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Productivity Growth in Grain Production in the United States, 1840–60 and 1900–10

WILLIAM N. PARKER

AND

JUDITH L. V. KLEIN

YALE UNIVERSITY

In nineteenth century America, productivity growth in grain production derived largely from two characteristic features of the century's history: westward expansion and technological change. We know that productivity increased and we know that both westward expansion and technological change occurred. By averaging the dispersed and fragmentary data we may even guess at the extent of the productivity increase—at least in the use of labor. Can we also assess the relative importance of the factors which produced this effect? This paper contains the results of an effort to do this, for the two elements just mentioned and for the three major grain crops: wheat, oats, and corn. These crops accounted for about 55 per cent of the land harvested for crops in the United States in 1910.[1]

To estimate the effect of one factor in history is an exercise in imagination controlled and guided by the available data. It requires a mental

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[1] *Historical Statistics of the United States, Colonial Times to 1957*, U.S. Bureau of the Census, Washington, 1960, Series K-98, K-265, K-269, K-274.

experiment in which one tries to conceive how the history would have developed if one element in a situation had varied while the others remained unchanged. In this study the effort is made to conceive how productivity would have moved from the levels of 1840, if westward movement had taken place without technological change, and if technological change had occurred without westward movement. The principal difficulty encountered arises from the fact—common enough in the nineteenth century economy—that while production was shifting westward and techniques were changing, total output was undergoing an enormous expansion. To do our work completely, then, we should like to know how productivity would have moved in the East under the same demand pressures for output expansion which in fact found their outlet in the western development. To estimate this, however, we would need data on the shape of the supply curve of the eastern regions at those levels of output which were in fact never attained. A close enough investigation into the production conditions in the East might permit such curves to be estimated, but such an effort lies far beyond the data and research resources at our disposal. As will appear in the course of the report, the interpretation of the indexes developed here is restricted by this deficiency.[2]

Even within these limits, a question arises about the independence of the two variables whose influence is under examination. Would movement into the Middle West and the shift in grain production which accompanied it have occurred without the improvements in farm machinery? And would those improvements, so well adapted to western conditions, have been available in the East, if the stimulus to invention offered by labor "scarcity" and abundant land in the West had not appeared? Such questions go behind the immediate influences on productivity to the causes of the changes from which productivity growth was produced. The evidence developed in this paper is designed to throw light on first-order causes of the productivity growth; the causes of those causes are left to further investigation.

Against these limitations may be set one opportunity that our data and technique appear to offer. That great, half-inbred family of ideas known as technological change has affected production conditions in agriculture through two main lines of descent. The succession of mechanical inventions—from simple tools to complex power-driven machinery in the field and barn—has affected most directly the changes in labor inputs in the

[2] A second deficiency in this study is the neglect of capital inputs and, with it, the lack of a production function and of a measure of total factor productivity. The measurement of agricultural capital is so uncertain that an attempt to include it would, in our opinion, add more to the study's range of error than to its completeness or precision.

operations on the soil or in the handling and processing of the crop. At a given level of mechanical techniques, however, the operations on the soil—plowing, sowing, and harrowing—use labor in a relatively fixed proportion to the area under cultivation. The productivity of this labor, measured in man-hours per bushel of harvested grain, depends then upon the yields of land, and these in turn are influenced less by mechanical techniques than by another branch of technology, agricultural chemistry and plant biology. Invention in biology and chemistry was, by modern standards, far less advanced in the nineteenth century than invention of mechanical equipment; and the levels of practice both in the development of seeds and in the management of the land depended less upon organized experiment than upon the process of natural selection, both in nature among plants and in the economy among innovating farmers. The movements of land yields reflect both the margin of cultivation and the results of the social processes of invention in this area, while the movements of labor inputs per acre are most strongly affected by the use of mechanical equipment.[3] These two results of the two compartments of technology—land yields and labor per acre—are available separately in the data here, and our analysis can consider the effect of holding one constant while varying the other by the same statistical operation as that by which the independent effect of the interregional shifts is identified.

Quantitative methods of a limited and partial character, such as those used in this study, veer rather rapidly into nonsensical results. Yet, used with sufficient caution they may yield meaningful statements about the causes or mechanisms of historical change and indicate where important lines of further investigation may lie. In the present study, thanks to much generous assistance, they have the advantage of being based upon a rather wide survey of the remaining quantitative materials from nineteenth century sources. They represent an effort to make precise, through numerical estimates, those general impressions about productivity and its sources which a reading of the history inevitably gives.

Definitions and Assumptions

The variables whose separate influences on labor productivity are assessed in this study are:

1. The weights of regions in total acreage and output, weights whose shifts form part of what the historian knows as westward movement.

[3] The correspondence of these two variables to the two types of technological change is not complete, of course. Use of mechanical equipment affects yields per acre, and a chemical invention such as fertilizer requires a large per acre labor input. These cross-effects do not appear to be strongly present in our period, and we have omitted labor in manuring from the calculations.

2. The mode of carrying out operations on the soil and on the standing and harvested crop, whose improvement reflects mechanical invention and changes in the amount and form of capital.

3. The choice of soils and plant strains, the timing of operations, and other bits of biological and chemical knowledge, mostly not incorporated into mechanical equipment and affecting the yield of the land.

The technique used here—essentially the "partitioning" technique familiar from the studies of Kuznets, Abramovitz, and Denison—has been selected with an eye both to the objective of exposing the influence of these variables and to the severe limitations of the available numerical data. To derive conclusions from the data by this technique requires certain definitions and assumptions.

First, we define the two periods of study: period 1, 1839, and period 2, 1907–11. These are terminal periods; so the study is confined to a comparison of two benchmarks. The periods are set by the availability of Census production data from the first agricultural Census, 1840, and the possibility of a five-year average of the Department of Agriculture's revised estimates of acreage and output around 1909. Data on labor inputs must be gathered over a somewhat wider period. For period 1 inputs, sources from the 1830's to the 1860's were used, and for period 2, reports from the late 1890's to mid-1910's. Production conditions are not uniform within either of these wider terminal periods. In the first period, rural settlement between the Ohio and the Mississippi rivers, begun forty years earlier, is intensified and the Mississippi is crossed. After 1845 the mechanical reaper begins to be sold, and used in the 1850's in significant numbers, and the horse- or mule-drawn cultivator in corn assumes increasing importance. Still, in comparison with the shifts to the Great Plains between 1860 and 1900 the movement—both geographical and technological—is relatively small. Data were selected from the earlier period to represent production conditions around 1840, and the estimate of yields and acreage distribution is taken as of 1839. In the 1907–11 period, both the westward movement and the development of the horse-drawn mechanical technology are almost complete. Between these terminal dates it has not seemed possible to assemble sufficient evidence on the diffusion of the mechanical techniques to permit labor input estimates to be drawn up.

The use of 1839 as the initial date is of course partly determined by the availability of the Census production data. In addition, it has the advantage that the West, by that time, was a distinct region and had achieved substantial development. In wheat and oats, on the basis of homogeneity in land yields, the United States appears to fall into two great regions: North and South. But in the North, labor inputs per acre in period 1 may be divided between the Northwest, with inputs resembling those of the South, and the Northeast, with higher levels of labor cost. Combining land yields and labor inputs per acre, then, gives three regions as follows:

	Wheat and Oats Output Per Acre	*Labor Input Per Acre*
Northeast	high	high
West	high	low
South	low	low

In corn, the border states separate from both North and South on the basis of land yields, and, with the division between Northeast and West on the basis of labor inputs, four regions may be delineated. The statistical basis for defining these regions is described more fully in Appendix A. To permit comparison, the same regions must be retained in period 2. However, for grains the effective boundary of the West in period 2 is extended from the Mississippi to the Pacific Ocean. The impact of the large intraregional shift within this extended West is analyzed separately (in the next to last section of this study).

In addition to period and region, it has been necessary to group the labor-using agricultural operations into the three customary groups: those on the soil before harvest, those on the standing crop (harvesting, including shocking of wheat), and those on the cut crop (threshing and shelling). The shelling of corn, as well as the transport of all the crops to the barn and to market, has been omitted from the calculation. These three groups of operations correspond to three engineering problems inventors faced in the effort to mechanize. The preharvest operations, involving contact of a tool with the soil (except for broadcast seeders), required knowledge of the soil's physical characteristics and the relation of plant growth to them. It required also the invention of implements—plows, cultivators, and harrows—to produce the required tilth, and their adaptation to soils of varying composition. This problem was especially acute as the prairie soils came under the plow. The harvest operation in wheat, handling not the soil but the unthreshed crop, required the appropriate adaptations of mowing and raking tools. In the humid areas it involved also the problem, never satisfactorily solved by mechanical means in this period, of protecting, ripening, and drying the crop between reaping and threshing. The postharvest (threshing) operation in wheat involved, when mechanized, the substitution of the beating motion of the flail or the hoof by a stripping motion not unlike that of the cotton gin. In corn, the problem of mechanical harvesting was never satisfactorily solved during this period. In the first two groups of operations movement over the field was required, and so they were suitable to improvement by animal power or self-propelled engine. In the second and third groups, mechanization required power transmission and the activation of movable parts.

These engineering requirements gave the production function in each group of operations its economic characteristics. In the first group for all the crops, under any technique, labor time varied with the character of the soil and the area planted. The yield of the land may depend partly on the care, timing, and skill in the operations—particularly in corn where cultivation is required. Rich land and hot weather grow weeds as well as crops and the tasks of hoeing and cultivating are heavier. But the connection between cultivation and yield in corn was not known in any scientific sense, and opinions on this relation were almost as numerous as the farmers holding them. The functional relation between yield and tillage as actually practiced cannot be defined, while the variation with acreage at any level of cultivation is quite apparent. In harvesting, time spent by laborers in travel over the fields depends partly on the area harvested and partly on the thickness of the stand. But in addition to travel time, the time in place during the gathering of the crop varies with the kind of crop and the yield. In wheat and oats it is secondary to the travel time; a thick crop can be reaped almost as fast as a thin one. In corn, a heavier crop involves larger ears as well as closer planting. Hence, in the grains, harvest labor is assumed to be proportional to acreage. The operations then are grouped as follows:

Preharvest (assumed fixed per acre)

Wheat and Oats	Corn
Plowing	Field preparation[a]
Sowing	Planting
Harrowing	Cultivating
	Hoeing

Harvest (assumed fixed per acre)

Wheat and Oats	Corn
Reaping	Picking or husking
Raking	
Binding	
Shocking	

Postharvest (assumed fixed per bushel)

Wheat and Oats	Corn
Threshing	Shelling[b]
Winnowing	

[a] Depending on regional variations in practices.
[b] Not included in this study.

The Statistical Technique

For each region (as defined above), and at each of the two periods, an estimate of average labor input is made for each of the three groups of operations. For groups 1 and 2, these estimates are made in man-hours per acre, and divided by an estimate of average regional yield to give man-hours per bushel. This estimate is then added to the estimate of man-hours per bushel in group 3 to give the total labor input per bushel. These estimates for each region are weighted by regional output to give national averages at each period. The productivity change is then the change in this national estimate (or rather in its reciprocal) between the two dates.

Symbols and the formulas are as follows:

L_1 = Preharvest labor (man-hours)
L_2 = Harvest labor (man-hours)
L_3 = Postharvest labor (man-hours)
R_1 = Northeast
R_2 = South (wheat and oats)
R_{2a} = Middle east (corn)
R_{2b} = South (corn)
R_3 = West
A = Area (acres planted)
O = Output (bushels of threshed grain)
$a = L_1/A \qquad y = O/A$
$b = L_2/A \qquad v = O/\Sigma O$
$c = L_3/O \qquad w = A/\Sigma A$
1 = period 1 (1839)
2 = period 2 (1907–11)

$$\sum_{R_1}^{R_3}\left(\frac{a+b}{y}+c\right)v = \text{national average labor input per bushel}$$

To analyze the effect of change in regional weights, labor inputs, and land yields, it is possible to calculate an index with changes in the subscripts of the variables v, abc, and y. Indexes which use the formula with period 1 labor inputs as a base, and with numerators in which the subscripts of the variables are changed one at a time from 1 to 2, show the effect of the change of each variable in isolation. Change in the subscripts in groups of two at a time shows the effect of combined changes in the variables. For the three variables there is thus generated a family of eight indexes on the period 1 base as follows: $v_2abc_2y_2$; $v_2abc_2y_1$; $v_2abc_1y_2$; $v_2abc_1y_1$; $v_1abc_2y_2$; $v_1abc_2y_1$; $v_1abc_1y_2$; $v_1abc_1y_1$. If we then consider each variable and each grouping of variables as a factor with measurable independent effect, a plausible solution to the index-number problem may be found by representing the relative effects of the factors by the relative algebraic sums of the rows of indexes with signs indicated in the following matrix:

Factors	$v_2abc_2y_2$	$v_1abc_1y_1$	$v_2abc_1y_1$	$v_1abc_2y_1$	$v_1abc_1y_2$	$v_2abc_2y_1$	$v_2abc_1y_2$	$v_1abc_2y_2$
v	+	−	+	−	−	+	+	−
abc	+	−	−	+	−	+	−	+
y	+	−	−	−	+	−	+	+
$v(abc)$	+	+	−	−	+	+	−	−
vy	+	+	−	+	−	−	+	−
$(abc)y$	+	+	+	−	−	−	−	+
$v(abc)y$	+	−	+	+	+	−	−	−

The source of this method and the formulas to prove the signs of the indexes are shown in Appendix C.

Our principal conclusions are obtained by applying this technique to the three variables just cited. It may also be applied within the variables v (regional weights) and abc (labor inputs) to indicate the relative importance of factors working in and through them. The change in regional weights has an effect on labor inputs, both directly in the differing labor inputs per acre of the period 1 regions, and indirectly through the different land yields of the period 1 regions; the relative importance of the effect through each of these channels can be calculated. Within labor inputs, too, indexes may be computed for wheat and oats, which vary each of the three groups of labor separately and in combination, while holding yields and regional weights at their period 1 levels. Both these subsidiary families of indexes were computed and the importance of the factors assessed, as shown above. Finally, indexes were computed using the period 2 subregional values of that portion of the western region included in the period 1 West. This was done to show the effect on the indexes of the intraregional shift from the old Northwest to the Plains and Pacific Coast states. A separate index showing the effect of the intraregional shift within the South was computed for corn.

The Data

Some understanding of the data for this study is necessary for a sympathetic—or an unsympathetic—appraisal of the conclusions. These data are presented in summary fashion in Appendixes B and D, and what follows here is only a general discussion of their sources and reliability.

The most dubious use of the data lies in the combination of the estimates of land yields by state, based on the USDA revised estimates, with an average of labor inputs per acre derived from a sample of contemporary evidence which, particularly for the early period, is drawn largely from the most productive farms. The labor data for period 1 are drawn largely from premium reports to state agricultural societies in the Northeast and, in the South, from the records of plantations. There is reason, however, to argue that labor inputs on such farms are less biased than a similar sample of yields would be. For one thing, if bias exists, it is not certain which way it would run. Are the premium farms and record-keeping plantations those which use more labor per acre to get higher yields, or less labor because of greater efficiency? Furthermore, in wheat and oats, the case is particularly strong since high yields are obtained by superior seed, soil, and skill rather than by the labor-intensive operations of weeding and cultivating. In plowing and planting, there is no clear reason that labor input should vary with yield, while in the harvest and postharvest operations it has been generally possible to take account of the techniques employed. In the few cases where a statement about average conditions or from a professedly average farm is obtained, the figure falls well within the range of the distribution.

