when 90 percent of cotton was harvested by machine within the U.S. cotton belt as a whole (the "10-90 lag"). The southeastern states, the latest to reach the first threshold of adoption, experienced the mostrapid diffusion—a 10-90 lag of nine years (see Table 1). The 10-90 lag figures for the West and Delta are eleven and fourteen years.[13]

The longer 10-90 lag in the Delta may have been due to the fact that diffusion stalled temporarily for a couple of reasons during the mid-1950s (see Figure 1 and the pattern in Mississippi, Arkansas, Louisiana, and Missouri). The Soil Bank program, which reduced the acreage devoted to cotton from 1956 to 1958, may have decreased labor demand and wages, and the unfavorable growing and harvesting season in the Delta in 1957 probably had a detrimental effect on harvest mechanization as well.[14]

Social Institutions within the South Given that initial adoption of the cotton harvester took place earlier in the West than in the South, social institutions may have played a role. But the relatively short lag between the West and the Delta and the long lag between the Delta and the Southeast in initial adoption, as well as the rapid diffusion in the Southeast, throws doubt on the argu-

13 In a study of 265 diffusion cases by Arnulf Grübler, "Diffusion, Long-Term Patterns and Discontinuities," *Technological Forecasting and Social Change,* XXXIX (1991), 159–180, a 10–90 lag range of fifteen to thirty years bounds the modal cell for diffusion lags in cells of fifteen-year periods; the mean 10–90 lag is forty-one years. The automobile diffused faster, the tractor a good deal more slowly (Olmstead and Rhode, "Reshaping the Landscape: The Impact and Diffusion of the Tractor in American Agriculture, 1910–60," *Journal of Economic History,* LXI [2001], 663–669). The cotton-harvester diffusion pattern lacked the often-observed *S*-shape. See Griliches, "Hybrid Corn"; Bronwyn Hall and Beethika Kahn, "Adoption of New Technology," National Bureau of Economic Research, working paper 9730 (Cambridge, Mass., 2003)).

14 For the 1957 crop year, see Clay Lyle, "Labor and Technology on Selected Cotton Plantations in the Delta Area of Mississippi, 1953–1957," Mississippi Agricultural Experiment Station Bulletin 575 (April 1959), 6, 17. For government cotton programs and mechanization, see Maier, "Economic Analysis." Note that in many USDA publications, Arkansas, Louisiana, and Mississippi were categorized as "Delta states," although only parts of these states fell within the Mississippi Delta sub-region proper. About half of the cotton in Arkansas and Mississippi and about 80% in Louisiana were produced within the fertile Mississippi Delta. The state of Tennessee defies clear categorization. For the Bracero Program that temporarily slowed western mechanization, see Grove, "The Mexican Farm Labor Program, 1942–1964," *Agricultural History,* XXV (1996), 302–320.

Table 1 Early Mechanization Threshold and 10-90 Lags

STATE OR REGION	YEAR THAT 10% MECHANIZATION SURPASSED PERMANENTLY	10–90 LAG, NUMBER OF YEARS
Alabama	1961	9
Arizona	1951	11
Arkansas	1954	13
California	1949	12
Georgia	1960	9
Louisiana	1951	16
Missouri	1953	12
Mississippi	1953	15
North Carolina	1960	8
New Mexico	1952	11
South Carolina	1961	8
Tennessee	1960	9
West	1951	11
Delta	1953	14
Southeast	1960	9
United States overall	1951	16

SOURCE Computed from *Statistics on Cotton and Related Data 1920–1973* (Washington, D.C., 1974), Table 185, 218.

ment that specifically southern institutions were solely or even mainly responsible for the observed pattern. But could their variation within the South still account for the lag in initial adoption between the Delta and Southeast?

As noted above, the most important conditions affecting technological diffusion were those associated with low levels of education. Hence, educational attainment can serve as an indirect measure of an institutional effect on diffusion. Schooling attainment also measures human-capital accumulation, which, in part, reflects how important education was to parents.[15]

Table 2 shows the median year of schooling attained for states in 1950 and 1960. Since the western states achieved higher levels of education than did the South, greater human capital could have been responsible for the earlier adoption of the cotton picker there. The South, however, shows relatively little variation in ed-

15 Margo, *Race and Schooling,* notes that parental demand for schooling was instrumental in African-American progress.

ucation. For example, the median years of educational achievement in the early mechanizing states of Louisiana and Mississippi were 7.6 and 8.1 in 1950; the median years of the later mechanizing states of North Carolina and South Carolina were 7.9 and 7.6. Similar relationships are revealed for 1960 and for the other states. Only Missouri shows a slightly higher figure relative to that of the other southern states. But note that cotton was produced only in a small part of Missouri (the so-called "boot-heal"); the schooling figures likely reflect the much greater population of the cities to the north, far outside the cotton-producing areas. Enrollment ratios of children aged fourteen to fifteen were also compared for 1950, though not shown. California had the highest ratio among the states in this study, which otherwise did not show much variation. Social institutions might have had some influence, but the primary explanation for the sequence of initial adoption and rate of diffusion across the cotton belt appears to lie elsewhere.[16]

REGIONAL DIFFERENCES IN THE CIRCUMSTANCES OF PRODUCTION If not primarily social institutions, what could have caused the major lag between southern and western adoption of the mechanical cotton harvester? Environmental differences played a substantial role in the regional pattern of mechanization. The different precipitation levels in the two regions strongly influenced weed growth and the incidence of pests and plant disease. Abundant weed growth in the humid South required additional pre-harvest labor, until the development of satisfactory labor-saving strategies during the 1960s. In the West, the drier, looser soils supported fewer weeds and permitted better tractor access to eliminate them, and the semi-arid climate fostered fewer pests. Picking machines could operate for four times as many hours per season there due to longer growing seasons and less harvest-time rainfall. The hilly terrain in parts of the South was less suited to machine production than the large, flat fields of the West. The natural environment influenced yields (output per acre), which depended upon soil quality, complementary practices (such as irrigation and fertilizer use), and seed varieties. Western cotton yields were almost double

16 According to John Donahue, James Heckman, and Petra Todd, "The Schooling of Southern Blacks: The Roles of Legal Activism and Private Philanthropy," *Quarterly Journal of Economics,* CXVII (2002), 225–262, schooling had improved by 1960, but regional differences remained stark.

