The U.S. Structural Transformation and Regional Convergence: A Reinterpretation

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We present a joint study of the U.S. structural transformation (the decline of agriculture as the dominating sector) and regional convergence (of southern to northern average wages). We find empirically that most of the regional convergence is attributable to the structural transformation: the nationwide convergence of agricultural wages to nonagricultural wages and the faster rate of transition of the southern labor force from agricultural to nonagricultural jobs. Similar results describe the Midwest's catch-up to the Northeast (but not the relative experience of the West). To explain these observations, we construct a model in which the South (Midwest) has a comparative advantage in producing unskilled labor–intensive agricultural goods. Thus it starts with a disproportionate share of the unskilled labor force and lower per capita incomes. Over time, declining education/training costs induce an increasing proportion of the labor force to move out of the (unskilled) agricultural sector and into the (skilled) nonagricultural sector. The decline in the agricultural labor force leads to an increase in relative agricultural wages. Both effects benefit the South

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(Midwest) disproportionately since it has more agricultural workers. With the addition of a less than unit income elasticity of demand for farm goods and faster technological progress in farming than outside of farming, this model successfully matches the quantitative features of the U.S. structural transformation and regional convergence, as well as several other stylized facts on U.S. economic growth in the last century. The model does not rely on frictions on interregional labor and capital mobility, since in our empirical work we find this channel to be less important than the compositional effects the model emphasizes.

I. Introduction

This paper presents a joint study of two key trends in U.S. economic growth in the last century: structural transformation and regional convergence. The basic facts about the structural transformation are summarized in panel A of table 1: the well-known secular decline in the weight of farm goods in U.S. output and employment; the slightly less well known fact that the relative price of farm goods does not display a clear trend either downward or upward; and least well known of all, the convergence of U.S.-wide agricultural labor incomes to nonagricultural labor incomes. Regional convergence is documented in panel B of table 1. Southern workers experienced a more than doubling of their labor earnings relative to workers in the North. Midwestern workers

TABLE 1
Structural Transformation and Regional Convergence in the United States

	1880	1900	1920	1940	1960	1980
	A. Structural Transformation					
Farm share of GDP[1]	.27	.19	.13	.09	.06	.02
Agricultural share of employment[2]	.50	.39	.26	.20	.06	.03
Farm relative price (1967 = 1)[3]	1.20	1.23	1.54	.99	1.10	1.01
Agricultural relative wage[2]	.20	.21	.32	.35	.51	.69
	B. Regional Convergence					
South/North relative wage[2]	.41	.44	.59	.60	.78	.90
Midwest/North relative wage[2]	.82	.89	.90	.84	.96	1.00
West/North relative wage[2]	1.28	1.15	1.00	.99	1.03	1.04

[1] Source: *Historical Statistics,* ser. F125, F127; 1998 *Economic Report of the President,* table B-10.
[2] Source: See Sec. II and App. A.
[3] Source: *Historical Statistics,* ser. E25, E135; 1998 *Economic Report of the President,* tables B-60, B-67 (farm relative price equals the wholesale price index for farm goods divided by the consumer price index).

also experienced considerable gains. Instead, western workers' incomes converged to northern levels "from above."[1]

Traditional explanations of the structural transformation rely on one or both of two mechanisms (see, e.g., Chenery and Srinivasan 1988, vol. 1): (i) an income elasticity of the demand for farm products less than one and (ii) faster total factor productivity growth in farming relative to other sectors in the economy. The first mechanism implies that as the economy grows, the demand for farm goods and, consequently, for farm labor declines. The second mechanism potentially reinforces this effect by further reducing the demand for farm labor, since fewer workers are needed to produce the same amount of farm goods. Hence, standard explanations have the potential to match the behavior of the *quantities* in the first two rows of table 1. We show in this paper, however, that by attributing the decline in farm output and employment to falling demands, the traditional explanations also predict falling relative prices for farm goods and falling relative wages for farm workers. In other words, they fail completely with respect to the less well known behavior of the *prices* in rows 3 and 4 of table 1.