The data for labor inputs by region in period 2 are much more plentiful and specific than those for the mid-nineteenth century. They were drawn from cost studies of the USDA and the Agricultural Experiment Stations and from a retrospective study in the 1930's by the WPA, National Research Project (NRP).

With respect to the two kinds of data, the usual—but perhaps not more than the usual—uncertainties appear. For land yields, the USDA estimates for 1866–75 were projected back by state to 1839, without allowance for trend. This procedure was thought to be justified in view of the small trend in the state series throughout the whole half-century after 1866. However, for grains in the Ohio Valley states, these levels differ from the higher contemporary estimates for the 1840's and 1850's, and an alternate estimate of all the indexes, based on a higher set of yields for these states in this period, is presented in Appendix B. In the data on labor inputs by operation and region, the variety of sources and the numerous qualifying considerations to individual figures make summary statement difficult. The scatter is greatest in the period 1 estimates for plowing, as might be expected, and the cases are least numerous for the West in period 1. In each case, the regional data have been examined to see whether a significant difference in the means is present and, where this is not the case, data for regions have been combined. Similarly, in a few cases it has been possible to combine data for the same operation in wheat and oats. In general, data have been collected to the limit of the time and resources of money and patience available to the project and—unlike the agricultural operations which are the subject of this paper—it was apparent at several points that diminishing returns had set in.

The averages and dispersion of the data, and count of cases, are shown in Appendix D.

The Principal Findings

LABOR INPUTS, LAND YIELDS, AND REGIONAL WEIGHTS

Table 1 shows averages of land yields and labor inputs for each of the regions at the two periods of this study, with national averages determined by the output weights of the regions. From these data the principal conclusions about the extent and sources of the productivity increase are

TABLE 1

LABOR INPUTS, LAND YIELDS, AND WEIGHTS, PERIODS 1 AND 2

	a		*b*		*y*		*c*		*v*		*w*	
Region	1	2	1	2	1	2	1	2	1	2	1	2
					WHEAT							
R_1	19.1	11.6	15.0	3.0	14.5	17.5	.73	.19	.334	.046	.259	.037
R_2	11.3	10.7	12.5	3.0	8.4	12.3	.73	.29	.342	.075	.459	.085
R_3*	12.4	4.7	15.0	2.3	13.0	14.0	.73	.19	.324	.879	.282	.878
U.S.	13.6	5.5	13.9	2.4	11.3	14.0	.73	.20				
					OATS							
R_1	14.3	9.3	12.8	3.4	28.5	29.7	.40	.23	.422	.087	.316	.077
R_2	8.8	9.5	11.0	4.5	13.9	17.0	.40	.24	.332	.044	.506	.068
R_3*	8.8	3.9	12.8	2.6	29.3	26.5	.40	.10	.246	.869	.178	.855
U.S.	10.5	4.7	11.9	2.8	21.3	26.1	.40	.12				
					CORN							
R_1	98.3	46.4	13.0	13.0	33.5	36.8			.097	.029	.057	.020
R_{2a}*	52.0	26.7	10.1	10.1	21.8	24.4			.344	.099	.310	.106
$_{2b}$*	67.3	21.3	4.3	4.3	11.8	16.1			.279	.175	.465	.285
R_{3a}*	46.2	14.2	13.0	7.6	32.7	31.0			.280	.697	.168	.589
U.S.	60.8	18.2	8.1	7.0	19.6	26.2						

Note: See text for explanation of the symbols.
Source: *v*, *w*, *y*: Table 10 below, and sources listed there.
a, *b*, *c*: Appendix D.

*Appendix B contains alternate yields (*y*) for period 1 for all crops in the western region and for corn in the South and Middle East.

derived by the indexes of Table 2. The first, and most apparent, conclusion is the index of labor productivity for each crop: wheat, 417; oats, 363; corn, 365. In Table 2, this total index is shown as one of the family of indexes generated by combining the three main variables, using all possible combinations of period 1 and period 2 values. From this it is apparent that mechanization, in combination with the regional shift (i_6), is responsible for nearly the whole effect in wheat and corn, and more than the whole effect in oats, and that even leaving the distribution of production in its period 1 proportions, mechanization within each region taken alone produces an effect which is large (i_3). Applying the technique described above, values indicating relative importance of the factors are derived as follows:

	Wheat	*Oats*	*Corn*
v	.170	.287	.207
abc	.598	.506	.562
y	.082	.005	.084
$v(abc)$	.158	.234	.120
vy	−.049	−.026	−.007
$(abc)y$	.046	.004	.032
$v(abc)y$	−.005	−.010	.002

The economic meaning to be given to these results is discussed in the concluding section of this paper.

TABLE 2

LABOR REQUIREMENTS (U.S. AVERAGE AND INDEXES) AS AFFECTED BY INTER-REGIONAL SHIFTS, REGIONAL YIELDS, AND REGIONAL LABOR INPUTS PER ACRE

Index	Period for Values of v	y	abc	Labor Requirement (L/O)* Wheat (1)	Oats (2)	Corn (3)	Productivity (O/L) Index (i_1/i_n x 100) Wheat (4)	Oats (5)	Corn (6)
i_1	1	1	1	3.17	1.45	3.50	100	100	100
i_2	1	2	1	2.68	1.37	2.94	118.3	105.8	119.0
i_3	1	1	2	1.29	0.78	1.54	245.7	185.9	227.3
i_4	2	1	1	2.90	1.18	2.70	109.3	122.9	129.6
i_5	1	2	2	1.05	0.72	1.32	302.1	201.2	265.2
i_6	2	1	2	0.84	0.39	1.06	377.3	371.7	330.2
i_7	2	2	1	2.69	1.23	2.45	117.8	117.9	142.9
i_8	2	2	2	0.76	0.40	0.96	416.7	362.6	364.6

*$\Sigma\ (\frac{a+b}{y} + c)\ v$.

TYPES OF MECHANIZATION

The effect of mechanization alone (Table 2, i_3) can be broken down into its effects on each of the three groups of operations in each region. The averages derived from our data for this calculation are given in Table 1. Here the relatively greater importance of the mechanization in harvesting and threshing, as compared with that of the improvements in power and implements in plowing and planting, is clear. By a similar calculation to that for Table 2, we produce for wheat and oats the indexes of Table 3 in which, at the land yields and distributions of period 1, each element is varied independently and in conjunction with each of the others. In corn, the lack of significant mechanization in harvest and postharvest operations makes such a calculation of no importance. The values indicating the relative importance of the factors are as follows:

	Wheat	*Oats*
a	.165	.126
b	.384	.456
c	.214	.250
ab	.074	.045
ac	.043	.026
bc	.093	.086
abc	.026	.011

TABLE 3

LABOR REQUIREMENTS (U.S. AVERAGE AND INDEXES) AS AFFECTED BY CHANGES IN REGIONAL LABOR INPUTS

Index	Period for Values of			Labor Requirement (L/O)*		Productivity (O/L) Index (i_1/i_n x 100)	
	a	b	c	Wheat (1)	Oats (2)	Wheat (3)	Oats (4)
i_1	1	1	1	3.17	1.45	100	100
i_2	1	2	1	2.19	1.08	144.7	134.2
i_3	1	1	2	2.66	1.26	119.2	115.1
i_4	2	1	1	2.79	1.36	113.6	106.7
i_5	1	2	2	1.68	0.88	188.7	164.7
i_6	2	1	2	2.28	1.16	139.1	125.0
i_7	2	2	1	1.80	0.98	176.1	147.9
i_8	2	2	2	1.29	0.78	245.7	185.9

* $\Sigma\ (\frac{a + b}{y_1} + c)v_1.$

THE TWO EFFECTS OF REGIONAL SHIFTS

The regions of our study are defined with respect both to labor per acre and to the yields of land. This definition of regions is discussed in Appendix A. It is apparent that interregional shifts will affect average labor per bushel through an effect on the national average labor input per acre and on the average yield in bushels per acre. It is possible then to break down the effect shown in Table 2 into an effect by way of each of these components. Moreover, the effect through labor per acre is further divisible into an effect by way of each type of labor input which shows interregional differences in period 1. In Table 4, these subsidiary indexes are given, holding the values of labor inputs and yields at the period 1 level, but weighting them by acreage rather than output weights to permit variation of the weights of yield and labor input variables independently.

TABLE 4

LABOR REQUIREMENTS (U.S. AVERAGE AND INDEXES) AS AFFECTED BY INTERREGIONAL SHIFTS

Index	Period for Values of			Labor Requirement (L/O)*			Productivity (O/L) Index (i_1/i_n x 100)		
	a_1w	b_1w	y_1w	Wheat (1)	Oats (2)	Corn (3)	Wheat (4)	Oats (5)	Corn (6)
i_1	1	1	1	3.17	1.45	3.50	100	100	100
i_2	2	1	1	3.07	1.39	3.15	103.3	104.3	111.1
i_3	1	2	1	3.25	1.49	3.61	97.6	97.3	97.0
i_4	1	1	2	2.90	1.20	2.69	109.3	120.8	130.1
i_5	2	2	1	3.15	1.43	3.26	100.6	101.4	107.4
i_6	2	1	2	2.82	1.15	2.42	112.4	126.1	144.6
i_7	1	2	2	2.97	1.22	2.77	106.7	118.9	126.4
i_8	2	2	2	2.89	1.18	2.50	109.6	122.9	140.0

* $\left(\frac{\Sigma a_1 w + \Sigma b_1 w}{\Sigma y_1 w}\right) + c_1$. For corn, $c = 0$. For i_1, this reduces to the formula of Table 2.

Intraregional Shifts

Nearly all of the acreage increase between 1840 and 1910 occurred in the region we have labeled West. In wheat, this expansion occurred in the 1860's, 1870's, and 1890's; in oats, in the 1880's; in corn, in the 1850's and 1870's. Acreage of wheat and oats remained fairly steady in the other two major regions of period 1, and their acreage and output weights (Table 1) had all fallen to less than 10 per cent in period 2. The behavior of the yields and labor-per-acre coefficients for the western region is thus of decisive importance in controlling the average productivity change in the nation as a whole. As might be expected from the changes in the regional weights, the western region exhibits a sharper fall in labor per acre than the other regions do (Table 1), and the enormous expansion does not seriously affect the level of land yields.

In the foregoing sections, the three regions have been treated as if each were a homogeneous unit whose yields and labor input coefficients changed only as a result of technical change. The stability of land yields in the presence of absolute changes of acreage was taken as evidence for this assumption. Within each region, however, it is possible that the stability of yields and the fall in labor costs per acre were due in part to intraregional shifts to acres of similar yield, but of a physical aspect more favorable to farming. A study of labor costs in land clearing shows, for example, that the shift from forested area to prairie was a major factor in saving labor in those operations.[4] In the Northeast and South, the period 2 weights for wheat and oats are too small to make further intraregional analysis useful. But for the West, and, in the case of corn in the South, a closer look at the yields and labor coefficients of the major geographic subregions must be obtained.

For this purpose, the West may be divided in period 2 into the major subregions used in the basic NRP reports of the WPA. These subregions with their output and acreage weights are shown in Table 5. The period 2 subregional weights show where the great acreage expansions in the West occurred. For wheat, the growth of the "small grain" tier of states (Montana, the Dakotas, Nebraska, and Kansas) was the most important development, but the secondary growth of acreage on the West Coast (Northwest and California), the Great Lakes states (WD) and in the corn belt (C) accounted together for an almost equally large new acreage. Of a 38-million-acre expansion in the West, about 20 million is accounted for by the new acreage in the small grain subregion. In oats, the expansion was more heavily concentrated in the corn belt and the western dairy states. For corn, as might be expected, almost 60 per cent of the acreage increase in the West was concentrated in the corn belt, and only 33 per cent in the small grain subregion. The differentials among these subregions in period 2 labor inputs are thus of considerable interest. If these differentials

[4] M. Primack, "Land Clearing under Nineteenth Century Techniques: Some Preliminary Calculations," *Journal of Economic History*, XXI, 1962, pp. 484–497.

TABLE 5

OUTPUT AND ACREAGE WEIGHTS OF WESTERN SUBREGIONS, PERIOD 2

	Output ($O/\Sigma O$)			Acreage ($A/\Sigma A$)		
Subregions	Wheat	Oats	Corn	Wheat	Oats	Corn
W	.879	.869	.697	.878	.855	.589
W:C	.235	.413	.490	.207	.379	.359
W:WD	.108	.190	.051	.098	.185	.042
W:SG + W:WC	.408	.212	.151[a]	.477	.249	.181[a]
W:R	.020	.015		.015	.012	
W:NW + Cal	.108	.079	.005	.081	.030	.007

Source: USDA, revised estimates, 1907-11.

Key: W = West; W:C = corn belt; W:WD = western dairy; W:SG = small grain; W:WC = western cotton; W:R = range; W:NW = Northwest; W:Cal = California. See Appendix D for states included in each subregion.

[a] W:SG only.

are large, much of the productivity improvement attributed above to mechanization might instead be attributed simply to the intraregional shift within the West.

In Table 6, the period 2 yields and labor inputs for the subregions of the West are compared. The region labeled W:C includes the states within whose limits most of the West's acreage of period 1 appears. The other subregions were almost wholly untouched in the 1840's. With

TABLE 6

YIELDS AND LABOR INPUTS IN THE WESTERN SUBREGIONS, PERIOD 2

				LABOR INPUTS								
	Yields (y)			Preharvest (a)			Harvest (b)			Postharvest (c)		
Subregions	Wheat	Oats	Corn	Wheat	Oats	Corn	Wheat	Oats	Corn	Wheat	Oats	Corn
W	14.0	26.5	31.0	4.7	3.9	14.2	2.3	2.6	7.6	.193	.098	0
W:C	15.8	28.4	35.8	5.5	3.3	15.2	3.0	2.6	7.4	.224	.092	0
W:WD	15.3	26.8	31.7	6.1	6.1	17.3	3.0	3.5	13.0	.165	.108	0
W:SG + W:WC	12.0	22.2	21.9[a]	4.2	3.0	11.4[a]	1.8	1.7	6.8[a]	.190	.094	0
W:R	18.6	32.7		6.0	7.6		7.5	8.3		.226	.129	
W:NW + Cal	19.4	33.8		3.2	3.2		2.0	2.0		.165	.095	

Source: Yields, from USDA, revised estimates. For labor inputs, see Appendix Tables D-10, D-12, D-13, D-15, D-17, D-18. For explanation of subregion symbols, see Table 5.

[a] W:SG only.

respect to land yields, it is apparent that the new subregions W:WD and W:SG were lower, and the northwestern coastal regions higher, than the old Northwest. That the lower level of W:WD was not a persistent trend is shown in Table 11 below; in previous decades and—in wheat—under somewhat larger acreages, the yields in the western dairy states (W:WD) were as high as, or higher than, those in the older states to the south of them (W:C). In the small grain states (W:SG) the yields in 1909 were much lower relative to the other subregions than in earlier years, and this is partly accounted for by the rapid rise in the subregion's acreage in the decade 1899–1909. The movement to W:SG did tend to depress yields in the West; for wheat this is partly balanced in the regional average by some rises in intrasubregional yields in the 1900's, and for all crops by the growth in the other, somewhat higher yielding regions. However, in the small grain subregion of the West, somewhat lower yields were balanced by easier conditions of cultivation and harvesting. This differential, shown in Table 6, is clearly significant for harvesting wheat and oats, where the dry weather at harvest time permitted the labor of binding and shocking to be eliminated on a large portion of the acreage. But it is also large for corn, where the simpler harvesting method of husking from the standing stalk was universally used (Appendix Table D-10).