Table 2 Years of Schooling Completed, 1950 and 1960

STATE	MEDIAN YEARS OF SCHOOL COMPLETED, PERSONS 25 YEARS AND OLDER, 1950	MEDIAN YEARS OF SCHOOL COMPLETED, PERSONS 25YEARS AND OLDER, 1960
West		
Arizona	10.0	11.3
California	11.6	12.1
New Mexico	9.3	11.2
Delta		
Arkansas	8.3	8.9
Louisiana	7.6	8.8
Missouri	8.8	9.6
Mississippi	8.1	8.9
Tennessee	8.4	8.8
Southeast		
Alabama	7.9	9.1
Georgia	7.8	9.0
North Carolina	7.9	8.9
South Carolina	7.6	8.7

SOURCE *Statistical Abstract of the United States, 1951* (Washington D.C., 1951), 117; *Statistical Abstract of the United States, 1961* (Washington D.C., 1961),121.

those in the Southeast, corresponding to the West-to-East timing of adoption.[17]

The size of operations varied substantially. Large operating units allowed costs to be spread over more acres than did smaller units. Since operational size is endogenous to land quality, it is a proxy for good, well-situated land that had been the location of previous investment. The mechanical cotton picker involved high fixed costs; manufacturers targeted customers whom they thought would provide the greatest market potential—highly capitalized,

17 Maier, "Economic Analysis," 28–37; Musoke and Olmstead, "Rise of the Cotton Industry," 387–391. After the turn of the century, the boll weevil spread throughout the high moisture areas of the Southeast, the Delta, and Texas but not to the semi-arid regions. Western growers also benefited from the federal government's Mexican Farm Labor, or Bracero, Program. See Heinicke and Grove, "Labor Markets, Regional Diversity, and Cotton Harvest Mechanization in the Post-WWII United States," *Social Science History,* XXIX (2005), 269–297. An operator in the North Carolina Piedmont gave two reasons for returning a picker to the dealer, each related to the steepness of slopes or narrowness of terraces on slopes. See J. Gwyn Sutherland and Brooks James, *Mechanical Cotton Harvesting in North Carolina* (Chapel Hill,1947), 7. Early implementation of the "one variety" system helped to produce great cotton yields in the far West (Olmstead and Rhode, "Hog-Round," 457–459).

large ownership units, located in areas of suitable terrain where high yields lowered average costs—areas such as the Mississippi Delta or the Central Valley of California.[18]

Marketing the Mechanical Cotton Picker Among the small number of firms that produced mechanical pickers, International Harvester and John Deere eventually dwarfed the competition. The fact that neither firm could completely dominate the market helped to keep prices in check. As the leader, however, International Harvester designed a machine that would find a thick market, thus producing a relatively expensive machine, suitable for purchase mainly by landowners with large savings or access to credit and high yields. As noted, the high fixed cost of ownership needed to be spread over a relatively large amount of output for cost-effectiveness.[19]

International Harvester's marketing approach turned out to be a greater success than the company had anticipated. The speed of adoption exceeded International Harvester's and contemporary experts' expectations. A 1947 International Harvester marketing study in the year prior to initial commercial production estimated total potential market sales of 7,113 machines. By 1963, however, long before complete mechanization, the firm had sold over 24,000 spindle pickers domestically. International Harvesters' marketing studies tripled the size of the potential spindle-picker market to more than 21,000 in 1951 and to 44,480 in 1953. Similarly, a USDA-commissioned study of state Agricultural Productive Capacity Reports estimated "attainable" cotton-harvest mechanization in Arkansas in 1955 as 10 percent; growers, however, gathered 25 percent of the crop by machine.[20]

18 It is misleading to think in terms of an exogenous "threshold" size needed for adoption. International Harvester's assessment of threshold size was hardly stable. Operation size was also endogenous with respect to tractor adoption, which led to a change in the size of operations. See Gilbert Fite, *Cotton Fields No More* (Chapel Hill, 1984), 184–185. On that issue nationally, see Olmstead and Rhode, "Reshaping."

19 Holley, *Second Great Emanicpation,* 111–118; Street, *New Revolution,* 120–123. The machine-harvest cost estimates in Maier's "Economic Analysis" explicitly include yields, given that higher output per unit of land, with a given velocity of the machine through the field, resulted in lower average costs (113–114, 116, Appendix G). Owners may have used the picker in their own ways (sharing and renting), but because cotton could remain in the fields only for a certain amount of time before it deteriorated, the length of time for which fixed costs could be spread over output was limited.

20 See the following three memos located in the International Harvester Company archives, State Historical Society of Wisconsin, Madison: J. A. Hamilton, "Cotton Picker Po-

Research and Development In 1946, Congress funded the Cotton Mechanization Project (as part of the Research and Marketing Act of 1946) to modify every aspect of cotton-plant growth and cotton production in accordance with the capacity of the harvesting machine. Similarly, ginning equipment had to be designed to accommodate machine-harvested cotton, which contained more debris and moisture than hand-harvested cotton. Congress had at its disposal the largest agricultural research and development network in the world (the USDA–state agricultural experiment-station system) and a well-established system of county-level extension agents who could inform farmers about the best production techniques. The USDA–state agricultural experiment-station system administered a mixed public and private research venture that required the coordinated efforts of biologists, geneticists, chemists, entomologists, mechanical engineers, and many other specialists. To share results, compare work, coordinate research agendas, and plan future projects, researchers and administrators from the USDA, state agricultural-experiment stations, private firms, and farmers began meeting in 1947 at the annual "Belt-wide Cotton Mechanization Conference," sponsored by the National Cotton Council.

Agricultural economists, engineers, and scientists at agricultural-experiment stations in each of the Cotton Belt states, in conjunction with farm-equipment manufacturers, conducted cost-benefit analyses of the mechanical harvester to improve its profitability. In order to accommodate differences in local growing conditions due to weather, soil, and other factors, state experiment stations performed field tests at major stations and sub-stations in production areas throughout each state. Based upon their technical reports, state extension services produced and disseminated bulletins of "best-practice techniques," and county-extension agents demonstrated local adaptations of regional guidelines. Government agencies thus played a significant role in promoting technological change.

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tential Market," March 10, 1947, Market Analysis and Consumer Research Department, Farm Equipment Division, International Harvester Company; M. J. Steitz, "The Market for Cotton Pickers," March 20, 1951, Market Research Section, Consumer Relations Department, Farm Equipment Division, International Harvester Company; *idem,* "The Total Industry Potential Market for Cotton Pickers and Strippers," January 20, 1953, Market Research Section, Consumer Relations Department, Farm Equipment Division, International Harvester Company.