The first contribution of this paper is to present a model featuring a third ingredient that seems essential to matching all four of the key facts of the structural transformation. Our new explanation includes a downward shift in the farm–labor supply curve, so that the decline in farm employment is consistent with the increase in farm wages. We model the relative supply of farmworkers as the result of farm-born workers' optimal decision whether to remain in agriculture or join the urban sector. Sectoral migration involves a cost, such as investment in the differential skills required by urban, nonagricultural employment.[2] The key new mechanism giving rise to the required shifts in the relative supply of farmworkers is (iii) a long-run decline in the relative cost of acquiring nonagricultural skills across subsequent cohorts of farm-born individuals. In the paper we discuss some of the possible sources of this decline, such as technological progress and scale economies in trans-

[1] States in the North are Connecticut, Delaware, Massachusetts, Maryland, Maine, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. States in the South are Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia. States in the Midwest are Iowa, Illinois, Indiana, Kansas, Michigan, Minnesota, Missouri, North Dakota, Nebraska, Ohio, South Dakota, and Wisconsin. States in the West are Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

[2] Alternative interpretations include utility costs from living in towns (e.g., because they are insalubrious) or acquisition of urban survival skills.

portation, improved quality of education, increased life expectancy, and school desegregation.[3]

The second contribution of the paper is to show that the same forces driving the structural transformation also lead to regional convergence. In our model there are two regions, North and South, which are equally efficient at producing nonfarm goods. However, atmospheric and soil conditions give the South a comparative advantage in farming. The two regions freely trade in the two goods, and all factors (other than land) freely move across regional borders. This leads to an optimum allocation of resources in which the production of farm goods is concentrated in the South. Per capita income in the South is then lower because the labor input for farm goods is mostly low-skilled workers. As the economy grows, mechanisms i–iii push increasing fractions of successive cohorts of southern workers out of lower-wage farming and into higher-wage manufacturing, while at the same time increasing relative wages for those southern workers remaining in farming.[4] Both these features of the structural transformation therefore lead to regional convergence in average labor incomes. We are able to calibrate a two-region model of commodity trade and factor mobility featuring mechanisms i–iii so that it closely replicates all the quantitative patterns in table 1.[5]

To see why a model of the structural transformation is also a model of regional convergence, it is useful to take a look at figures 1 and 2. Figure 1 shows that state labor income per worker in 1880 was strongly negatively correlated with the fraction of the state population working in agriculture (the correlation coefficient is −.87). It is clear that increasing agricultural wages will therefore favor low-income states disproportionately. Figure 2 plots state labor income growth per worker between 1880 and 1990 against the change in the fraction of the population working in agriculture: states with relatively high per capita income growth tended to be those in which a relatively large fraction of the population moved out of farms (the correlation coefficient is −.80). Hence, labor reallocation out of agriculture also contributed to regional convergence. To make this interpretation empirically rigorous, in the paper we precede the theoretical work with decompositions showing that increasing relative farm wages, and labor reallocation out of farm-

[3] It should be clear that mechanisms i and ii, although not sufficient, are still necessary to tell the story; mechanism iii alone would lead to increasing prices for farm goods and would in general not predict a decline in the output share of farming—at least in a closed economy.

[4] As argued in Caselli and Coleman (2000), changing the skilled/unskilled wage premium may also change the kinds of technologies that are adopted.

[5] Furthermore, consistent with the historical pattern, the model predicts South to North migration.

Fig. 1.—Labor income per worker and employment in farming, 1880

ing, account for the bulk of the convergence of the states in the South and the Midwest to those of the Northeast.[6]

As mentioned, our contribution to the vast literature on the structural transformation is to introduce a new mechanism that allows it to explain prices as well as quantities.[7] The topic of regional convergence has recently been revived by Barro and Sala-i-Martin (1991, 1992), who have documented patterns of regional convergence in regional per capita personal incomes that are closely matched by our labor income data. Wright (1986) and Barro, Mankiw, and Sala-i-Martin (1995) interpret convergence in the context of a one-sector model with frictions to the movement of (physical or human) capital. Instead, we emphasize—both empirically and theoretically—the sectoral composition of output and the labor force. Therefore, our analysis is closer to that in Kuznets, Miller, and Easterlin (1960), Williamson (1965), Kim (1998), and, especially, Krugman (1991*a,* 1991*b*) and Krugman and Venables (1995),

[6] In contrast, these trends do not explain much of the changes in the incomes of the western states relative to the Northeast.