To indicate the net effect of this intraregional shift within the West on the indexes calculated in Table 2, one may assume that the westward movement took place under the period 2 yields and labor inputs, shown for the period 1 western region (W:C in period 2). The effect of replacing the period 2 W values by W:C values may be seen by comparing the first two lines of Table 6 and by the calculations of Table 7. In all our indexes where y_2 values appear, the replacement would raise the productivity index by less than 10 per cent, and the portion of the rise attributed to intraregional changes in land yields would be raised. The difference between this index and the one calculated in Table 2 is a measure of the depressing effect of intraregional shifts on productivity in the West by way of their effect on land yields. In wheat, the replacement of W by W:C values for labor inputs would reduce the productivity index by about 12½ per cent, and reduce the portion to be attributed to mechanical improvements within the regions. In oats the reverse would be true and in corn the change would be negligible. The net effect on labor per bushel in the West is shown in Table 7; the indexes of Table 2, with the W values altered to W:C values in period 2, are shown in Table 8. From the comparison it appears that in wheat the total productivity index (i_8) is depressed by about 8 per cent because of the higher labor inputs in W:C (i_3) and especially through the interaction of this with the regional

TABLE 7

PERIOD 2 VALUES OF CORN BELT AND WEST COMPARED

	Wheat		Oats		Corn	
Variables	W:C	W	W:C	W	W:C	W
a	5.5	4.7	3.3	3.9	15.2	14.2
b	3.0	2.3	2.6	2.6	7.4	7.6
$a+b$	8.5	7.0	5.9	6.5	22.6	21.8
y	15.8	14.0	28.4	26.5	35.8	31.0
$\frac{a+b}{y}$	0.538	0.500	0.208	0.245	0.631	0.703
c	0.224	0.193	0.092	0.098	0	0
$\frac{a+b}{y}+c$	0.762	0.693	0.300	0.343	0.631	0.703

Source: Table 6.

shift (i_6). In oats the index is raised about 10 per cent largely through the interaction between the small reduction in labor inputs per acre and the massive interregional shift (i_6). In corn, the rise of about 5 per cent in i_8 caused by the substitution of the W:C values for the W values comes from the effect on land yields in conjunction with the regional shift (i_7). It is evident then that the indexes would not have been strongly affected if the intraregional shifts within the West—which permitted the growth

TABLE 8

EFFECT ON TABLE 2 INDEXES OF SUBSTITUTION OF CORN BELT FOR WEST

	Period for Values of			Wheat		Oats		Corn	
Index	v	y	abc	Table 2	W=W:C	Table 2	W=W:C	Table 2	W=W:C
i_1	1	1	1	100	100	100	100	100	100
i_2	1	2	1	118	122	106	107	119	122
i_3	1	1	2	246	236	186	189	227	226
i_4	2	1	1	109	109	123	124	130	130
i_5	1	2	2	302	297	201	207	265	270
i_6	2	1	2	377	326	372	400	330	324
i_7	2	2	1	118	127	118	123	143	154
i_8	2	2	2	417	385	363	403	365	385

TABLE 9

OUTPUT WEIGHTS, ACREAGE WEIGHTS, YIELDS AND LABOR INPUTS FOR CORN IN THE SOUTHERN SUBREGIONS, PERIOD 2

Variables	South (S)	Eastern Cotton (S:EC)	Delta Cotton (S:DC)	Western Cotton (S:WC)
$A/\Sigma A$	0.285	0.112	0.062	0.111
$O/\Sigma O$	0.175	0.058	0.041	0.076
Yields (y)	16.1	13.7	17.1	18.1
Labor				
Preharvest (a)	21.3	24.75	28.0	10.2
Harvest (b)	4.3	4.3	4.3	4.3
Postharvest (c)	0	0	0	0
$\frac{a+b}{y}+c$	1.590	2.120	1.888	0.801

Source: Yields from USDA, revised estimates. For labor inputs, see Appendix Tables D-10, D-12, D-14.

of output to occur—had taken place under conditions similar to those on the acreage under wheat in period 2 in the corn belt.

In the case of corn, significant intraregional shifts occurred among the southern as well as the western subregions. The relevant data for the southern subregions are shown in Table 9. Recalculation of the indexes, as shown in Table 2, substituting the S:EC values for the South affects the indexes as follows:

	Table 2 O/L Index	*S = S:EC*
i_1	100	100
i_2	119	111
i_3	227	215
i_4	130	130
i_5	265	239
i_6	330	315
i_7	143	135
i_8	365	331

It will be noted that this substitution reduces index i_8 by about 10 per cent, whereas the calculation in Table 8 substituting the W:C data for the West raises the final index by about 5 per cent. The combined effect of both substitutions would thus be less significant than that of either one taken alone.

Conclusions and Speculations

Over the seventy years between 1839 and 1907–11, output of wheat, oats and corn in the United States each increased about 7½ times, and acreage between 5 and 6 times. The growth of the West relative to the low-yield border states of the upper South raised average land yields about 25 per cent. Within the West, the relative growth of the plains states between 1890 and 1910 exercised a downward pressure on regional yields, balanced by yield rises in the other major western subregions (Table 11). Otherwise, taking the regions individually, the yields of land given in Table 10 showed no marked or continuous trend. Acreages planted in the Northeast and—for wheat and oats—in the South also changed very little. Nearly the whole rise in acreage and output in wheat and oats was accounted for by the expansion North and West of the Ohio River, where the share of national output rose from 32 per cent in wheat and 25 per cent in oats in 1839 to about 87 per cent in both crops in 1907–11. In corn, about two-thirds of the acreage rise occurred in the West and about one-quarter in the South. Rising yields in the South were a result of the rapid growth of the western cotton subregion (Table 12).

Even before the Civil War, the West had some advantage over the South in land yields and over the Northeast in labor costs per acre. Table 13 shows the extent of this advantage with the techniques prevailing in that period. At these differentials, the rise in the West's share to its period 2 level, without changes in yields or labor inputs per acre within the regions, would have raised productivity only 9 per cent in wheat, 23 per cent in oats, and 30 per cent in corn (Table 2, index i_4). Table 4 indexes i_4 and i_5 show that most of this improvement would have been attributable to the shift from the relatively lower yielding lands of the South. Had the land yield changes within each region occurred simultaneously with the regional shifts, the improvement would have been a bit more in wheat and corn (Table 2, index i_7) but less in oats.[5] On the other hand, if the land yield changes had not occurred, but if the regional shifts had been accompanied by improvements in labor input per acre (Table 2, index i_6), resulting largely from mechanization, virtually the whole productivity change in both crops would have been achieved without change in average yields of land. Alternatively, if the mechanical equipment of 1900–10 could have been used in the output of 1840, then labor in wheat and corn

[5] The lower level of the oats index, with yield changes (Table 2, indexes i_7 and i_8 compared with i_4 and i_6), is a result of the unusually low western yield in 1907–11. At the levels around 1900, this result would not be obtained.

TABLE 10

ACREAGES AND YIELDS, BY REGION, 1839-1909
(acres in millions and yields in bushels per acre)

	Northeast		Middle East		South		West	
	Acres (*A*)	Yield (*O/A*)	Acres (*A*)	Yield (*O/A*)	Acres (*A*)	Yield (*O/A*)	Acres (*A*)	Yield (*O/A*)
				WHEAT				
1839	2.0	14.5			3.5	8.4	2.1	13.0
1849	2.2	14.4			2.8	8.8	3.5	12.8
1859	1.7	14.3			5.3	8.4	8.2	12.7
1869	2.2	15.0			3.7	8.6	14.1	13.4
1879	2.4	15.8			5.9	8.2	26.0	13.7
1889	2.1	16.1			5.2	9.9	29.8	14.2
1899	2.1	16.4			6.5	11.5	40.6	14.0
1909	1.7	17.5			3.9	12.3	40.2	14.0
				OATS				
1839	1.8	28.5			2.9	13.9	1.0	29.3
1849	2.1	28.5			3.2	13.7	1.4	30.0
1859	2.7	28.5			2.1	14.0	2.2	30.6
1869	2.6	28.6			2.1	14.5	4.9	32.1
1879	3.0	29.1			3.6	13.0	9.4	31.7
1889	3.1	26.2			4.0	12.9	20.6	29.9
1899	2.8	27.3			2.6	15.4	24.4	30.0
1909	2.7	29.7			2.4	17.0	30.4	26.5
				CORN				
1839	1.1	33.5	5.9	21.8	8.9	11.8	3.2	32.7
1849	1.7	33.3	7.3	22.1	12.6	12.2	6.8	32.5
1859	2.0	33.4	7.8	22.1	15.0	12.8	12.6	32.3
1869	2.5	33.2	7.1	21.9	10.0	13.4	17.1	33.8
1879	2.7	31.4	9.0	20.7	14.5	13.2	35.1	31.1
1889	2.8	34.6	9.8	22.3	17.0	14.7	46.9	31.2
1899	2.9	35.2	10.2	22.1	22.8	14.7	56.4	29.6
1909[a]	1.9	36.8	10.1	24.4	27.1	16.1	56.0	31.0

Source: 1839, 1849, and 1859, based on 1866-75 average yield by state and census production data. 1869-1909, USDA, revised estimates.

[a] Total acreage reduced by 3.9 per cent to allow for corn grown for silage. Estimates for regions and subregions on the basis of 1919 ratios are as follows: Northeast, 29 per cent; Corn belt (W:C), 4 per cent; Western dairy (W:WD), 25 per cent; Small grain (W:SG), 2 per cent. (See USDA-AMS Crop Reporting Board, *Corn Acreage, Yield and Production*, June 1954, and USDA Monthly Crop Report, July 15, 1915.)

TABLE 11

ACREAGES AND YIELDS IN MAJOR WESTERN SUBREGIONS, 1839–1909
(acres in millions and yields in bushels per acre)

	W:C		W:WD		W:SG	
	Acres (A)	Yields (O/A)	Acres (A)	Yields (O/A)	Acres (A)	Yields (O/A)
			WHEAT			
1839	2.0	12.8	0.2	14.4		
1849	2.8	12.4	0.7	13.9		
1859	5.7	12.1	1.9	13.8		
1869	8.8	12.8	3.8	14.3	0.3	12.9
1879	13.1	14.0	6.5	13.8	3.4	11.0
1889	10.8	14.4	6.2	14.5	8.5	13.3
1899	10.5	14.1	8.1	14.2	14.8	12.7
1909	9.5	15.8	4.5	15.3	20.1	12.0
			OATS			
1839	1.0	29.1	0.1	32.3		
1849	1.2	29.3	0.2	32.5		
1859	1.5	30.0	0.5	32.9		
1869	3.6	31.4	1.1	34.4	0.2	31.8
1879	6.1	31.6	2.2	34.7	0.6	27.7
1889	11.4	30.2	4.2	31.8	4.0	27.6
1899	12.4	32.1	5.5	32.3	4.6	25.9
1909	13.5	28.4	6.6	26.8	7.6	22.1
			CORN			
1839	3.2	32.7	0.1	33.2		
1849	6.6	32.6	0.2	33.1		
1859	11.6	32.4	0.7	32.8	0.3	29.7
1869	15.2	33.8	1.3	34.4	0.6	33.4
1879	27.5	31.2	2.4	33.5	5.0	29.8
1889	31.4	32.6	3.2	30.2	12.1	27.9
1899	35.4	32.9	4.5	32.5	16.3	21.8
1909[a]	34.2	35.8	4.0	31.7	17.2	21.9

Source: See source to Table 10.

[a] See note a to Table 10.

would have been more than twice—and labor in oats just under twice—as productive as it was (Table 2, index i_3).

Mechanization, then, was the strongest direct cause of the productivity growth in the production of these grains. It accounted directly for over half the improvement, according to the values derived from Table 2 (wheat, .598; oats, .506; corn, .562). The effects of mechanical harvesting and threshing were felt with equal strength in all the regions, as the averages of Table 1, columns *b* and *c*, indicate. In the operations of plowing, harrowing, and planting, improvements were relatively less effective in the East and South, but were strongly felt in the West. Hence, a significant interaction appears between the interregional shifts in acreage weights and the changes in labor inputs per acre. The values following Table 3, showing the relative importance of the different types of mechanization, indicate that the traditional emphasis on the reaper and the thresher is not misplaced. Alone or in interaction, these accounted for over 80 per cent of the improvement due to mechanization in both wheat and oats. In corn, on the other hand, nearly all of the fall in labor inputs per acre, shown in Table 1, occurred in preharvest operations, principally from the abandonment of hoe cultivation. In view of these different sources of

TABLE 12

CORN ACREAGES AND YIELDS IN THE SOUTHERN SUBREGIONS, 1839-1909

	Eastern Cotton (S:EC)		Delta Cotton (S:DC)		Western Cotton (S:WC)	
	Acres (A)	Yield (O/A)	Acres (A)	Yield (O/A)	Acres (A)	Yield (O/A)
1839	7.3	11.1	1.6	14.9		
1849	9.5	11.1	2.8	15.0	0.3	20.6
1859	10.1	11.1	4.2	15.3	0.8	20.6
1869	6.6	11.2	2.4	16.3	0.9	21.5
1879	8.3	10.7	3.6	15.6	2.5	18.3
1889	9.4	11.6	4.2	16.6	3.4	21.0
1899	10.9	11.2	5.6	15.5	6.3	20.0
1909	10.7	13.7	5.9	17.1	10.5	18.1

Source: See source to Table 10.

the productivity growth in the crops, it is interesting to note how close the productivity indexes in corn come to those in wheat and oats.

Mechanization had a direct effect, appearing at once in the statistical evidence. The influence of improvements in nonmechanical technology are more deeply hidden—although not for that reason more fundamental. In these crops, the most important contribution of nonmechanical technology lay in the adaptation of practices and seed to the new conditions of soil and climate in the West. Little is known about the causes of the stability of land yields in the East. Some intraregional shifting of the crops was involved, and some benefits were obtained from the proliferation of varieties of improved seed. It seems likely, however, that a satisfactory set of practices for maintaining yields in these crops had been evolved in the East by the mid-nineteenth century, and little may have been added to this knowledge until the rises in yields in the late 1930's. But how might techniques have altered to maintain yields and reduce labor costs in the East under the pressure of a growing demand, if the western lands had not been available? To answer this question requires, first, a guess as to the shape of cost curves in the East under rapidly growing output, and then, an inquiry into the feed-back from rising costs to technological change.