Cotton Yields Rising yields were among the most important causes of the unexpectedly rapid diffusion of the mechanical harvester. Farmers widely adopted the mechanical cotton harvesters only when cotton yields were sufficiently high. The post-World War II productivity revolution led to a 74 percent increase in cotton yields; production rose from an average of 273 lb. of lint per acre between 1945 and 1949 to 475 lb. between 1960 and 1964. This unprecedented gain in productivity was unexpected as late as 1951. During the Korean War, the federal government assembled a group of contemporary agricultural experts in every state—the Inter-Agency Production Capacity Committee—to estimate changes in output and the use of technology from 1950 to 1955. The experts predicted steady but slow technological change, but in Arkansas, for example, yields rose four times faster than projected and harvest mechanization more than twice as fast. Although the increases in yields after 1950 resulted partially from improved seeds, the heavy use of new and better fertilizer and more intensive farming on the best land, as producers tried to maintain or increase production in the face of government-imposed acreage reductions.[21]

DIFFUSION, COSTS, AND COTTON YIELDS OVER TIME AND ACROSS THE COTTON BELT Did farmers substitute machines for labor because wages increased vis-à-vis mechanical picking expenses or because the cost of machines declined relative to that of hand picking? The absence of individual-level data for a large sample of mechanical cotton-harvester adopters compels us to estimate the effect of costs on diffusion using annual aggregate data for twelve states in which growers predominantly used spindle pickers—the major cotton-producing areas, except for Texas and Oklahoma, where growers widely used the cotton-stripping device, for the years 1949 to 1964.[22]

21 U.S. Dept. of Commerce, *Historical Statistics of the U.S., Colonial Times to 1970* (Washington, 1970), Part 1, Series K 458, 500. Olmstead and Rhode referred to this increase in yield as the "other revolution" ("Hog-Round," 480). For contemporary under-predictions, see "Appraisal of Agricultural Productive Capacity in Arkansas, 1955," Form 3 National Archives RG 164, Records of the Office of Experiment Stations, Arkansas Agricultural Experiment Station; Raymond P. Christensen and Ronald O. Aines, *Economic Effects of Acreage Control Programs in the 1950s,* (1962) USDA, ERS, Agricultural Economic Report 18.

22 Data on the relevant variables, except for the percentage of cotton harvested mechanically, are unavailable after 1964.

Equation 1 estimates the effect of machine and hand-harvest costs on mechanical-harvester diffusion. Hand-labor costs consist of the "wage" for the picker (the compensation for the amount of seed cotton picked per pound of lint) and the overhead expense of organizing the hand harvest. An average-yield variable is entered separately to measure any effect not included in the machine-cost measure, despite the fact that the machine-cost variable partially measures the effect of yields, since greater output per acre implies lower average and marginal costs of harvesting. No explicit way to measure learning-by-doing is available, but equation 1 is estimated with and without time dummy variables and a time trend.

$$\text{mharvest}_{it} = \beta_0 + \beta_1 \text{ mcosts}_{it} + \beta_2 \text{ harvest wage}_{it} + \beta_3 \text{ overhead costs}_{it} + \beta_4 \text{ cotton yields}_{it} + \varepsilon_{it} \qquad (1)$$

The dependent variable, *mharvest,* is the fraction of cotton harvested by machine annually for each state. The cost data are deflated by the CPI, and all of them are measured in natural logs: *mcost,* the machine harvest cost per pound of lint by state and year; *harvestwage,* wages received by laborers; *overhead costs* of contracting, transporting, and providing in-kind (food and housing) benefits; and three-year average *yields,* the amount of cotton produced per acre. All of the variables on the right-hand side of the equation are lagged one year to reflect producer expectations concerning costs and production conditions.[23]

23 See U.S. Department of Agriculture, *Statistics on Cotton and Related Data 1920–1973* (Washington, D.C. 1974), Tables 48–61, 64–77. Maier, "Economic Analysis," 104–162, estimated machine harvest costs for the spindle picker from 1949 to 1964 based on (1) fixed and variable costs, such as purchase prices, depreciation schedules, interest rates, storage costs, insurance, taxes, tractor costs, repairs, lubricants, fuel, and labor; (2) estimates of the hours of potential use by state during a typical harvest season; (3) field waste relative to hand picking; and (4) grade loss relative to hand picking. Correction to these data came from Whatley, "New Estimates of the Cost of Harvesting Cotton: 1949–1964," *Research in Economic History,* XIII (1991), 199–225, who added the cost of the machine operator's "helper," and Grove, "The Economics of Cotton Harvest Mechanization in the United States, 1920–1970," unpub. Ph.D. diss.(University of Illinois, Urbana-Champaign, 2000), 25–137, who added ginning costs associated with machine harvesting. Grove also provides a time series of hand-harvest costs to match the Maier machine-cost data that (1) converts piece-rate wages to cash wages per lb. of lint and (2) estimates non-wage costs for resident laborers, day-haul workers, domestic migrants, and foreign contract workers. Annual state hand-harvesting costs are obtained by combining state wage and non-wage labor expenses, weighted according to the type of labor as estimated by the state for each year. Cash wages (used in other studies), paid per 100 lb. of unprocessed "seed-cotton," do not reflect growers' total hand-harvest costs because they do not reflect the unit costs per pound of lint and because they ignore other employer expenses. No measure of operation size is available for the full panel. Farm size, which

The usual assumption is that individual adopters would have substituted machine harvesting for manual labor, and thus responded to harvest wage rates and related costs if they increased. Although actually measured at the state level, the above specification is designed to detect these effects. Note, however, that aggregate cotton-harvest wage rates may well be endogenous with respect to harvester diffusion, in light of the large decrease in labor demand associated with diffusion. Measurement based on our state aggregate data may not be fine enough to capture the response of individual producers to changes in wages (to be addressed in the results section).[24]

Estimation Results The OLS estimation results, reported in Table 3, include versions with and without regional and yearly fixed effects (year dummy variable coefficients are not shown). The machine-cost coefficient has the expected sign and is statistically significant with and without fixed effects included, although including fixed effects reduces the magnitude of the coefficient. Regarding the coefficients, a 1 percent change in each right-hand-side variable implies a $\beta/100$ change in the percentage harvested by machine, ceteris paribus. For instance, given the coefficient of -0.44 on the machine-cost variable in the reduced form equation with fixed effects (Table 3), a 4 percent decrease in machine costs (about the average for this period) implies an increase of nearly two percentage points in machine harvesting. Reduced machine costs thus contributed substantially to the diffusion of machine harvesting.[25]

Table 4 reports the results with separate dummy variables for each state. Controlling for this additional variation among states reduces the size of the machine-cost variable (in absolute value) but otherwise does not alter the effect.

The coefficients on the labor-cost variables are less stable, and

is recorded only for agricultural census years, is misleading, since sharecropper plots are entered as farms in the agricultural census. Hand costs are measured per lb. of lint—the same unit as machine-harvest costs.