TABLE 13

LABOR INPUTS AND LAND YIELDS, PERIOD 1

Region	Preharvest and Harvest Labor			Postharvest Labor	Total
	L/A (1)	*O/A* (2)	*L/O* (3)	(*L/O*) (4)	(*L/O*) (5)
			WHEAT		
Northeast	34.1	14.5	2.35	0.73	3.08
South	23.8	8.4	2.83	0.73	3.56
West	27.4	13.0	2.11	0.73	2.84
U.S.	27.5	11.3	2.44	0.73	3.17
			OATS		
Northeast	27.1	28.5	0.95	0.40	1.35
South	19.8	13.9	1.42	0.40	1.82
West	21.6	29.3	0.74	0.40	1.14
U.S.	22.4	21.3	1.05	0.40	1.45
			CORN		
Northeast	111.3	33.5	3.32	0	3.32
Middle east	62.1	21.8	2.85	0	2.85
South	71.6	11.8	6.07	0	6.07
West	59.2	32.7	1.81	0	1.81
U.S.	68.8	19.6	3.51	0	3.51

Source

Col. 1: Table 1.
Col. 2: Output from U.S. Census of 1840. Acreage obtained by dividing 1839 state output by estimated state yield. Yields, by state, estimated at 1866-75 average in USDA, revised estimates. For alternative yield estimates, see Appendix B.
Col. 3: Column 1 divided by column 2.
Col. 4: See discussion in Appendix D, "Period 1, Postharvest Labor."
Col. 5: Sum of columns 3 and 4.

One may indeed speculate more broadly on alternative growth paths for the American economy in the nineteenth century. Our statistical analysis takes us a short direction along three such paths: (1) westward movement without technological change; (2) technological change without westward movement; (3) westward movement and technological change, as they actually occurred.

Without technological change, westward expansion would have been accompanied by very little rise in productivity in agriculture. Shipment of crops and movements of population away from farms would perforce have been less rapid and less complete. The effects on economic welfare would have depended strongly upon the effects of a growing density of rural settlement upon the rate of rural population growth. The second alternative, technological change without westward movement, might have occurred under different political arrangements or land policies beyond the Appalachians. Confined to an eastern region with sharply different factor proportions, technology might have appeared quite a different animal from the labor-saving, land-using creature that emerges in our statistics. Could the land-saving developments in agricultural chemistry and biology that have raised yields since 1940 have emerged a century earlier in place of the labor-saving cultivator, reaper, and thresher? Even a passing look at the state of scientific knowledge in the fields of mechanical and chemical invention casts great doubt upon the plausibility of such an alternative. Despite the external economy of transport derivable from a less extensive agriculture, neither alternative appears likely to have produced by itself any large portion of the productivity gain actually achieved. The great opportunity for American agriculture, and the economy growing from it in the nineteenth century, derived from the simultaneous presence of many factors—technological change, empty lands, a growing population, a means of increase in the capital stock, improvements in transport, and the expansion of markets. Nor is the task of economic history finished with a simple suggestion of the relative weights of these factors, even if the suggestion be accompanied by a zealous use of quantitative data and techniques of measurement. The crucial question is: why did all these opportunities appear so close to one another in time? One is led thus, by all routes, out of factorial analysis back to examination of the complicated process of change in social behavior, of which these specific developments—great as they are—are manifestations. Scientific historiography has substituted the mind of man for the mind of God in which the ultimate explanations of an earlier age could come to rest. The substitution has not made the work simpler or the final end less elusive.

Appendix A: Definition of the Regions

The definition of a region required for the analysis of the effect of interregional shifts on productivity is implicit in the choice of variables measured. For these purposes, a region is an area over which man-hours per output unit, under the techniques of period 1, remain grouped in a stable distribution around a constant mean, distinct from that of other similarly defined regions during rather wide variations in acreage. On this definition, a region forms, on the curve relating productivity and acreage for the country as a whole, a plateau over which output may expand or contract at more or less constant per unit labor costs. Such statistical plateaus are not, of course, necessarily geographically contiguous pieces of land. Ideally, we should define labor costs under the given technique for every acre on which a grain might be produced, and group together those, wherever located, with a common cost coefficient.

In practice, the only bases for such regionalization in the mid-nineteenth century are the series of land yields by state, beginning in 1866 in the USDA revised estimates, and the labor input data presented in this study. The USDA estimates are given for each state and year from 1866 on, and their averages by state for the earliest ten years (1866–75) are arrayed as shown in Table A-1. We can break these series between North and South, and, moving Delaware and Maryland below the line in the wheat series, we produce the same two major regions for all three crops on the basis of yield. In corn, another break occurs between the so-called "border" states and the lower South.

To regionalize on the basis of the labor/output relation, it is necessary next to examine the variation within the yield regions with respect to labor per acre in various operations. The labor data are too scarce and too variable to define regions even as roughly as the land yield data can do. However, we observe that in period 2 (1895–1915) those northern states producing corn, wheat, and oats in period 1 are divided into two regions: a northeast region, including New England, New York, and Pennsylvania; and a western region, including Missouri and the states north and west of the Ohio River.[6]

Our period 1 labor data do appear good enough to test whether these divisions, as well as the North-South division made for land yields, are significant at mid-century. In Appendix D the labor data are arrayed for major preharvest operations, singly and together, and for harvesting in three regions for wheat and oats, and in four for corn. Table A-2 gives means of these distributions for preharvest and harvest labor totals. Perceptible differences occur between the means of the series for preharvest labor between the Northeast and the other northern region, and the differences in a given operation among the three crops in each region probably reflect differences in practice. In the harvest operations, our

[6] These period 2 divisions are adopted from the WPA/NRP report (see Appendix E, U.S. Document 5).

TABLE A-1
AVERAGE YIELDS BY STATE, 1866-75

State	Wheat Yield (*O/A*)	First Differ- ence	State	Oats Yield (*O/A*)	First Differ- ence	State	Corn Yield (*C/A*)	First Differ- ence
Connecticut	17.2		Iowa	34.4		New Hampshire	37.6	
Massachusetts	17.0	0.2	Vermont	33.4	1.0	Vermont	37.4	0.2
Vermont	16.7	0.3	Wisconsin	33.0	0.4	Iowa	37.3	0.1
New York	16.1	0.6	Michigan	32.0	1.0	Ohio	35.7	1.6
New Hampshire	16.1	0	New Hampshire	31.1	0.9	Massachusetts	34.8	0.9
Michigan	14.6	1.5	Illinois	30.5	0.6	Pennsylvania	34.7	0.1
New Jersey	14.1	0.5	New York	29.9	0.6	Connecticut	33.7	1.0
Maine	13.6	0.5	Ohio	29.8	0.1	Indiana	33.5	0.2
Ohio	13.4	0.2	Connecticut	28.8	1.0	Michigan	33.3	0.2
Pennsylvania	13.2	0.2	Rhode Island	28.2	0.6	Wisconsin	32.7	0.6
Wisconsin	13.1	0.1	Massachusetts	28.2	0	New York	32.1	0.6
Missouri	12.4	0.7	Pennsylvania	27.4	0.8	New Jersey	31.7	0.4
Indiana	12.2	0.2	Indiana	27.3	0.1	Rhode Island	31.5	0.2
Maryland	12.1	0.1	Maine	26.9	0.4	Nebraska	31.1	0.4
Iowa	12.1	0	Missouri	26.8	0.1	Minnesota	31.0	0.1
Delaware	12.0	0.1	New Jersey	23.9	2.9	Illinois	30.6	0.4
Illinois	11.3	0.7	Delaware	19.1	4.8	Maine	30.2	0.4
Virginia-			Maryland	18.6	0.5	Kansas	29.4	0.8
West Virginia	9.5	1.8	Kentucky	17.7	0.9	Missouri	29.2	0.2
Kentucky	9.2	0.3	Arkansas	17.6	0.1	Kentucky	25.1	4.1
Arkansas	9.2	0	Tennessee	15.6	2.0	Maryland	22.8	2.3
Tennessee	7.4	1.8	Louisiana	14.2	1.4	Tennessee	21.6	1.2
Mississippi	7.3	0.1	Virginia-			Virginia-		
Alabama	6.7	0.6	West Virginia	12.3	1.9	West Virginia	19.0	1.6
North Carolina	6.3	0.4	Mississippi	12.1	0.2	Arkansas	18.9	0.1
Georgia	6.0	0.3	Georgia	11.9	0.2	Delaware	18.6	0.2
South Carolina	5.7	0.3	North Carolina	11.8	0.1	Louisiana	14.8	3.8
			Alabama	11.6	0.2	Mississippi	13.9	0.9
			South Carolina	10.9	0.7	North Carolina	12.4	1.5
			Florida	10.3	0.6	Alabama	12.3	0.1
						Georgia	9.9	2.4
						Florida	9.9	0
						South Carolina	9.8	0.1

Source: USDA, revised estimates (see Appendix E below, U.S. Documents 7, 8, 9).

TABLE A-2

LABOR INPUT COEFFICIENTS: PREHARVEST AND HARVEST LABOR FOR PERIOD 1

	Northeast		Middle East		South		West	
	No.of Cases	Man-Hours Per Acre	No.of Cases	Man-Hours Per Acre	No.of Cases	Man-Hours Per Acre	No.of Cases	Man-Hours Per Acre
Wheat								
Preharvest	32	19.1			43	11.3	21	12.4
Harvest	40[a]	15.0			b	12.5	40[a]	15.0
Oats								
Preharvest	25	14.3			51[c]	8.8	51[c]	8.8
Harvest	17[a]	12.8			b	11.0	17[a]	12.8
Corn[d]								
Preharvest		98.3		52.0		67.3		46.2
Harvest		13.0		10.1		4.3		13.0

Source: Appendix D. Preharvest labor, Tables D-1, D-1a; harvest labor, Tables D-8, D-9, D-10 and notes.

[a] Northeast and West treated as a single region.

[b] See Appendix D, period 1, harvest labor, for derivation of this figure.

[c] South and West treated as a single region.

[d] On number of cases, see Appendix D.

data for the southern region are deficient but the differences between the two northern regions do not appear significant.

On the basis of these considerations, we may separate Northeast from the rest of the North as defined by land yields, and produce the regions shown in the text.

Appendix B: Alternative Land Yield Estimates and Indexes

The average land yields shown in Table A-1 are taken from the 1866–75 USDA revised series, by state. Period 1, defined by our output and labor input data, however, relates to the period around 1839. Can the USDA 1866–75 state average yields be extrapolated back to the antebellum decades without allowance for trend? Shifts in the distribution of acreage between states of differing average yields within each region imply that extrapolation of regional averages might involve avoidable error. But the relative absence of strong trends in the state data from 1866–96 suggests that extrapolation by state may be justified. Fortunately, the *Annual Reports* of the Commissioner of Patents for the years 1843–55 contain estimates of county yields at several points within many of the states, and in a few states, state censuses provide similar information. Table B-1 compares these estimates, in summary form, with the average 1866–75 USDA revised estimate. Except in the frontier states, where acreages

TABLE B-1

ESTIMATES OF COUNTY LAND YIELDS, 1843-61, AND USDA AVERAGE, 1866-75
(bushels per acre)

State or Region	County Estimates, 1843-55			USDA 1866-75
	Number (1)	Range (2)	Median (3)	State Average (4)
WHEAT				
New England	20	10-25	15	16
New York	23	10-25	18	18
Pennsylvania	22	8-30	15	13
Delaware	6	14-20	15	12
New Jersey	5	12-30	20	14
Maryland	4	6-20	15	12
Virginia	13	8-15	9	9
South[a]	17	5-20	10	7
Ohio	18	10-35	15	13
Michigan	8	12-30	21	15
Wisconsin	12	12-40	20	13
Illinois	14	10-20	16	11
Indiana	16	9-25	16	12
Iowa-Missouri	9	10-20	15	12
OATS				
New England	31	17-50	30	30
New York	19	28-50	35	30
Pennsylvania-New Jersey	13	30-50	40	26
Delaware-Maryland	8	9-50	20	19
Virginia	6	10-28	16	12
South[a]	12	12-60	16	14
Ohio, Indiana, Illinois, Iowa	14	20-55	40	30
Michigan-Wisconsin	13	30-60	40	33
CORN				
New England	36	20-50	35	
New York	28	25-50	30	32
New Jersey	3	35-50	45	32
Ohio	22	25-60	39	36
Pennsylvania	12	30-50	38	35
Indiana	17	30-60	40	34
Michigan	9	15-40	30	34
Wisconsin	6	25-50	45	33
Iowa	7	22-40	35	37
Illinois	8	40-50	43	31
Missouri	7	30-60	40	29
Kentucky	5	40-60	50	25
Maryland	1		30	23
Tennessee	3	30-35	35	22
Texas	8	30-70	50	21
Virginia	21	10-40	20	19
Delaware	6	22-50	35	19
Arkansas	1		20	19
Louisiana	4	10-50	30	15
Mississippi	7	15-50	25	14
Alabama	6	20-37	30	12
North Carolina	4	10-20	15	12
Georgia	5	5-40	18	10
South Carolina	3	15-50	25	10

Source: Cols. 1-3, *Annual Report: Agriculture,* U.S. Commissioner of Patents, 1843-56; col. 4, USDA, revised estimates.

[a]States south of Ohio and Maryland, except Virginia.

are small in any case and yields high for a few years, the median of the 1843–55 county reports, by state, taken without regard to year, falls surprisingly close to the 1866–75 USDA state average.[7] The state estimates from contemporary sources shown in Table B-2 also fall close to the 1866–75 USDA state averages. It is probably justifiable then to extrapolate the state averages back to the 1840–60 period. Taking these yields, we calculate acreages by state from the Census production data for 1840, 1850, and 1860, and produce regional average yields (shown in Table 1).

Such extrapolation does indeed result in yields in the western region (R_3) decidedly below those shown in Tables B-1 and B-2. We have therefore prepared a set of alternative indexes based on an assumption of western yields (O/A) in 1839 (with a corresponding reduction in the regional acreage estimate) as follows:

	Wheat	*Oats*	*Corn*
Ohio	15	40	40
Indiana	16	40	40
Illinois	16	40	40
Iowa	15	40	38
Missouri	15	40	40
Michigan	21	40	33
Wisconsin	20	40	40
Minnesota	20	40	40

For corn, the presumption of higher yields arising from the newness of the region exists in the South and border states as well. In the Southeast, there is also the possibility that yields were abnormally depressed during the "reconstruction" period. On the basis of Table B-2, it seems desirable to allow for yields in the South and middle-east regions 50 per cent higher than the 1866–75 state averages.

These assumptions produce a set of regional yields in period 1 which compare with those of text Table 1 as follows:

	Wheat		*Oats*		*Corn*	
	Table 1	Alternative	Table 1	Alternative	Table 1	Alternative
R_1	14.5	14.5	28.5	28.5	33.5	33.5
R_{2a}	8.4	8.4	13.9	13.9	21.8	32.6
R_{2b}					11.8	17.7
R_3	13.0	15.3	29.3	40.0	32.7	39.8

[7] Surprise is reduced and confidence in the result perhaps raised, if we consider that the USDA series was itself derived from county crop reporters, though the number of such reporters was greater and the data supplied more explicit after 1870 than under the Patent Office.

TABLE B-2

ESTIMATES OF STATE LAND YIELDS, 1844-62, COUNTY LAND YIELDS, 1843-56, AND USDA AVERAGE, 1866-75
(bushels per acre)

State	1866-75 USDA Revised Series (1)	1843-56 Median County Estimates (2)	1844-62 State Land-Yield Estimates (3)	
		WHEAT		
United States			1842	15-20
			1845	18
Massachusetts	17	15	1853	17
			1855	15
New York	16	18	1844	14
			1854	11
Virginia	9	9	1847	8-10
Tennessee	7	11	1849	15
Ohio	13	15	1845	13
			1850-57	8-17
Michigan	15	21	1845-49	15-20
Indiana	12	16	1844-48	20
		OATS		
United States			1845	35
Northeast			1847	30-40
Northwest			1847	30
South			1847	10
Massachusetts	28	30	1847	35
			1853	30
			1855	21
			1861	26
New York	30	35	1844	26
			1854	20
Delaware	19	20	1848	26
Georgia	12		1848	12-15
Tennessee	16	16	1848	25-30
Wisconsin	33	40	1849	35
Michigan	32	40	1848	40
			1849	35
		CORN		
New England	35	35	1847	25-30
New Hampshire	38		1862	38
Vermont	37		1862	35
Massachusetts	35		1854	25
			1855	29
			1862	37
Connecticut	34		1862	32
Rhode Island	32		1862	37
New York	32	30	1844	25
			1845	24
			1855	21
			1862	35
New Jersey	32	45	1862	37
Pennsylvania	35	38	1847	25-30
			1862	36

(continued)

TABLE B-2 (concluded)

State	1866-75 USDA Revised Series (1)	1843-56 Median County Estimates (2)	1844-62 State Land-Yield Estimates (3)	
Ohio	36	39	1847	43
			1845-48 (average)	38
			1850	36
			1852	34
			1853	40
			1854	26
			1855	40
			1856	28
			1857	37
			1858	28
			1862	33
Indiana	34	40	1862	42
Illinois	31	43	1848 (prairie)	40-50
			1862	40
Michigan	33	30	1847	40
			1854	23
			1856	18
Wisconsin	33	45	1860	40
Iowa	38	35	1862	38
Minnesota	31		1862	45
Missouri	29	40	1862	38
Kentucky	25	50	1847	30-40
Delaware	19	35	1862	20
Louisiana	15	30	1854	15-25
Alabama	12	30		
North Carolina	12	15	1847	20-35
Georgia	10	18		

Source

Cols. 1 and 2: Table 3.
Col. 3: *Annual Report: Agriculture*, U.S. Commissioner of Patents, 1844-62; and, for New York, State Censuses of 1845 and 1855; Ohio, 1850-58 from State Censuses of Agriculture; Massachusetts, 1855 State Census.

Since the period 1 acreage weights in Table 1 are derived by dividing estimated yields into Census production data for 1839, change in the yield estimate alters acreage weights as follows:

	Wheat		*Oats*		*Corn*	
	Table 1	Alternative	Table 1	Alternative	Table 1	Alternative
R_1	.259	.273	.316	.331	.057	.080
R_{2a}	.459	.482	.509	.521	.310	.291
R_{2b}					.465	.435
R_3	.282	.246	.178	.138	.168	.194

TABLE B-3

PRODUCTIVITY INDEXES BASED ON ALTERNATIVE ESTIMATES OF WESTERN YIELDS IN PERIOD 1

	Text Table 2,[a] Estimate	Variant	Text Table 3,[b] Estimate	Variant	Text Table 4,[c] Estimate	Variant
			WHEAT			
i_1	100.0	100.0	100.0	100.0	100.0	100.0
i_2	118.3	113.8	144.7	143.3	103.3	103.1
i_3	245.7	242.1	119.2	119.6	97.6	97.1
i_4	109.3	117.8	113.6	112.5	109.3	118.6
i_5	302.1	290.7	188.7	188.3	100.6	100.3
i_6	377.3	401.6	139.1	138.7	112.4	122.5
i_7	117.8	113.4	176.1	172.4	106.7	115.1
i_8	416.7	401.6	245.7	242.1	109.6	119.2
			OATS			
i_1	100.0	100.0	100.0	100.0	100.0	100.0
i_2	105.8	102.9	134.2	134.2	104.3	105.3
i_3	185.9	185.5	115.1	116.1	97.3	97.9
i_4	122.9	139.7	106.7	106.8	120.8	141.0
i_5	201.2	195.7	164.7	165.8	101.4	102.1
i_6	371.7	414.9	125.0	125.9	126.1	146.8
i_7	117.9	114.7	147.9	146.8	118.9	138.3
i_8	362.6	352.1	185.9	185.5	122.9	142.5
			CORN			
i_1	100.0	100.0			100.0	100.0
i_2	119.0	85.7			111.1	112.2
i_3	227.3	226.4			97.0	96.1
i_4	129.6	124.3			130.1	118.0
i_5	265.2	191.6			107.4	107.3
i_6	330.2	316.4			144.6	132.4
i_7	142.9	103.0			126.4	113.7
i_8	364.6	261.6			140.0	127.0

Source: See text accompanying Tables 2, 3, and 4.

[a]See cols. 4, 5, and 6 of Table 2, for wheat, oats, and corn, respectively.

[b]See cols. 2, and 4 of Table 3 for wheat and oats, respectively.

[c]See cols. 4, 5, and 6 of Table 4 for wheat, oats, and corn, respectively.

The productivity (O/L) indexes derived by inserting those values in the formulas of Tables 2, 3, and 4 are shown, with the text indexes for comparison, in Table B-3. It is apparent that the levels and relative values of the indexes are not strongly affected by this alternative assumption.

Appendix C: Measurement of Relative Importance of the Factors

The assessment of the relative importance of a factor is derived from Yates (see Appendix E, book 9). Gratitude is owed to Leo Katz of Michigan State University for calling attention to the method, though he bears no responsibility for the transfer of it to the present context. To derive the signs shown in the matrix in the text, let the variables of Table 2 (v, abc, y) be represented by a, b, c (period 1 values) and A, B, C (period 2 values). Then the independent effect of A is taken as the mean difference between the indexes where it appears in a period 2 value (A) and those where it appears in a period 1 value (a). The independent effect of AB is the sum of two differences $(ABC - abC) + (ABc - abc)$, with each reduced by the indexes of the independent effects of the other period 2 values occurring in them. The whole equation is

$$\begin{aligned} AB = (ABC - abC) &- [(AbC - abC) + (aBC - abC)] \\ + (ABc - abc) &- [(Abc - abc) + (aBc - abc)]. \end{aligned}$$

The independent effect of ABC takes the whole difference $ABC - abc$ less a similar allowance for the effects of the other indexes.

$$\begin{aligned} (ABC - abc) &- [(ABc - abc) - [(Abc - abc) + (aBc - abc)] \\ &- [(aBC - abc) - [(aBc - abc) + (abC - abc)] \\ &- [(AbC - abc) - [(Abc - abc) + (abC - abc)] \\ &- (Abc - abc) - (aBc - abc) - (abC - abc) \end{aligned}$$

These formulas reduce to the terms with their signs shown in the text matrix.

Appendix D: Summary Tables for Labor Requirements by Type of Operation

The tables are in four groups: period 1, preharvest; period 1, harvest and postharvest; period 2, preharvest and harvest; period 2, postharvest.

SYMBOLS

n = number of cases; $\bar{X}$ = arithmetic mean; M = median; σ = standard deviation; s = standard error of the mean.

REGIONAL ABBREVIATIONS AND DEFINITIONS

NE, Northeast (Pa., N.J., N.Y., Vt., N.H., Mass., Conn., Me., R.I.)
S, South[8]
S:ME, South: Middle east (Md., Del., Va., Ky., W.Va., Tenn., Ark.)
S:EC, South: Eastern cotton (N.C., S.C., Ga., Fla., Ala.)
S:DC, South: Delta cotton (Miss., La.)
W, West
W:C, West: Corn (Ohio, Ind., Ill., Mo., Iowa)
W:WD, West: Western dairy (Mich., Wis., Minn.)
W:SG, West: Small grain (Nebr., Kans., S.Dak., N.Dak., Mont.)
W:WC, West: Western cotton (Tex., Okla.)
W:R, West: Range (N.Mex., Ariz., Colo., Utah, Nev., Wyo.)
W:NW, West: Northwest (Idaho, Ore., Wash.)
W:Cal., West: Calif.

PERIOD 1: PREHARVEST LABOR, CORN

For period 1, total preharvest labor for each region is composed of the sum of the average man-hours per acre for the standard operations as follows:

R_1 Plowing, harrowing, planting, cultivating, and hoeing
R_{2a} Plowing, harrowing, running off rows, planting, cultivating, and hoeing
R_{2b} Clearing and cutting stalks, plowing, running off rows, planting, cultivating, and hoeing
R_3 Plowing, harrowing, planting, cultivating and hoeing.

For all regions except R_{2a} (middle east), there were also a number of cases where complete preharvest totals were available (see Table D-1). In the case of the Northeast and the West, these were remarkably close to the totals obtained by the above method which is based on the prevailing techniques within each region (Table D-1a). Where our data indicated that time differences for the same operation were insignificant, regional averages were combined. In the case of "running off rows," regions R_{2a} and R_{2b} (middle east and South) were combined, and for cultivating and hoeing, middle eastern and western regional averages were combined. In addition, an allowance for cutting and clearing stalks in Tennessee was made by weighting the R_{2b} labor coefficient for this operation by Tennessee's acreage weight in the R_{2a} region. This was due to the fact that the corn was harvested in Tennessee by the southern method of pulling off the

[8] For corn, the middle east (S:ME) becomes a separate region (ME) and the South (S) includes the eastern cotton (S:EC), delta cotton (S:DC), and western cotton (S:WC) regions, with Arkansas included in the delta cotton states.

TABLE D-1

PERIOD 1: PREHARVEST LABOR, TOTAL

	NE	S:ME	S:EC	S:DC	S	W:C	W:WD	W
				WHEAT				
n	32.0	36.0	7.0		43.0			21.0
$\bar{X}$	19.1	11.3	10.9		11.3			12.4
M	20.0	10.2	11.6		10.2			10.9
σ	7.3	4.1	2.3		3.8			7.2
s	1.3	0.7	0.94		0.6			1.6
				OATS				
n	25.0	23.0	11.0	7.0	41.0			10.0
$\bar{X}$	14.3	9.4	7.2	10.5	9.0[a]			8.7[a]
M	13.7	9.0	7.1	10.5	8.6			7.9
σ	3.7	2.4	2.4	1.9	2.6			1.9
s	0.75	0.5	0.76	0.84	0.4			0.63
				CORN				
n	61.0		28.0	6.0	34.0	19.0	2.0	21.0
$\bar{X}$	97.8		55.0	68.2	57.3	48.4	47.5	48.3
M	88.0		54.3	68.9	56.7	42.0		42.0
σ	42.5		23.9	8.0	22.5	18.0		18.0
s	5.5		4.6	3.5	3.9	4.3		4.0

[a]South and West treated as a single region for Table 1.

TABLE D-1a

PERIOD 1: PREHARVEST LABOR FOR CORN, BY OPERATION

	NE	ME	S	W
Clearing and cutting stalks		2.5[a]	7.5	
Plowing	11.9	7.4	8.9	7.5
Harrowing	5.4	1.2		2.9
Running off rows		3.5	3.5	
Planting	14.5	7.5	8.8	5.9
Cultivating	14.7	12.0	17.8	12.0
Hoeing	51.8	17.9	20.8	17.9
Totals	98.3	52.0	67.3	46.2

Source: Tables D-2 to D-7, and Appendix D text.

[a]Allowance for cutting and clearing stalks in Tennessee.

TABLE D-2

PERIOD 1: PREHARVEST LABOR, PLOWING

	NE	S:ME[a]	S:EC	S:DC	S	W:C	W:WD	W
				WHEAT				
n	32.0	24.0	3.0		27.0			22.0
$\bar{X}$	12.4	6.3	7.3		6.4			6.5
M	10.0	5.8	5.6		6.0			5.7
σ	6.7	2.1			2.1			2.8
s	1.2	0.45			0.4			0.62
				OATS				
n	25.0	12.0	1.0	7.0	20.0			10.0
$\bar{X}$	7.1	5.7	7.27	7.0	6.2			5.4
M	7.1	5.6		6.7	6.1			5.0
σ	2.2	2.1		1.5	1.8			1.2
s	0.45	0.64		0.6	0.41			0.41
				CORN				
n	72.0	12.0	29.0	12.0	41.0	44.0	4.0	48.0
$\bar{X}$	11.9	7.4	7.9	11.4	8.9	7.5	6.9	7.5
M	10.0	6.3	7.5	9.5	8.0	7.1	6.5	7.1
σ	5.2	4.8	4.14	5.1	4.7	2.9	2.2	2.81
s	0.62	1.5	0.8	1.6	0.75	0.4	1.27	0.40

[a]For corn, the region is ME.

TABLE D-3

PERIOD 1: PREHARVEST LABOR, HARROWING

	NE	S:ME[a]	S:EC	S:DC	S	W:C	W:WD	W
				WHEAT				
n	32.0	26.0	2.0		28.0			23.0
$\bar{X}$	6.2	3.0	2.8		3.0			4.9
M	5.0	2.5	2.8		2.5			3.3
σ	3.4	1.5			1.5			3.4
s	0.61	0.31			0.28			0.71
				OATS				
n	22.0	13.0	1.0	1.0	15.0			11.0
$\bar{X}$	4.7	2.0	11.1	5.0	2.8			2.3
M	5.0	1.8			1.8			2.5
σ	2.0	0.9			2.5			1.0
s	0.44	0.27			0.67			0.32
				CORN				
n	44.0	5.0				27.0	2.0	29.0
$\bar{X}$	5.4	1.2				2.8	3.75	2.9
M	5.0	1.0				2.5		2.5
σ	3.7	0.5				1.8		1.79
s	0.6	0.25				0.3		0.34

[a]For corn, the region is ME.

TABLE D-4

PERIOD 1: PREHARVEST LABOR, SOWING AND PLANTING

	NE	S:ME[a]	S:EC	S:DC	S	W:C	W:WD	W
				WHEAT				
n	9.0	11.0	1.0					12.0
$\bar{X}$	1.68	1.5	1.1					1.2
M	1.65	1.5						1.3
σ	0.6	0.34						0.55
s	0.21	0.11						0.17
				OATS				
n	9.0	4.0						1.0
$\bar{X}$	1.2	1.5						1.42
M	1.0	1.5						
σ	0.6	0.26						
s	0.21	0.15						
				CORN				
n	68.0	23.0	40.0	23.0	63.0	40.0	6.0	46.0
$\bar{X}$	14.5	7.5	8.8	8.6	8.8	5.6	7.5	5.9
M	12.5	7.7	8.66	7.0	7.9	5.0	5.6	5.0
σ	9.7	2.9	4.7	5.0	4.9	3.8	5.8	4.1
s	1.2	0.62	0.76	1.1	0.62	0.6	2.59	0.62

[a]For corn, the region is ME.