24 Grove and Heinicke, "Better Opportunities or Worse? The Demise of Cotton Harvest Labor in the US, 1949–1964," *Journal of Economic History,* LXIII (2003), 753; Wright, "Economic Revolution," 171. Olmstead and Rhode, "Reshaping," 682–691, find that substitute draft-animal prices are endogenous with respect to tractor diffusion. Despite the fact that the wage rates measured herein are lagged one year, a high degree of autocorrelation in this series suggests that testing for endogeneity is in order.

25 That is, $0.018 \approx (-0.44/100) \times (-4)$. The average annual increase in machine harvesting was 4.3 percentage points.

Table 3 OLS Estimates

	DEPENDENT VARIABLE: MACHINE HARVEST/TOTAL HARVESTED ACREAGE			
			REDUCED FORM	
INDEPENDENT VARIABLE (NATURAL LOGS): (*t*-STATS)		INCLUDING REGION AND YEAR FIXED EFFECTS		INCLUDING REGION AND YEAR FIXED EFFECTS
MCOST	−0.86 (−10.64)	−0.44 (−3.37)	−0.95 (−11.78)	−0.45 (−3.46)
HARVESTWAGE	−0.16 (−2.55)	−0.01 (−0.23)		
OVERHEAD COSTS	0.15 (3.16)	−0.04 (−0.95)		
YIELDS	−0.07 (−0.93)	0.26 (2.48)	−0.18 (−2.49)	0.25 (2.44)
Regional fixed effects (Southeast omitted)				
Delta		−0.01 (−0.35)		−0.01 (−0.35)
West		−0.10 (−1.33)		−0.09 (−1.22)
Yearly fixed effects included (not shown)	No	Yes	No	Yes
Intercept	2.84	−0.08	3.33	−0.01
Adjusted R^2	0.77	0.85	0.76	0.85
$N \times T = 12 \times 16$	192	192	192	192

Table 4 OLS Estimates with Individual State and Yearly Fixed Effects

INDEPENDENT VARIABLE (NATURAL LOGS): (*t*-STATS)	DEPENDENT VARIABLE: MACHINE HARVEST/TOTAL HARVESTED ACREAGE: INCLUDING STATE AND YEARLY FIXED EFFECTS	REDUCED FORM: INCLUDING STATE AND YEARLY FIXED EFFECTS
MCOST	−0.27 (−2.00)	−0.34 (−2.34)
HARVESTWAGE	−0.31 (−2.92)	
OVERHEAD COSTS	−0.18 (−4.38)	
YIELDS	0.05 (0.40)	0.13 (1.09)
State fixed effects (Alabama excluded)		
Arkansas	0.17 (3.63)	0.07 (1.68)
Arizona	0.31 (3.13)	0.07 (0.73)
California	0.45 (4.92)	0.24 (2.79)
Georgia	0.08 (2.49)	0.06 (2.02)
Louisiana	0.19 (4.99)	0.16 (4.04)
Missouri	0.29 (4.76)	0.10 (2.42)
Mississippi	0.09 (2.14)	0.05 (1.14)
North Carolina	0.09 (2.19)	−0.001 (−0.04)
New Mexico	0.07 (1.08)	−0.01 (−0.13)
South Carolina	0.02 (0.62)	0.01 (0.37)
Tennessee	0.02 (0.45)	−0.05 (−1.40)
Yearly fixed effects included (not shown)	Yes	Yes
Intercept	1.47	0.43
Adjusted R^2	0.92	0.91
$N \times T = 12 \times 16$	192	192

not consistent with the substitution of machine harvesting by cotton producers in response to changes in labor costs. The wage variable has a negative coefficient, and the overhead-cost coefficient becomes negative with inclusion of fixed effects (these anomalies are discussed below).[26]

Wages and Diffusion The unstable behavior of the hand-cost variables might indicate that hand-harvest wages are endogenous to the diffusion process (see above). Testing for the endogeneity of wages and overhead costs with a Durbin-Wu-Hausman test for both variables did not result in the rejection of the hypothesis; in both cases, hand-harvest wages and overhead-labor costs are endogenous.[27]

A plausible approach to the problem of the endogeneity of labor costs would be to re-estimate equation 1 using instrumental variables. Unfortunately, variables that are highly correlated with hand-harvest wages also tend to involve the same endogeneity problems. Furthermore, the results did not improve by resorting to either the nonagricultural (manufacturing) wage rate or the per capita federal grants to states as instruments. Since diffusion is the major interest of this article, the reduced form is reported in Tables 3 and 4, with harvest-labor compensation and overhead costs excluded (the last two columns on the right). The machine-costs variable remains stable with this exercise. The endogeneity of wages is consistent with other evidence concerning the diffusion period. Despite the fact that rising agricultural wages during World War II may have provided the incentive to invent the mechanical picker, once the adoption phase commenced, the tendency was to reduce the demand for labor at a rate that outpaced the decrease in supply.[28]

26 The estimates hold up reasonably well with different specifications, including one with a time trend. One exception is that the version with the log of the odds ratio as the dependent variable results in a positive machine-cost coefficient in the full (year and state) fixed-effects model, although inclusion of a time trend restores the negative coefficient. There is no reason to suggest that the functional form is logistic, even with respect to time, however (see Figure 1).

27 Regressing each potentially endogenous variable on the exogenous variables, with the nonagricultural wage rate (lagged) added as a regressor for identification, finds the F-statistic for these tests to be 24.98 (df = 1, 184; p-value = 0.0018) for harvest wages, and 13.9 (1, 184; p-value = 0.0003) for overhead costs.

28 See Day, "Technological Change"; Grove and Heinicke, "Better Opportunities"; Wright, *Old South*. The variable federal grants to states is problematical because it is a weak instrument for harvest wages; the correlation coefficient with cotton-picking wages is 0.2.

Figure 2 shows that labor costs drift downward in most states along with machine costs. Exceptions are Arizona and some of the southeastern states (Alabama, Georgia, and South Carolina). Hence, rapid diffusion of the mechanical cotton harvester put pressure on labor markets, decreasing the demand for hand pickers in the majority of states. Most of the states with "flat" wage-rate series (except for Arizona) adopted the mechanical picker after 1959.[29]

Cotton Yields, Machine Costs, and Adoption Although yields were crucial in the cross-sectional timing of mechanization, the coefficient is not statistically significant in every version of the estimated regression model. The likely reason is that one of the main effects of yields was to lower machine costs, a factor that is already measured in the machine-cost variable, having been incorporated in Maier's initial cost calculations upon which this series is based. Average yields and machine costs are negatively and strongly correlated (correlation coefficients of −0.84 for yields and machine costs and −0.92 for the natural logs of those variables). The positive effect of yields on harvesting by machine is shown in Table 3, when regional fixed effects are included. Apparently, that variable is highly correlated with specific location, and the size of the effect is reduced (and becomes statistically insignificant) when individual state dummy variables are included in Table 4.[30]

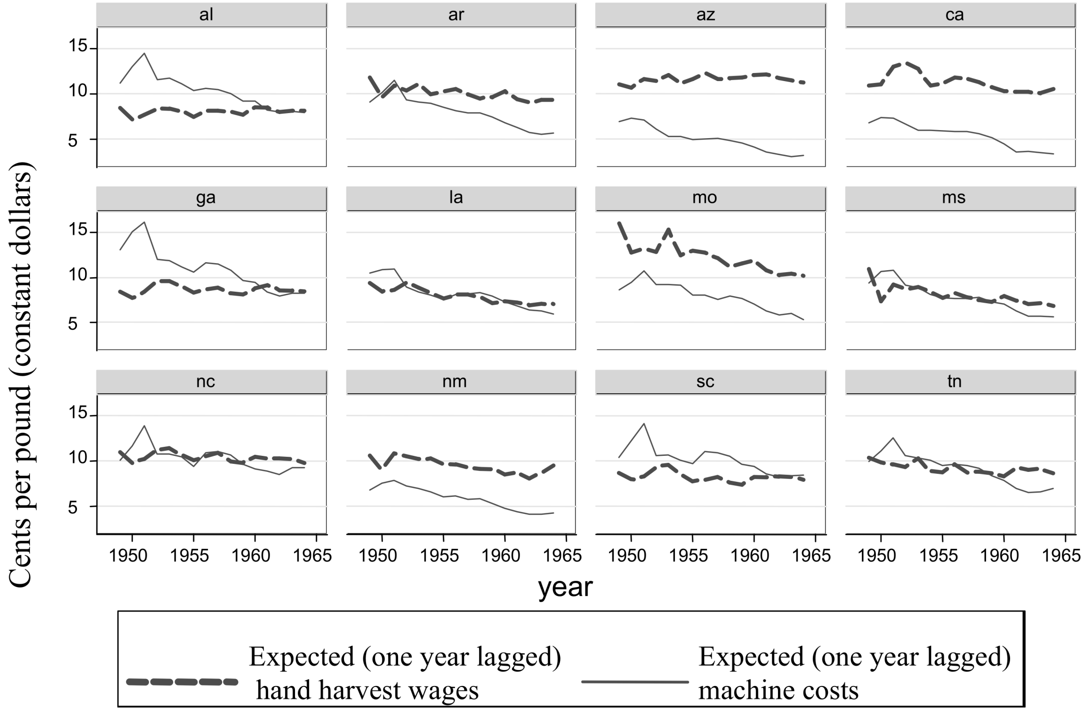
Figure 3 shows three-year-average yields for three states, one

Given that these data include a time-series element, there is the possibility that the variables are nonstationary. Insufficient time periods exit to perform formal tests for unit roots. Along the lines of recommendations by A. Levin and C. F. Lin, "Unit Root Test in Panel Data: Asymptotic and Finite-Sample Properties," Economics Working Paper 93–56 (University of San Diego,1993); Levin, Lin, and C. J. Chu, "Unit Root Tests in Panel Data: Asymptotic and Finite Sample Properties," *Journal of Econometrics,* CVIII (2002), 1–24; Badi H. Baltagi, *Econometric Analysis of Panel Data* (New York, 1995), 235–238, the variable was regressed on its lag with fixed effects (including an intercept, and with or without a time trend). Whereas Levin and Lin suggest a formal-hypothesis test, we simply compared the standard errors to see whether the coefficient on the lagged value is "close" to 1, with inconclusive results. Despite the lack of evidence for a nonstationary harvesting variable, we ran a first-differenced equation one (available upon request). The machine-cost coefficient is negative but not statistically significant (10% or lower) with that specification.

29 Regressions of the log of cotton-harvest wages on a time trend show a negative and significant (10 percent or lower) coefficient for our period except for Alabama, Arizona, Georgia, and South Carolina.

30 Maier, "Economic Analysis," 113–114. A regression of the natural log of machine costs on the log of average yields produces a coefficient of −.041 ($t = -6.57$), controlling productivity with the U.S. manufacturing productivity index.

Fig. 2 Machine Harvest Costs and Wages by State



SOURCE Calculated from Grove, "The Economics of Cotton Harvest Mechanization in the United States, 1920–1970," unpub. Ph.D. diss.(University of Illinois, Urbana-Champaign, 2000), 25–137.

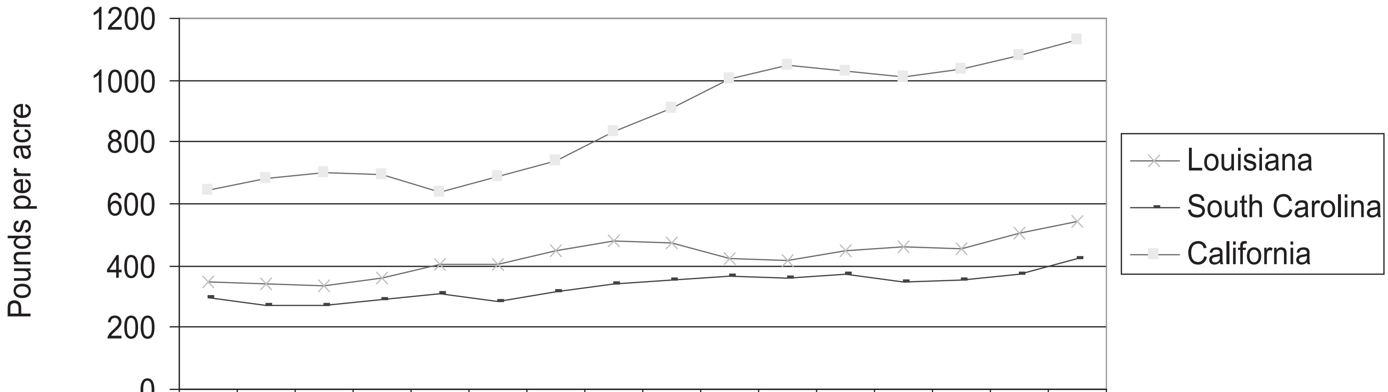
state in the West and one in each of the two main sub-regions of the South. As noted, yields helped to determine the timing of initial adoption. As Maier points out, yields for the southern states were within "a well defined range" five years prior to adoption. Figure 3 shows that yields in Louisiana during the early 1950s were similar to those in South Carolina during the late 1950s, just before initial adoption occurred in each state. Yet, yields were much higher in the West just before initial adoption, suggesting that diffusion would have occurred earlier there if the mechanical cotton picker had been marketed earlier. Environmental differences and yields affected the timing of initial adoption, but what effect did the increase in yields over time have? A regression of the natural log of yields on a time trend and an interaction South dummy variable with a time trend indicate yield growth was similar, if slightly slower, in the South to that in the West.[31]

If yields had not continued to increase, the southeastern states might not have reached the point of profitable adoption of the mechanical cotton picker until much later than they did. This subregion of the South attained profitability during the late 1950s; yield growth beyond that point contributed further to diffusion. Once diffusion commenced, it was more rapid in the Southeast than in the regions to the west. By that time, best practices were well known; complementary inputs to the finished product, such as ginning mechanically harvested cotton, were well established; and network costs had been reduced, contributing to rapid mechanical harvester diffusion.