TABLE D-5

PERIOD 1: PREHARVEST LABOR, CORN CULTIVATING

	NE	ME	S:EC	S:DC	S	W:C	W:WD	W
n	44.0	16.0	41.0	11.0	52.0	41.0	2.0	43.0
$\bar{X}$	14.7	12.1	18.5	15.3	17.8	11.7	16.0	11.9
M	12.0	11.9	16.7	14.8	16.4	10.0		10.0
σ	9.9	3.8	9.6	6.3	9.1	6.9		6.9
s	1.5	0.975	1.5	2.0	1.3	1.1		1.1

TABLE D-6

PERIOD 1: PREHARVEST LABOR, CORN HOEING

	NE	ME	S:EC	S:DC	S	W:C	W:WD	W
n	48.0	8.0	37.0	10.0	47.0	19.0	2.0	21.0
$\bar{X}$	51.8	11.5	20.0	23.7	20.8	23.1	17.5	20.4
M	48.0	10.8	14.25	21.3	16.5	20.0		20.0
σ	30.7	5.64	20.68	10.6	19.1	14.7		13.9
s	4.5	2.1	3.4	3.5	2.8	3.5		3.1

TABLE D-7

PERIOD 1: PREHARVEST LABOR FOR CORN, MISCELLANEOUS OPERATIONS

	ME	S:EC	S:DC	S	ME+S
		CLEARING AND CUTTING STALKS			
n					11.0
$\bar{X}$					7.5
M					2.3
σ					8.4
s					2.65
		RIDGING, BEDDING, OR FURROWING			
n		15.0	1.0	16.0	
$\bar{X}$		8.0	3.9	7.8	
M		7.06		6.9	
σ		4.3		4.3	
s		1.1		1.1	
		RUNNING OFF ROWS			
n	3.0	17.0	3.0	20.0	23.0
$\bar{X}$	4.4	3.0	5.5	3.37	3.5
M	6.0	2.25	5.4	3.65	3.8
σ		1.73	1.0	1.9	1.97
s		0.43	0.7	0.4	0.42

ears, necessitating the removal of stalks the following spring before land could be plowed.

We have assumed that plowing was standard practice in all regions, although in the South, the cornfield was frequently ridged or bedded instead. Sixteen cases for this operation gave us an average of 7.8 man-hours per acre, which is somewhat less than the plowing average of 8.9 man-hours per acre obtained from forty-one cases, and almost the same as the plowing time for the eastern cotton area (twenty-nine cases, 7.9 man-hours per acre) from which fifteen of our sixteen cases originated. It therefore did not appear necessary to make an allowance for the alternative operation.

In the Northeast, instead of being harrowed, the field was occasionally dragged or rolled. In only two cases out of ten was rolling carried out in addition to harrowing, but in both cases the combined time was less than the regional average for harrowing. Four cases gave a combined figure for rolling, dragging, and harrowing, of which two were below the regional average. It would appear that either the cornfield was harrowed or dragged and rolled, but that harrowing was the usual operation. In the South the harrow was rarely used before planting, although occasionally a harrow was used to "cover" after planting or for the first cultivation. In place of harrowing, we find that "running off rows" precedes planting. This appears to be a somewhat more elaborate operation than "marking" in the Northeast and West before the days of the corn planter. But whereas "marking" time was included with planting in those two regions, running off rows was taken into account separately in the South, and, combined with the three middle-eastern cases, applied to both regions.

The planting operation in all regions includes an allowance for replanting, where the records show that this was done. No allowance has been made for manuring.

PERIOD 1: HARVEST LABOR, WHEAT AND OATS

To estimate harvest labor requirements in period 1, we have three bodies of evidence: (1) a number of cases for total harvest labor in the North and for reaping alone in the South; (2) a few cases for individual operations in the North and operations other than reaping in the South; (3) Rogin's estimates (Appendix E, book 7), based on a few cases of labor in each operation by various techniques.

From (1), shown in Table D-8, we derive an average figure for Northeast and West, in the same way as for preharvest operations. Since the averages for each region are close to one another, the two are combined into a single sample (col. 3). This is the more plausible since harvest labor is affected less by natural conditions, other than yield and regional differences in farm practice, than the preharvest operations are. The lower figure for oats, despite very high yields in many cases, is probably due to less careful handling of the crop after cutting.

The problem then is to derive a figure for the South based on the reaping data, summarized in Table D-8, and the few figures on other operations shown in Table D-9. These scattered figures may be summarized as follows:

	Operation								*Wheat*		*Oats*	
	Reaping	Raking	Binding	Taking Up	Setting Up	Shocking	Stacking	Total	$\bar{X}$	*n*	$\bar{X}$	*n*
1.	x	x	x						7.2	5	10.0	3
2.		x	x						4.3	1	5.0	1
3.						x			3.5	3		
4.							x		5.8	2	9.0	3
5.		x	x			x			5.3	1		
6.			x				x		11.3	3		
7.					x						3.3	1
8.				x			x				5.3	5
9.	x			x							6.0	1
10.								x	12.2	8	11.0	3

The estimates for wheat (12.5) and oats (11.0) in Table 1 in the text are derived from these data in several ways. For wheat, the estimates are as follows:

1. 12.2, the total figure (line 10). This, however, is a simple average of four figures from region S:EC (10.0) and region S:ME (14.4) and so may be too low.

2. 12.7, the average of line 1 (7.2) plus the average of lines 4 and 5 (5.5).

3. 12.3, the sum of the estimate for reaping, Table D-8 (3.6) plus line 2 (4.3) plus average of lines 3 and 4 (4.4).

4. Rogin's estimate of 11.0–13.5. This estimate appears a little too low for the North, and Rogin states that binding labor was probably

higher in proportion to cradling in Virginia than in the West. The lower yields of the South, however, make a lower total figure plausible.

For oats, the figure in Table 1 is derived from these data by several routes:

1. 11.1, reaping (4.0), Table D-8, plus line 2 (5.0) plus 2.0 for shocking, estimated from the Northeast figures of Table D-9.
2. 12.0, line 1 plus 2.0 for shocking.
3. 11.0, line 10.
4. 11.3, line 8 plus line 9, as a maximum, with "taking up" double-counted.

TABLE D-8

PERIOD 1: HARVEST LABOR FOR WHEAT AND OATS

	Harvesting, Total			Reaping
	NE (1)	W (2)	NE and W (3)	S (4)
			WHEAT	
n	21.0	19.0	40.0	48.0
$\bar{X}$	15.3	14.8	15.0	3.6
M	14.6	13.3	13.7	3.25
σ	7.2	5.6	6.4	1.3
s	1.6	1.3	1.03	0.19
			OATS	
n	12.0	5.0	17.0	36.0
$\bar{X}$	13.1	12.1	12.8	4.1
M	12.5	10.0	12.5	4.14
σ	3.3	3.1	3.3	1.4
s	0.99	2.3	0.81	0.23

Other combinations of the data, involving the high stacking figure for oats (line 4), would yield higher estimates. But these three cases are all from one Virginia plantation in one year and it is not clear what the term stacking here means. The small differences between oats and wheat are explainable in the same terms in the South as in the North, and between southern and northern oats in the same terms as for wheat. That yields affect both the wheat and oats figures is indicated by the relatively low reaping figure for the South compared with Rogin's estimate of 5.0 for cradling.

TABLE D-9

PERIOD 1: MISCELLANEOUS HARVESTING FIGURES FOR WHEAT AND OATS

(man-hours per acre)

PART A. WHEAT

Region	Reaping	Reaping, Raking, and Binding	Raking and Binding	Setting Up	Shocking	Stacking	Raking, Binding, and Shocking	Binding and Stacking	Total Harvest
NE	5.0								*15.3*
S:ME	*3.6*		4.3		2.8		5.3		*10.0*
		8.4			4.5				17.5
		6.3			3.1				14.5
		7.7							15.6
		5.7							
		8.1							
S:EC						4.8		8.6	8.3
						6.8		16.2	9.0
								9.1	9.9
									13.1
W		15.0					4.7	5.2	*14.8*
US (Rogin)	5.0		5.0-7.5		1.0				11.0-13.5

PART B. OATS

Region	Reaping	Reaping, Raking, and Binding	Raking and Binding	Setting Up	Shocking	Stacking	Taking Up and Stacking	Reaping and Taking Up	Reaping, Binding, Taking Up, and Shocking	Total Harvest
NE	5.0		5.0		2.5					*13.1*
		8.8			2.2					
		8.6			2.1					
S:ME	*4.1*[a]		5.0	3.3		8.8	4.5[b]	6.0[c]	10.0[c]	11.1[d]
						7.9	8.9[b]			11.9[d]
						10.3	4.3[b]			
							6.4[b]			
							2.5[b]			
S		10.0								12.1
US (Rogin)	5.0		5.0-7.5		1.0					11.0-13.5

Source: Italicized figures are averages, derived from Table D-8. The Rogin figure is the summary estimate from Rogin (Appendix E, B-7), pp. 125-37. The source of the other figures is given in Appendix Tables S-25 and S-26 (not shown).

[a]Includes S:EC region.

[b]Figures from North Carolina.

[c]Figures from Georgia.

[d]Figures from Mississippi.

PERIODS 1 AND 2: HARVEST LABOR, CORN

Harvesting of the corn grain consists of picking or snapping the ear from the stalk. Throughout the North, husking is generally performed as the ears are picked. The data, therefore, give single figures for the picking and husking operations combined. Operations on the corn plant—topping, pulling leaves, or cutting and shocking—are not part of grain harvesting, and the considerable amounts of time devoted to them, especially in the Northeast, are chargeable to fodder or stover production. Since the acreage thick-sown and cut for silage in period 2 is not included in the acreage figures of Table 10, it is not necessary to estimate labor costs in these operations.

Three methods of harvesting the corn grain were in use in the United States in the period 1840–1910: (1) The plant was cut and shocked, and the ears picked and husked from the shocks in the field or barn before storage. (2) The ears in the husks were picked from the standing stalks, stored in the husks, and husked as used during the year. (3) The ears were picked and husked from the standing stalks in one operation. These methods are known respectively as: (1) husking from the shock; (2) snapping from the standing stalk; (3) husking from the standing stalk. In the two periods, these methods appear to have prevailed in the various regions as follows:[9]

	Period 1 Method	*Period 2 Method*
R_1 plus Ohio, W:WD and North Dakota	1	1
R_{2a} except Tennessee	1	1
R_{2b} plus Tennessee	2	2
R_3 less Ohio, W:WD and North Dakota	1	3

In the mid-nineteenth century, all our contemporary figures are for cutting and shocking in the North and border states and for snapping in the South below Kentucky and Virginia. In the West, some corn land was harvested, grain and all, by livestock, but the method of going through the field to husk from the standing stalks did not appear until the 1870's. In 1840, the weight of the eastern portion of the corn belt

[9] In period 2, the division between method 1 and methods 2 and 3 is shown in USDA, *Yearbook, 1917* (Appendix F, U.S.-ld), pp. 566–567. Here, in fact, method 1 extends across most of North Dakota and Montana, and occupies a large island in central Missouri. Methods 2 or 3 include the western quarter of Kentucky and the southern third of Minnesota. These adjustments partly balance out along the boundaries as we have drawn them. The distinction between the regions using methods 2 and 3 is shown roughly in the NRP Report A-5, Appendix Tables D-5 and D-10 (Appendix E, U.S.-6).

where cutting and shocking were universal, and the evident predominance of the practice even in Illinois, justifies the use of the method 1 figure for the region as a whole.

For methods 1 and 3, a basic source is USDA, *Bulletin 3*, 1913 (see Appendix F, U.S.-1b), giving results for an extensive survey and indicating standard coefficients for the United States in these operations as follows:

Method	*Yield in Bushels of Ears*	*Bushels per 9½-hour day*
1	1–40	35
	41–60	42
	61 and over	50
3	1–40	60
	41–60	70
	61 and over	75

Taking two bushels of husked ears as the equivalent of one bushel of shelled corn, it appears that the yields in the North—25–35 bushels per acre—would require 10–14 hours per acre by method 1, and 7–9 hours per acre by method 3. These results, however, are based on returns heavily weighted from the North Central states and "adjusted" arbitrarily by the compilers to compensate for assumed biases in the farmers' reports.

For method 1, several pieces of evidence indicate that the estimate should be placed at the upper limit of *Bulletin 3*'s range of 10–14 man-hours per acre. For western New York, a survey reported in USDA, *Bulletin 412*, 1913 (see Appendix F, U.S.-1b) indicates a range of 12–14 man-hours per acre for a 30-bushel (shelled) yield. A similar survey in 1915, for Chester County, Pennsylvania,[10] also yields an estimate of 13.5 man-hours per acre for a yield of 50 bushels.

In West Virginia, in 1913–15, a survey of fifteen to thirty farms in each of twelve counties[11] gave an average of 15.6 man-hours per acre for an average yield of 40 bushels, with a county range of 13.2–17.7. Finally, in two counties in Minnesota, estimates of 12.8 and 14.0 were obtained as an average during the 1910's.[12] The figure used in Table 1, therefore, is taken to indicate conditions outside the corn belt, for the range of yields in the states where method 1 was prevalent.

The *Bulletin 3* range for method 3, on the other hand, appears a little high on the basis of other evidence. Here the sources of evidence are:

1. NRP, Report A-5, giving county estimates for sixteen counties scattered through the central West.

[10] USDA, *Bulletin 528*, 1915, p. 13 (Appendix F, U.S.-1b).
[11] West Virginia AES *Bulletin 163*, 1917, p. 6 (Appendix F, S-23).
[12] Minnesota AES *Bulletin 179*, p. 31, and *Bulletin 157*, p. 29 (Appendix F, S.-12).

2. Illinois AES *Bulletin 50*, 1896 (Appendix F, S.-6), p. 50, giving figures for 16,600 acres, including a sampling of every county in the state.
3. A survey of several thousand acres in Iowa, Illinois, and Indiana (USDA, *Bulletin 1,000*, 1919, pp. 5–11; see Appendix F, U.S.-1b).
4. Scattered reports (five) given by farmers.

By averaging these data taken by counties or region and omitting the scattered reports, the following values are obtained (see Table D-15):

n	$\bar{X}$	σ	s
28	6.67	1.6	0.31

The labor time required in method 2 is less than that in method 1 largely because time is not used in pulling the shock apart to get to the ears of corn. In method 2, husking time is not included in our data, since the corn is husked as used over the year. Storing corn in the husks in the South is said to help protect it against insect damage.[13] In any case, the husking time must be accounted negligible. The labor at odd moments over the year has little value, the husks are thoroughly dried, and the rather small variation of labor time in methods 1 and 3 with yield per acre indicates that even when the corn is only partially dried, husking itself takes only a small part of the time spent in moving over the field, finding and pulling the ears from the plant. The omission of the husking operation and the much lower yields of shelled corn in the South, reduce the harvesting time in method 2 below the western (method 3) standard. The average of thirteen NRP sample counties in the cotton region[14] shows (see Table D-15):

n	$\bar{X}$	σ	s
13	4.3	0.6	0.2

In Table D-10, the period 2 coefficients are used without change for the regions to which the methods apply in period 1. Hence, the only improvement shown is the substitution of method 3 for method 1 in the West between the two periods. Even this improvement is partly offset in our figures by inclusion of a cost item for clearing the field of stalks in method 3, while this operation in method 1 is charged to the value of

[13] USDA Office of Experiment Stations, *Bulletin 173*, p. 33 (Appendix F, U.S.-1k).

[14] USDA, *Bulletin 1181*, 1924, p. 15 (Appendix F, U.S.-1b), gives a higher figure (6.1 as an average of seven counties) for a standardized yield of 25 bushels per acre in Arkansas in 1924, but the higher yield and restricted area of this study indicate that it should not be included in our data.

TABLE D-10

PERIOD 1 AND 2: HARVEST LABOR FOR CORN[a]

	Period 1		Period 2	
	Method[b]	Man-Hours Per Acre	Method[b]	Man-Hours Per Acre
R_1	1	13.0	1	13.0
R_{2a} (excl. Tennessee)	1	13.0	1	13.0
Tennessee	2	4.3	2	4.3
R_{2b}	2	4.3	2	4.3
R_3 (excl. Ohio, W:WD, and North Dakota)	1	13.0	3	6.7
Ohio, W:WD, and North Dakota	1	13.0	1	13.0

[a]The harvest labor coefficients b in Table 1 for R_{2a} in periods 1 and 2 and for R_3 in period 2 are the weighted regional averages.

[b]Method 1, husked from shock; method 2, snapped; method 3, husked from standing stalk.

fodder production. The direct data from period 1 for the Northeast give much higher figures per acre, but include hauling and housing, and in some cases probably cutting and shocking as well. They are based largely on premium reports with yields two to four times the regional average. In Maryland and Tennessee, seven cases from plantation manuscripts show costs of 0.8 to 1.8 man-hours per bushel for unknown yields, presumably for harvesting from the shock, and probably including hauling.

In the eastern cotton region, thirty-two manuscript cases for the operation of "gathering" or picking give an average of 6.6 man-hours per acre (Table D-11), including in at least one case, and probably in others, hauling and housing.

TABLE D-11

PERIOD 1: HARVEST LABOR, CORN

	ME	S:EC	S:DC	W:C
n	2.0	32.0	2.0	14.0
$\bar{X}$	20.1	6.6	31.5	11.3
M		6.1		11.6
σ		3.02		3.7
s		0.54		1.03

In the corn region of the West, fourteen cases from contemporary sources designated harvesting, gathering, or husking (including hauling and cribbing in some cases) average 11.3 man-hours per acre. The method of harvesting is not known, and seven extreme cases of 20–40 man-hours per acre are omitted. Yields in all these cases run two to four times the regional average.

PERIOD 1: POSTHARVEST LABOR, WHEAT AND OATS

In postharvest labor (threshing) only the size of the crop and method of threshing affect labor cost. For threshing, the flail, the treading floor, and small hand- or horse-powered machines were all in common use. For 1838–61, our contemporary sources for wheat, based largely on Virginia and Illinois manuscripts, yield a bimodal series of fifteen items bunched between 0.47–0.74 and 1.00–1.50 man-hours per bushel. If these two groups correspond to the ranges of treading floor and machine techniques, or the hand method, then the median (0.73) is the upper limit of methods[15] other than flail and winnowing sheet.

For oats, the mix of techniques may have been somewhat less labor-saving since a portion was grown for feed on farms which grew no wheat. But the lighter weight and larger grain of oats make it easier to thresh by any technique. One source for the flail and sheet method gives the same labor for an acre of oats at 40 bushels per acre as for an acre of wheat at 20 bushels.[16] On this basis, an estimate of 0.40 man-hours per bushel for oats appears to be comparable to one of 0.73 for wheat.

[15] Though stated somewhat unclearly, Rogin's data appear to yield the following rough estimates for the various techniques:

	Technique		*Man-Hours Per Bushel of Wheat*		
	Threshing	Winnowing	Threshing	Winnowing	Total
1.	flail	sheet	1.00	0.30	1.30
2.	flail	hand-mill	1.00	0.06	1.06
3.	treading	sheet	0.37	0.30	0.67
4.	treading	hand-mill	0.37	0.06	0.43
5.	machine-horsepowered				0.30
6.	machine-horsepowered				0.11

Source: Rogin (See Appendix E, B-7), pp. 176–191.
The figure 0.73 is just the midpoint of the range of techniques 1 to 5, as estimated by Rogin.

[16] Source: See Appendix E, U.S.-4, Vol. II, pp. 446, 470. The estimate used here for winnowing with a sheet is considered high by Rogin.

TABLE D-12

PERIOD 2: PREHARVEST LABOR FOR WHEAT, OATS, AND CORN

	NE	ME	S:EC	S:DC	S[a]	W:C	W:WD	W:SG + WC[b]	W:R	W:NW + Cal.	W:NW + Cal.
					WHEAT						
n	4.0				9.0	14.0	10.0	78.0	7.0	23.0	29.0[c]
$\bar{X}$	11.6				10.7	5.5	6.1	4.2	6.0	3.1	3.2[c]
M	12.5				10.0	5.4	6.2	4.1	5.7		3.3[c]
σ	2.2				2.8	1.7	1.5	1.6	1.7		1.1[c]
β	1.2				0.97	0.47	0.49	0.19	0.7		0.2[c]
					OATS						
n	10.0				10.0	15.0	15.0	12.0	8.0	6.0	
$\bar{X}$	9.3				9.5	3.3	6.1	3.0	7.6	4.3	
M	9.8				9.3	2.7	6.0	2.95	7.8		
σ	1.8				2.4	1.9	1.8	0.9	2.3		
β	0.6				0.8	0.5	0.47	0.27	0.86		
					CORN						
n	34.0	12.0	10.0	11.0	8.0	56.0	18.0	21.0			
$\bar{X}$	46.4	26.7	26.9	29.1	11.4	15.2	17.3	11.4			
M	34.4	25.6	24.75	28.0	10.2	13.75	14.75	9.5			
σ	30.9	5.6	5.0	4.8	4.6	4.9	5.8	5.3			
β	5.4	1.7	1.7	1.5	1.7	0.6	1.4	1.2			

[a]For corn, the region is S:WC.

[b]For corn, the region is W:SG.

[c]For wheat and oats combined.

TABLE D-13

PERIOD 2: PREHARVEST AND HARVEST LABOR, DERIVATION OF W FROM WESTERN SUBREGIONS

	Wheat			Oats			Corn	
	Preharvest		Harvest	Preharvest		Harvest	Preharvest	
Subregion	w (Ar/Aw)	a (L/A)	b (L/A)	w (Ar/Aw)	a (L/A)	b (L/A)	w (Ar/Aw)	a (L/A)
W:C	0.236	5.5	3.0	0.443	3.3	2.6	0.610	15.2
W:WD	0.112	6.1	3.0	0.216	6.1	3.5	0.072	17.3
W:SG + W:WC[a]	0.543	4.2	1.8	0.291	3.0	1.7	0.307	11.4
W:R	0.017	6.0	7.5	0.014	7.6	8.3	0.011	11.4[b]
W:NW + Cal.	0.092	3.2	2.0	0.035	3.2	2.0		
West (Σaw)		4.66			3.88			14.2
(Σbw)			2.33			2.5		

Source: Weights, from USDA, revised estimates; labor requirements from Tables D-12, D-15.

[a]For corn, W:SG only.

[b]No data available. W:SG figure.

TABLE D-14

PERIOD 2: PREHARVEST LABOR FOR CORN, DERIVATION OF S FROM SOUTHERN SUBREGION

Subregion	w (Ar/Aw)	a (L/A)
S:EC	0.393	26.9
S:DC	0.218	29.1
S:WC	0.389	11.4
South (Σaw)		21.3

Source: Weights, from USDA, revised estimates; labor requirements, from Table D-12.

TABLE D-15

PERIOD 2: HARVEST LABOR

	NE	S	W:C	W:WD	W:SG + W:WC[a]	W:R	W:NW + Cal.
				WHEAT			
n	7.0	8.0	21.0	10.0	44.0	7.0	10.0
$\bar{X}$	3.0	3.0	3.0	3.0	1.8	7.5	2.0
M	2.9	3.2	2.7	2.1	1.7	8.2	1.9
σ	0.8	1.5	1.0	1.5	0.8	2.1	0.8
s	0.26	0.59	0.23	0.5	0.12	0.85	0.26
				OATS			
n	10.0	10.0	14.0	15.0	11.0	9.0	10.0
$\bar{X}$	3.4	4.5	2.6	3.5	1.7	8.3	2.0
M	2.9	4.4	2.2	2.6	1.4	8.3	1.9
σ	1.4	1.9	0.9	2.0	0.5	1.4	0.8
s	0.35	0.64	0.25	0.53	0.17	0.5	0.26
				CORN			
n		13.0[b]			28.0[c]		
$\bar{X}$		4.3			6.7		
M		4.3			6.2		
σ		0.6			1.6		
s		0.2			0.3		

[a]For corn, the region is W:C + W:SG.

[b]Method 2.

[c]Method 3. See notes on period 1 harvest labor.

PERIOD 2: POSTHARVEST LABOR, WHEAT AND OATS

The estimates of labor per acre, shown in Table D-16, present some superficial anomalies. In wheat, the lower average for W:SG + W:WC than for the eastern regions is due to the lower yield and to a number of cases where threshing was done from the header stack rather than the shock. The NRP sample cases (Appendix E, U.S.-5) show nearly uniform use of the header in western Kansas and a noticeable proportion (10–30 per cent) throughout W:SG and west of it. Technical manuals disagree on whether grain harvested by a header threshes more easily than reaped grain, but the AES studies seem unmistakable. Though methods are not stated, the use of the header in Minnesota probably accounts for the low figure in W:WD. Use of the combine in wheat is confined largely to a portion of W:NW, and is neglected in these estimates. In W:R, the high figure is not easy to explain, but the weight is negligible.

In oats, the higher figure for NE is due largely to use of NRP figures based on barn threshing. If, as seems likely, that was a common practice in this region, it would seem desirable to charge the labor time in storing the grain to this operation. In the South, barn threshing was the major technique in the two NRP survey counties, but the lower yields may partly account for the lower per acre figure.

The use of regional average yields with per acre figures from sample studies is a weak feature of these estimates. To check them, we have compared them with three other estimates:

1. Average labor per bushel, by region, in those of our cases where both yield and labor per acre are given.
2. NRP reports of data by county, divided by counties' "normal yield."
3. NRP estimates by region, based on its cases, divided by regional yield.

The results were as follows:

	Wheat					*Oats*		
	NE	S	W:C	W:SG + W:WC	W:NW + Cal.	NE	W:C	W:SG + W:WC
Table D-17, line 3	0.195	0.287	0.224	0.189	0.165	0.234	0.092	0.094
1.	0.075	0.230	0.215	0.125				
2.	0.334	0.256	0.221	0.195	0.110	0.258	0.116	0.085
3.	0.334	0.256	0.219	0.213	0.092	0.250	0.103	0.078

TABLE D-16

PERIOD 2: POSTHARVEST LABOR PER ACRE

	NE	S	W:C	W:WD	W:SG + W:WC	W:R	W:NW + Cal.
				WHEAT			
n	5.0	8.0	20.0	8.0	31.0	1.0	7.0
$\bar{X}$	3.42	3.59	3.54	2.53	2.28	4.2	3.21
M	3.3	3.5	3.4	2.4	2.1		3.9
σ	0.9	1.1	1.1	0.5	0.9		1.1
s	0.45	0.41	0.25	0.12	0.16		0.46
				OATS			
n	6.0	8.0	9.0	11.0	8.0	1.0	a
$\bar{X}$	6.96	4.07	2.62	2.91	2.35	4.23	
M	7.5	3.95	2.5	3.2	2.4		
σ	1.9	1.5	1.0	0.8	0.8		
s	0.87	0.55	0.35	0.26	0.34		

[a]No figures available. Wheat figure used in our calculations.

TABLE D-17

PERIOD 2: POSTHARVEST LABOR, DERIVATION OF L/O

	NE	S	W:C	W:WD	W:SG + W:WC	W:R	W:NW + Cal.
				WHEAT			
L/A	3.42	3.59	3.54	2.53	2.28	4.20	3.21
O/A	17.5	12.3	15.8	15.3	12.0	18.6	19.4
L/O	0.195	0.292	0.224	0.165	0.190	0.226	0.165
				OATS			
L/A	6.96	4.07	2.62	2.91	2.35	4.23	3.21
O/A	29.7	17.0	28.4	26.8	22.2	32.7	33.8
L/O	0.234	0.239	0.092	0.108	0.094	0.129	0.095

Source: L/A, Table D-16. O/A, USDA, revised estimates, 1907-11. L/O, $L/A \div O/A$.

TABLE D-18

PERIOD 2: POSTHARVEST LABOR, DERIVATION OF WESTERN REGION FROM SUBREGIONS

	Wheat		Oats	
Region	v (O_R/O_W)	c (L/O)	v (O_R/O_W)	c (L/O)
W:C	0.267	0.224	0.475	0.092
W:WD	0.123	0.165	0.219	0.108
W:SG + W:WC	0.465	0.190	0.244	0.094
W:R	0.023	0.226	0.017	0.129
W:NW + Cal.	0.122	0.165	0.045	0.095
W = (Σcv)		0.193		0.098

Source: v, USDA, revised estimates, 1907-11.
c, Table D-17.

Except for the first column, our estimates are not implausible, considering the small number of cases and the possibilities of variation. In the first column, the NRP figure (lines 2 and 3) is based on cases from a single county (Lancaster County, Pennsylvania) and may be disregarded.

Appendix E: Source Bibliography for Period 1

U.S. DOCUMENTS

1. Commissioner of Patents, *Annual Report*, "Agriculture," Washington, 1841-61.
2. Commissioner of Agriculture, *Annual Report*, Washington, 1862–81.
3. Dept. of Agriculture, *Annual Report*, Washington, 1882.
4. Commissioner of Labor, *13th Annual Report*, Washington, 1898.
5. Works Progress Administration, National Research Project (NRP), Changes in Technology and Labor Requirements in Crop Production, Report A10, *Wheat and Oats*, Phila., Apr. 1939.
6. *Idem.*, Report A5, *Corn*, Phila., June, 1938.
7. Dept. of Agriculture, Bureau of Agricultural Economics, *Revised Estimates of Wheat Acreage, Yield and Production, 1866–1929*, Washington, July 1934.
8. *Idem., Revised Estimates of Oats Acreage, Yield and Production, 1866–1929*, Washington, July 1934.
9. *Idem., Revised Estimates of Corn Acreage, Yield and Production, 1866–1929*, Washington, May 1934.
10. Censuses of Agriculture, 1840–1910, Washington.

STATE DOCUMENTS

1. Illinois: *Transactions*, Ill. State Agricultural Society, Springfield, 1853–60.
2. Indiana: *Annual Report*, Ind. State Board of Agriculture, Indianapolis, 1848–60.
3. Maine: 1853–55, *Transactions*, Agricultural Societies in the State of Maine, Augusta.
   1856–75, *Annual Report*, Secretary of the Maine Board of Agriculture, "Abstract of Returns of Agricultural Societies."
4. Massachusetts: 1837, *Report on the Agriculture of Massachusetts*, Boston; 1853–75, *Annual Report*, Secretary of the Board of Agriculture, with Reports of Committees Appointed to Visit the County Societies.
5. Michigan: *Transactions*, Mich. State Agricultural Society, Lansing, 1849–61.
6. New York: *Transactions*, N.Y. State Agricultural Society, Albany, 1842–75.
7. Ohio: 1850–56, *Annual Report*, Board of Agriculture; 1856–75, *Annual Report*, Board of Agriculture, with an abstract of Proceedings, County Agricultural Societies, Columbus.
8. Tennessee: *Biennial Report*, State Agricultural Bureau, Nashville, 1855–58; *Transactions*, 1854–59.