Social Institutions and Education Revisited Education varied little across the South during this period, but it was better in the West than in the South. We thus attempted to measure this effect in the regressions. Educational attainment is conventionally used to measure the stock of human capital. As noted above, however, the South was associated with discrimination against African Americans, resulting in substandard schooling probably for both blacks and whites. Educational attainment can therefore serve as an indirect measure of the effect of custom in this context. A substantial drawback concerning this variable is its availability only for

31 Maier, "Economic Analysis," 26, 28. Western yield growth was about 0.038 per year; the difference in the southern growth rate was −0.007, with a *t*-statistic value of −1.26. If this figure were statistically significant at usual levels, the southern yield growth would be almost three-quarters of a percentage point per year lower than that in the West.

Fig. 3 Three-Year-Average Cotton Yields



	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
Louisiana	350	341	336	362	402	405	450	480	474	423	416	446	458	454	507	545
South Carolina	294	270	272	293	312	282	315	341	355	365	363	373	350	357	372	425
California	642	679	703	694	636	689	737	835	911	1003	1046	1028	1009	1034	1082	1130

Year

SOURCE United States Department of Agriculture, *Statistics on Cotton and Related Data 1920–1973* (Washington, D.C, 1974), 64–77.

the census years 1950 and 1960, although these two time periods apply to all twelve states in the study. Table 5 presents the coefficients for the two years and twelve states with the variables in equation 1 and educational attainment included. As before, machine cost is an important variable, even when only two cross-sections of states are involved.[32]

The coefficients in Table 5 show an unstable pattern with respect to the measure of schooling. Although the coefficient is positive without fixed effects, it is not statistically significant, and it becomes negative when state dummy variables and a dummy variable for 1950 are included (again, only two cross-sections can be used). The effect of educational attainment may have been subject to some delay. If that variable is measured with a lag, the results show more of a contribution from educational attainment to cotton-harvester diffusion. Based on the estimation of five different lag versions, using from zero to four lagged years for educational attainment and the structural model of equation 1 with state and year fixed effects, the mean coefficient on educational attainment is 0.86, though it is not stable across the different models. The estimated coefficients are −0.64, 1.72, 1.652, 1.365, and 0.225 for zero through four lags. Part of the instability may be due to the fact that each lag necessarily entails a different pair of years. For example, since schooling is available only for 1950 and 1960, a two-year lag necessarily involves the the twenty-four observations for 1952 and 1962, which differ from the zero-lag case, which uses the years 1950 and 1960.

Despite these qualifications, it may be instructive to see how differences in educational attainment between states could affect machine harvesting. As an example, take the mean value of 0.86 for the schooling coefficient and the five models above as an estimate of the effect that educational attainment had on mechanically harvested cotton by state. The percentage difference in schooling attainment between California and Louisiana, the two states that began mechanized cotton harvesting earliest in the West and

32 The measure for educational attainment in the West is likely to register values for large urban centers to a much greater extent than in the South, given the population distributions. In 1950, the West's urbanization rates were 70% for whites and 90% for blacks; the South's were 49% for whites and 48% for blacks (Johnson and Campbell, *Black Migration,* 132). Hence, the differences between the West and the South may be overestimated. Working in the other direction, the quality of southern schools was poor, despite improvements by 1960.

Table 5 OLS Estimates, Including Years of Schooling as an Independent Variable, 1950 and 1960 only, Twelve States

	DEPENDENT VARIABLE: MACHINE HARVEST/TOTAL HARVESTED ACREAGE			
			REDUCED FORM	
INDEPENDENT VARIABLE (NATURAL LOGS): (*t*-STATS)		INCLUDING STATE AND YEARLY FIXED EFFECTS		INCLUDING STATE AND YEARLY FIXED EFFECTS
MCOST	−0.97	−1.84	−0.96	−2.95
	(−3.76)	(−2.32)	(−3.72)	(−3.09)
HARVESTWAGE	−0.14	−0.55		
	(−0.74)	(−1.55)		
OVERHEAD COSTS	−0.13	−0.34		
	(−1.13)	(−2.40)		
YIELDS	−0.44	−1.36	−3.75	−1.51
	(−1.41)	(−2.42)	(−1.22)	(−2.00)
SCHOOLING	0.68	−0.64	0.44	−0.93
	(1.19)	(−0.68)	(0.80)	(−0.77)
State fixed effects (Alabama excluded) Arkansas		0.02		−0.36
		(0.12)		(−1.78)
Arizona		0.57		−0.26
		(1.22)		(−0.56)
California		0.97		0.33
		(1.86)		(0.57)
Georgia		0.07		0.11
		(0.65)		(0.90)

Table 5 (Cont.)

	Dependent variable: machine harvest/total harvested acreage			
			Reduced form	
Independent variable (natural logs): (*t*-stats)		Including state and yearly fixed effects		Including state and yearly fixed effects
Louisiana		−0.0002 (−0.00)		−0.22 (−1.24)
Missouri		0.30 (1.24)		−0.26 (−1.18)
Mississippi		−0.07 (−0.42)		−0.30 (−1.62)
North Carolina		0.18 (1.42)		−0.03 (−0.27)
New Mexico		0.07 (0.19)		−0.40 (−1.06)
South Carolina		−0.9 (−0.83)		−0.14 (−1.04)
Tennessee		0.18 (1.37)		−0.02 (−0.15)
Yearly fixed effect (1960 omitted)	No	Yes	No	Yes
Intercept	3.78	1.47	3.57	17.73
Adjusted R^2	0.78	0.92		0.80
$N \times T = 12 \times 2$	24	24	24	24

South, was 42 percent in 1951. The predicted difference in mechanization would be 0.36; the actual mechanization difference in 1951 is 0.42. Hence, the difference in educational attainment could conceivably account for 86 percent of the difference in machine harvesting in 1951 between those two states (that is, $0.36 = (0.86/100) \times 42$, which is about 86 percent of the actual rate of 0.42).