PERIODICALS

(1) *Agriculturist*, Nashville; (2) *American Farmer*, Baltimore; (3) *Carolina Planter*, Columbia (S.C.); (4) *Country Gentleman*, Albany; (5) *Cultivator*, Albany; (6) *Farmer and Gardener*, Baltimore; (7) *Farmer and Planter*, Pendleton; (8) *Farmers' Cabinet*, Philadelphia; (9) *Illinois Farmer*, Chicago; (10) *Journal of Agriculture*, St. Louis; (11) *Maine Farmer*, Augusta; (12) *New Genesee Farmer*, Rochester; (13) *Pennsylvania Farm Journal*, Lancaster; (14) *Prairie Farmer*, Chicago; (15) *Soil of the South*, Columbus (Ga.); (16) *Southern Agriculturist*, Laurensville (S.C.); (17) *Southern Cultivator*, Columbia (Tenn.); (18) *Southern Planter*, Richmond; (19) *Tennessee Farmer*, Jonesborough (Tenn.); (20) *Union Agriculturist*, Chicago; (21) *Valley Farmer*, St. Louis; (22) *Western Farmer*, Cincinnati.

MANUSCRIPTS

Library	*Title*	*County and State*
1. Virginia Historical Society, Richmond	Diary of Robert Henderson Allen	Lunenburg, Va.
2. Southern Historical Collection, Univ. of N.C., Chapel Hill	Plantation Journal of John D. Ashmore	Anderson and Sumter, S.C.
3. Department of Archives, Louisiana State Univ., Baton Rouge	Eli J. Capell Plantation Diaries and Record Books	Amite, Miss.
4. Maryland Historical Society, Baltimore	H. D. G. Carroll, "The Perry Hall Farm Journal"	Baltimore, Md.
5. Virginia Historical Society, Richmond	Papers of Phillip St. George Cocke, "Belmead Plantation"	Powhatan, Va.

Library	Title	County and State
6. Univ. of Georgia, Athens	Wm. J. Dickey Diaries, "Birdsong Plantation"	Hancock, Ga.
7. Univ. of Illinois, Urbana	M. L. Dunlap's Ledger	Cook, Ill.
8. Louisiana State Univ., Baton Rouge	Ferchaud Papers	St. James Parish, La.
9. South Carolina Library, University of S.C., Columbia	Samuel P. Gaillard Plantation Journal	Sumter, S.C.
10. College of William and Mary, Williamsburg, Va.	James Galt: Diary and Plantation Memoranda	Fluvanna, Va.
11. Maryland Historical Society, Baltimore	Gittings Account Book, "Roslin Farm"	Baltimore, Md.
12. Georgia Dept. of Archives and History, Atlanta	Seaborn Hawks Farm Journal	Jasper, Ga.
13. Univ. of Georgia, Athens	John B. Lamar Plantation Book	Sumter, Ga.
14. Louisiana State Univ., Baton Rouge	Liddell Plantation Book, "Llanada Plantation"	Concordia Parish, La.
15. Louisiana State Univ., Baton Rouge	The Marston (Henry W. and family) Papers, Plantation Diary	Feliciana Parish, La.
16. Southern Historical Collection, Univ. of N.C., Chapel Hill	Farm Journal of Nicholas Massenburg	Franklin, N.C.
17. Virginia State Library, Richmond	Farm Journal of William Massie	Nelson, Va.
18. The Filson Club, Louisville	The Howard Miller Diary	Jefferson, Ky.
19. Southern Historical Collection, Univ. of N.C., Chapel Hill	The Norfleet Diaries	Bertie, N.C.
20. Library of Congress, Washington, D.C.	The Physick Family Papers	Cecil, Md.
21. Univ. of Maryland, College Park	The John Piper Family Record and Time Book	Allegany, Md.
22. Virginia State Library, Richmond	The Ruffin Papers	Hanover, Va.
23. The Filson Club, Louisville, Ky.	Robert W. Scott Diary	Franklin, Ky.
24. Hall of Records, Annapolis, Md.	John H. Sellman Diary	Anne Arundel, Md.
25. The Filson Club, Louisville	Deacon's Journal of the Shaker Community	Mercer, Ky.
26. National Agricultural Library (USDA), Washington	E. J. Tayloe Agricultural Journal	King George, Va.
27. Virginia State Library, Richmond	L. W. Tazewell Plantation Book	James City, Norfolk, Northampton, Va.
28. Georgia Dept. of Archives and History, Atlanta	Diary, Ledger, and Account Book of James Washington Watts	Bartow (formerly Cass), Ga.

BOOKS

1. John Spencer Bassett (ed.), "The Westover Journal of John A. Seldon, Esq., 1858–1862," *Smith College Studies in History*, Vol. VI, No. 4, Northampton, Mass., July 1921.
2. P. D. Coburn, *Swine Husbandry*, New York, 1877.
3. Edwin A. Davis, "Plantation Life in the Florida Parishes of Louisiana, 1836–1846 as Reflected in the *Diary of Bennet H. Barrow*," New York: Columbia University Press, 1943.
4. F. Gerhard, *Illinois as It Is*, Chicago, Philadelphia, 1857.
5. George N. Lamphere, "History of Wheat Raising in the Red River Valley," *Minnesota Historical Society Collections*, Vol. 10, pt. 1, St. Paul, 1905.
6. Frank L. Riley (ed.), "Diary of a Mississippi Planter," *Publications of the Mississippi Historical Society*, X, Oxford, 1909.
7. Leo Rogin, *The Introduction of Farm Machinery in its Relation to the Productivity of Labor in the Agriculture of the United States during the Nineteenth Century*, Univ. of California Publications in Economics, Vol. 9, Berkeley, Univ. of California Press, 1931.
8. Edmund Ruffin, *Essays and Notes on Agriculture*, Richmond, 1855.
9. F. Yates, *The Design and Analysis of Factorial Experiments*, Imperial Institute of Soil Science, Technical Communication 35, Harpenden, Eng., 1937.

Appendix F: Source Bibliography for Period 2

U.S. DOCUMENTS

1. Department of Agriculture
   a. Department Circular 183, Washington, 1922.
   b. Department Bulletins 3, 214, 218, 219, 412, 482, 528, 595, 757, 814, 917, 943, 961, 1000, 1181, 1198, 1296, 1421, 1446, Washington.
   c. Bureau of Agricultural Economics, Divisions of Cost of Production and of Farm Management, Preliminary Report, *Cost of Wheat Production and Incomes for Farming*, Washington, 1923.
   d. *Yearbook*, 1917, 1923, Washington.
   e. Division of Statistics, Bulletin 20, Washington, 1901.
   f. Office of Farm Management, *Farm Management Monthly*, Vol. II, Washington, 1914.
   g. Office of Farm Management, *Farm Management Circular 3*, Washington, 1919.
   h. Special Report 40, Washington, 1882.
   i. Agricultural Marketing Service, Crop Reporting Board, *Corn Acreage, Yield and Production*, Washington, 1954.
   j. Monthly Crop Report, Washington, 1915.
   k. Office of Experiment Stations, Bulletin 173, Washington, 1907.
2. WPA-NRP: See Appendix E, items U.S.-5, and U.S.-6.
3. Commissioner of Labor, *13th Annual Report*, Washington, 1898.
4. *Hearings Before the Senate Committee on Agriculture and Forestry*, 65th Cong., 2d Sess., Washington, 1918.
5. *Hearings Before the Joint Commission of Agricultural Inquiry*, 67th Cong., 1st Sess., Washington, 1922.

STATE DOCUMENTS

1. Alabama: Alabama Polytechnic Institute Extension Service, Circular 33, Auburn.
2. California: Univ. of California, College of Agriculture Agronomy Project 337, Berkeley.
3. Colorado: State Agricultural College of Colorado, AES Bulletins, Fort Collins.
4. Georgia: Georgia State College of Agriculture, Extension Division, Bulletins 270, 273, and 428, Athens.
5. Idaho: Univ. of Idaho, AES Bulletins 123 and 195, Moscow.
6. Illinois: Univ. of Illinois, AES Bulletins 50 and 277, Urbana.
7. Iowa: (1) Iowa Department of Agriculture, *Sixth Annual Iowa Year Book of Agriculture*, Des Moines, 1905. (2) Iowa AES Bulletin 16, Ames. (3) Iowa Bureau of Labor Statistics, Fourth Biennial Report of the Commissioner of Labor, Des Moines, 1891.
8. Kansas: (1) *Report*, State Board of Agriculture, Topeka, 1920. (2) *Ninth Annual Report*, Bureau of Labor Statistics, Topeka, 1893.
9. Maine: (1) Maine Board of Agriculture, *Twenty-Second Annual Report of the Secretary*, Augusta. (2) Univ. of Maine, College of Agriculture, M.D. Jones, *The Cost of Producing Sweet Corn*, Orono, 1920.
10. Massachusetts: Massachusetts State Board of Agriculture, Abstract of Returns of the Agricultural Societies of Massachusetts with the *Twenty-Eighth Annual Report* of the Secretary, Boston, 1880.
11. Michigan: *19th* and *27th Annual Report*, State Board of Agriculture, Lansing.
12. Minnesota: Univ. of Minnesota, AES Bulletins 157 and 179, St. Paul.
13. Missouri: Univ. of Missouri, AES Bulletins 125 and 165; Research Bulletin 6; Circular 100, Columbia.
14. Montana: (1) Univ. of Montana, AES Bulletins 116 and 122, Bozeman. (2) Montana Extension Service in Agriculture and Home Economics, Bulletin 71, Bozeman.
15. Nebraska: Univ. of Nebraska, AES Bulletin 29, Lincoln.
16. New Jersey: (1) *Thirty-Third Annual Report*, New Jersey State AES, Union Hill, 1912. (2) New Jersey AES Bulletin 312, New Brunswick.
17. New York: (1) State College of Agriculture, Experiment Station Bulletins, Cornell Station, 377, 414, and 475, Ithaca. (2) New York State College of Agriculture, Dept. of Agricultural Economics and Farm Management, *Farm Cost Accounting Project*, Ithaca, 1931. (3) New York Dept. of Agriculture, Bulletin 86, Albany.
18. North Dakota: (1) North Dakota Agricultural College, AES Bulletins 142 and 144, Agricultural College. (2) *Third Biennial Report*, Commissioner of Agriculture and Labor, Bismarck.
19. Ohio: (1) Ohio State Univ. Agriculture Extension Service, Vol. 18, No. 5, Colombus. (2) Ohio AES Bulletin 266, Wooster. (3) AES Bimonthly Bulletin, Vol. 12. (4) Monthly Bulletin Vol. 3, Wooster.

20. South Carolina: South Carolina Agricultural Experiment Station of Clemson College, Bulletin 221, Clemson.
21. Utah: Utah Agricultural College Experiment Station, Bulletin 165, Logan.
22. Washington: State College of Washington, AES Bulletins 175 and 244, Pullman.
23. West Virginia: West Virginia AES Bulletins 163 and 187, Morgantown.
24. Wisconsin: Bureau of Labor and Industrial Statistics, *9th Biennial Report*, 1897–98, Madison.

PERIODICALS

(1) *Atlantic Monthly*, Boston; (2) *Breeders Gazette*, Spencer, Indiana; (3) *Indiana Farmer*, Huntington, Indiana; (4) *National Stockman and Farmer*, Pittsburgh, Buffalo; (5) *Orange Judd Farmer*, Chicago; (6) *Pennsylvania Farmer*, Mercer, Philadelphia, Pittsburgh; (7) *Practical Farmer*, Camden, New Jersey; (8) *Rural New Yorker*, New York; (9) *Southern Planter*, Richmond; (10) *Tribune Farmer*, New York; (11) *Utah Farmer*, Salt Lake City; (12) *Wallace's Farmer*, Des Moines, Ames, Iowa.

BOOKS

1. *North Dakota State Historical Society Collections*, Vol. III, Bismarck, 1910.
2. Howard M. Eliot, *The Elementary Principles of Farm Management*, Ann Arbor, Mich., 1923.
3. Melville L. Bowman and Bruce W. Crossley, *Corn*, Ames, Iowa, 1908.
4. George D. Leavens, *Corn*, New York, 1915.
5. Herbert Myrick, *The Book of Corn*, New York, Chicago, 1903.

COMMENT

Glen T. Barton, U.S. Department of Agriculture

Output per man-hour in the production of wheat and oats in the early 1900's was about four times as great as in the 1840's. In their paper the authors set as their objective the allocation of this increase in labor productivity among three broad sources: (1) westward movement of the crop; (2) changes in yields per acre; and (3) improvements in mechanization and other practices which reduce labor inputs per acre. Three broad regions, the Northeast, South, and West, were delineated for the analysis. The authors concluded that the bulk of the rise in labor productivity was due to mechanization of harvesting operations in all the producing regions and that very little improvement resulted from westward movement of the crop or from change in yields.

I have no major quarrel with the authors' conclusions. They are to be complimented on their careful, painstaking analysis, and especially for

NOTE: This comment was prepared for an earlier version of the Parker paper in which the data on corn were omitted.

the development of methodology which should prove useful to other research workers.

Study of the paper raised several points in my mind, some by way of constructive criticism of the paper per se, others regarding degree of emphasis or points made by the authors and, perhaps most important, facets omitted or not developed fully by the authors.

1. Despite the careful and thorough assembly of data and the rigor of the authors' analysis, quantitative conclusions reached in the paper should be regarded as broad indications, rather than as precise measurements. As the authors recognize, the basic data used, especially those on labor inputs per acre for wheat and oats, leave much to be desired. There is a strong suspicion that the labor coefficients assembled generally reflect operations on farms with above-average management practices. Also, it is generally recognized that estimates of acreage and yield of the two grain crops in the early part of the period studied are not as accurate as most of our agricultural data today.

2. From a statistical point of view, the authors are quite correct in concluding that little change occurred in yields of the two grains during the period of analysis. However, I want to give even more emphasis than they did to the importance of technological improvement in crops during the period. Even today, the small grain crops pointedly illustrate the crucial importance of variety improvements in preventing sharp reductions in yields because of persistent, potential ravage by diseases and insects.

3. In view of my own research background in the field of "productivity" measurement, I believe the authors were somewhat hasty in their ready acceptance of average labor productivity as a measuring device. Admittedly, lack of data would have prevented any major attempt to examine changes in output-input ratios of other factors of production. The authors' conclusion that mechanization of harvest operations was by far the dominant influence in raising production of wheat and oats per man-hour directly implies that substitution of capital for labor may have been an important influence during the period analyzed.

4. The authors rigidly adhered to their stated purpose of measuring *sources* of improvement in labor productivity in small grain production. However, I wish they had engaged in some speculation as to *causes* of these changes in terms of probable economic, social, and institutional factors. This observation leads me to my final point.

5. Granting the authors' thorough and workmanlike job of data collection and analysis and the general accuracy of their conclusions, just what does the paper contribute to our body of useful economic intelligence?

More attention to causes of changes in labor productivity might have provided some basis for projections of what lay ahead in the twentieth century. Data available in the Economic Research Service, for example, indicate that production per man-hour of wheat in 1961-62 was 9 times that prevailing in 1910–14. Present-day output of oats per man-hour is 5.5 times that of the early 1900's. These improvements in production per man-hour are substantially greater than those that occurred from the 1840's to the early 1900's.

If as a result of our analysis of given historical periods we can develop better frameworks for looking ahead, both economists and historians can better serve their function as social scientists. Such analysis also should contribute to a more complete understanding of the forces behind economic growth. Obviously, contributions of this sort are badly needed in providing better guidelines for policy decisions in the many underdeveloped and developing economies throughout the world.