Comparison of other states between the West and South provide similar orders of magnitude for 1951, even if the numbers are a little smaller. In a comparison of Arizona and Georgia—the median states in each region with respect to the timing of initial mechanization—71 percent of their difference in mechanization could be predicted from their different levels of educational attainment in 1951. The proportions are lower, however, for 1961, when about 37 percent of their difference in mechanization could be predicted based on schooling difference (the difference between California and Louisiana, however, would remain at around 70 percent). Hence, differences in schooling can account for large proportions of the differences in mechanization between western and southern states.

Schooling, however, can account for little of the differences in mechanization within regions—for example, between Louisiana and Georgia or South Carolina—given the similar educational characteristics within regions (see Table 2). Particularly noteworthy in this respect is the lag of the Southeast behind the Delta states. Since, for instance, Louisiana and South Carolina show identical median educational attainment in 1950, none of the difference in mechanization in that year, and almost none in 1960, is attributable to educational attainment. Thus, if level of education indeed measures the effect of social institutions indirectly, mechanization within the South was impervious to southern institutions so construed. Yet, as suggested above, even though schooling appears to have had a more meaningful influence on the difference between the West and the South with regard to machine-harvested cotton in a given year, the finding must be qualified with the caveat that the schooling coefficient is unstable across different specifications.

Note that differences in machine costs also would have accounted for a substantial portion of the differences in machine harvesting across regions. For the five models of lags in schooling discussed above, the mean coefficient on machine costs is −0.932.

Since the percentage difference in machine costs between California and Louisiana in 1951 was 40.4, the predicted difference due to machine costs would be 0.38; the actual difference in mechanization was 0.42 in 1951. Thus about 90 percent of the difference could be attributed to machine-costs differences in that year.[33]

A combination of more productive soils, the absence of pests, and terrain that favored mechanical harvesting fostered a westward shift in cotton production. High yields and favorable environmental conditions made mechanization profitable in the West as soon as International Harvester's new machines left the assembly line in Memphis, and greater human capital contributed to earlier diffusion there. The Southeast, with the poorest yields, took more than ten years to initiate its harvest mechanization. While the West's market share of cotton increased, the Southeast's declined. Once in motion in each region, exogenous technological change and rising yields contributed to rapid mechanization. Although unmeasured in the regressions herein, learning-by-doing and local improvements with the help of the government's experimental stations probably contributed further to rapid mechanization. Yields would not have risen as quickly as they did without the help of the land-grant agricultural-experiment stations, although this benefit cannot be measured statistically.

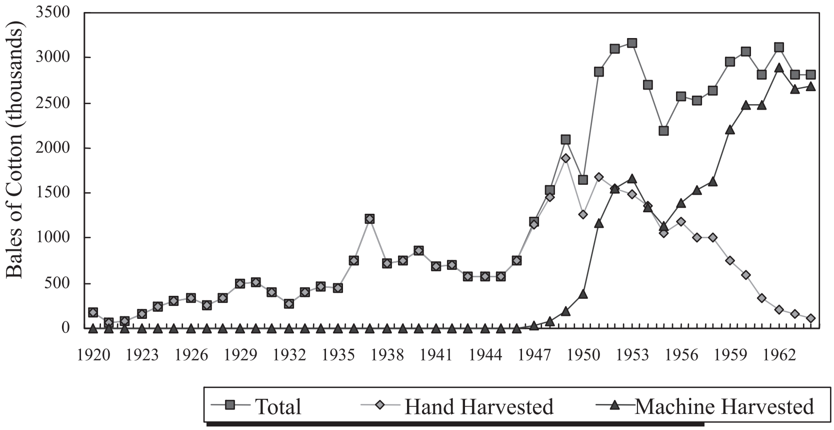
REGIONS, INCENTIVES, AND SOCIAL CONSEQUENCES REVISITED The diffusion of the mechanical harvester implied a large-scale displacement of hand-harvest workers, but the displacement was not uniform and mainly occurred after 1959. Moreover, the behavior of western and southern producers in this context was not the same.[34]

In the West, growers' extraordinarily rapid and early cotton-harvest mechanization proceeded until 1953 without displacing harvest labor, because the increase in the proportion of cotton harvested by machine was due to the expansion of cotton output, and all of that additional increment was machine-harvested. The U.S.

33 The combination of machine costs and schooling attainment "over-predicts" the difference in machine harvesting between these two states in 1951. Since the schooling-attainment figures for many of the states in the South show little variation, the predicted differences across states due to that variable would be close to zero, and most of the difference in mechanization would be due to other factors, such as machine-cost differences.

34 In the 1950s, the federal government's Soil Bank displaced labor in the South but not in the West (Heinicke and Grove, "Labor Markets," 288–289).

Fig. 4 Cotton Harvested in the West by Hand and Machine

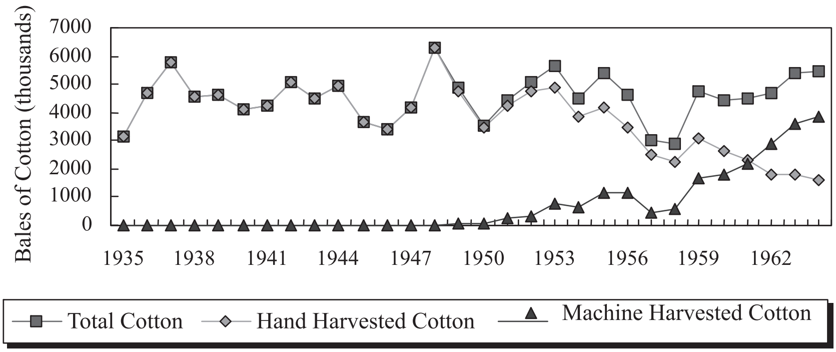


SOURCE Calculated from United States Department of Agriculture, *Statistics on Cotton and Related Data 1920–1973* (Washington, D.C, 1974), 64–77, 218

Department of Agriculture's cotton-acreage allotment and marketing-quota programs limited cotton expansion in the West in accord with previous planting "histories." Acreage allotments were lifted from 1943 to 1949 due to wartime contingencies, reimposed in 1950, and lifted again from 1951 to 1953 during the Korean conflict. As Figure 4 shows, western cotton production surged during both periods of open planting, and growers were able to establish new acreage "histories" that would determine future allotments. Given that labor is often considered the more variable factor in production relative to capital, is it surprising that mechanized harvesting rather than hand labor responded to the short-term increase in cotton production from 1951 to 1953? An explanation for the apparent exclusive use of the machine on such short notice might be that an active rental market for it emerged in the West relatively early.

Key for the social consequences of mechanization is that the timing of labor displacement was concentrated mainly after 1959 in the South when total output and hand-harvested output finally diverged in both sub-regions of the South (see Figures 4–6 and note that the scales of these figures vary, given that the Delta and Southeast began with much larger production figures). This observation may help to reconcile starkly contradictory statements in

Fig. 5 Cotton Harvested in the Delta by Hand and Machine



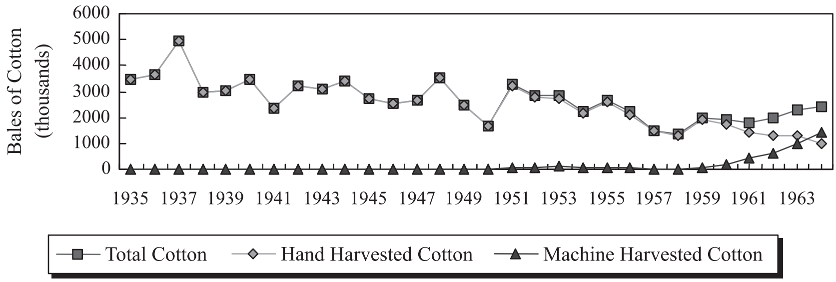
SOURCE Calculated from United States Department of Agriculture, *Statistics on Cotton and Related Data 1920–1973* (Washington, D.C, 1974), 64–77, 218.

the literature that harvest workers were either predominantly "pulled" to or "pushed" from the cotton fields. Although downward pressure due to mechanization was exerted on harvest wage rates throughout the period, the accentuated "push" or "displacement" of labor was not uniformly distributed throughout the sixteen-year diffusion period but took place mostly in the late 1950s and early 1960s. Furthermore, in the South, a pronounced downward shock in cotton production occurred during the Soil Bank years of 1956 to 1958, whereas in the West, cotton production during this period actually increased (see Figures 4–6).[35]

COTTON HARVESTER DIFFUSION IN LONG-RUN CONTEXT According to Daniel, the spread of the mechanical cotton picker brought a "change in the mode of production, in social organization, and in the nature of rural life [that] proved the most revolutionary in southern history." Emphasizing the broad implications of this technological breakthrough, Fite argues that nothing changed the southern landscape more than the demolition of the thousands of sharecropper shacks that once lined fields and roadsides. Aban-

35 Peterson and Kislev, "Cotton Harvester in Retrospect," 213–215, and Holley, *Second Great Emancipation,* 171–175, find that the decline in labor supply was greater than demand, and Heinicke, "African-American Migration," 513–517, finds that harvest mechanization was not necessarily the cause of migration in the 1950s. Contrast Grove and Heinicke, "Better Opportunities," 754–761, and Day, "Technological Change," 441–443, for whom decreasing labor demand was predominant.

Fig. 6 Cotton Harvested in the Southeast by Hand and Machine



SOURCE Calculated from United States Department of Agriculture, *Statistics on Cotton and Related Data 1920–1973* (Washington, D.C, 1974), 64–77, 218.

doning a monoculture crop, the South finally began to exhibit the highly capitalized, scientific, and diversified agriculture that a number of southern commentators had recommended for generations.[36]

The consequences reached well beyond the cotton belt, all the way to the cities of the North and to the West coast, as displaced workers joined the migrant stream, particularly of African Americans from the South. Petersen and Kislev and Holley argued that rising wages outside of agriculture were responsible for the disappearance of hand-harvesting labor in cotton, although more recent data-intensive studies have found that, on balance, the machine displaced rather than replaced this labor. This article adds that the social and demographic ramifications of the mechanical picker did not emerge until the years after 1959, when a concentrated burst of displacement took place. Such timing may have implications for related historical events. The urban social tensions of the 1960s could have been accentuated by the displacement of poor southern African Americans who joined the rural-to-urban migration stream. According to Alston and Ferrie, the cotton picker also affected the nation's political economy, linking the decline in southern paternalism and rise of the welfare state to the disappearance of the incentives to preserve a southern labor force in agriculture.[37]

36 Daniel, *Breaking the Land,* 239; Fite, *Cotton Fields No More.*

37 Peterson and Kislev, "Cotton Harvester in Retrospect," 213–215; Holley, *Second Great Emancipation,* 171–174; Grove and Heinicke, "Better Opportunities," 761; Alston and Ferrie, *Southern Paternalism,* 117–121.

Consequences aside, this article is concerned primarily with the determinants of the distinct regional pattern of the mechanical cotton picker's diffusion. Cotton clearly lagged behind corn and wheat with respect to complete mechanization. Yet, although cotton was a largely southern crop, the idea that southern social institutions stymied the use of a profitable new method to harvest is mistaken. That such traditional constraints, however, may have delayed its invention is consistent with Street's view that hand picking persisted through the mid-twentieth century when rapid progress in virtually every aspect of American economic life threw the South's anachronistic methods into relief. The undermining of southern social institutions by the federal programs of the 1930s and by out-migration during World War II may also have helped to weaken the obstacles to technological change. In any event, the evidence suggests that southern social institutions did *not* severely impede the adoption of the mechanical harvester, once it was on the market.[38]

That the cotton-harvester diffusion lag within the South exceeded that from the West to the South throws further doubt on the notion that the major factor determining the timing of the diffusion was the presence of "stultifying" southern customs and other social institutions. Cotton producers in the West and in the South appear to have responded similarly to a new and untried method of production, although greater human capital in the West contributed to earlier diffusion there. When the machine proved profitable, it was adopted rapidly. The environment provides a key. How did social tradition and the environment fit together?

After the Civil War, and for much of the first half of the twentieth century, southern landowners reconstructed and preserved a system of cheap labor with substandard educational quality and access, and a paternalism that mitigated incentives for mechanization of the cotton harvest. The dire consequences for African Americans formed an enduring context for subsequent social developments. In time, more fertile lands suitable to cotton began to attract investment; the older sections of the cotton belt—the Carolinas, Georgia, and Alabama—lost ground first to the Mississippi Delta and later to the far West.[39]

38 Street, *New Revolution*.

39 Musoke and Olmstead, "Rise of the Cotton Industry," 386–389.

After World War II, higher wages and the marketing of the mechanical cotton picker paved the way for a new production regime, which started in the West before moving to the Delta and finally to the Southeast. When cotton yields were high enough—thanks to private and public investment and the government's acreage programs—and thus costs low enough for profitable harvest mechanization, the oldest cotton regions of the Southeast leaped within the space of nine years from hand picking to complete mechanization. Exogenous improvements embodied in the new capital helped to fuel both the diffusion of the harvesting machine and a dramatic increase in cotton yields. Government aid funneled through land-grant colleges contributed to complementary technological developments. Hand picking disappeared in less than twenty years, taking with it the old ways of the South.