[7] We shall not attempt a comprehensive survey of this literature. The classics on this topic include Clark (1940), Nurkse (1953), Lewis (1954), and Kuznets (1966). Some recent additions are Matsuyama (1991), Echevarria (1997), Kongsamut, Rebelo, and Xie (1997), and Laitner (1997). Matsuyama's paper is the closest to ours in that he studies a similar overlapping generations economy with sectoral choice at the beginning of life. In his model, however, the distribution of skills is invariant over time, so that the decline in the size of the agricultural sector—which is driven by increasing returns in the nonagricultural sector—is associated with a decline in the relative agricultural wage.

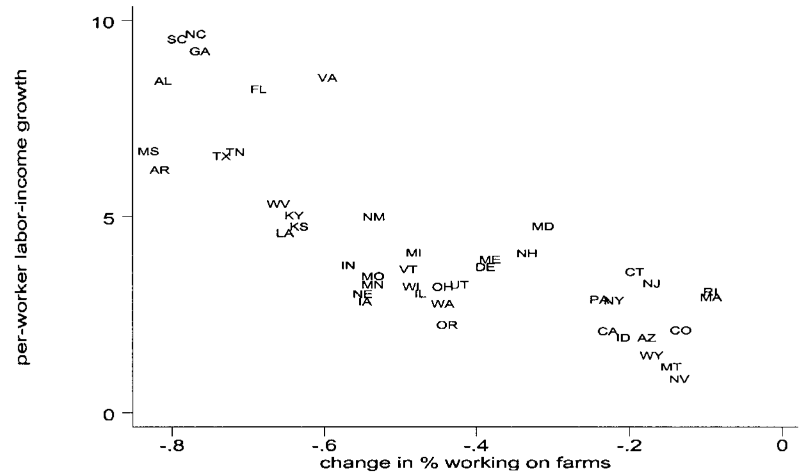

FIG. 2.—Growth and the structural transformation, 1880–1990

all of whom tightly link interregional or international convergence or divergence in incomes to convergence or divergence in economic structure.

As applied to the U.S. experience, Krugman's argument is that in the nineteenth century, as transport costs declined, demand externalities and increasing returns dictated that manufacturing production be concentrated in one region, and historical accident determined this region to be the Northeast. Subsequently population growth in the other regions made it possible to sustain a manufacturing sector outside of the Northeast, leading to convergence. Our account differs in that comparative advantage, rather than historical accident, determines the initial pattern of specialization; and changes in the relative supply of farmworkers, rather than demand forces, drive the subsequent convergence. A quantitative analysis that compares the two accounts is beyond the scope of this paper, and we leave it for future research.

Section II presents our empirical decomposition of the sources of regional convergence. Section III discusses the empirical plausibility of assumptions i–iii that underlie our model. The model's structure, solution, and quantitative results are presented in Sections IV, V, and VI, respectively. Section VII surveys alternative explanations, including skill-biased technical change in agriculture, and Section VIII offers some concluding remarks.

II. Accounting for Regional Convergence

This section establishes the empirical link between the structural transformation and regional convergence. We shall mostly focus on the convergence between the most and the least farm intensive of the four regions of the United States: the South (S) and the North (N). For $i = S,\ N$ we have

$$w_t^i = w_{ft}^i L_{ft}^i + w_{mt}^i(1 - L_{ft}^i), \qquad (1)$$

where w_t^i is the average labor income in region i in year t,[8] w_{ft}^i is labor income per worker in agriculture, w_{mt}^i is income per worker outside of agriculture, and L_{ft}^i is the share of the labor force that is employed in agriculture. Convergence of average labor incomes may be due to three possible channels. First, there might be convergence of w_{ft}^S to w_{ft}^N and of w_{mt}^S to w_{mt}^N, that is, the catching up of southern wages to northern wages *within* each industry. This channel is the one relied on by accounts of regional convergence that emphasize the gradual removal of interregional frictions preventing factor price equalization (e.g., Wright 1986; Barro et al. 1995). Second, there is convergence of L_{ft}^S to L_{ft}^N. As documented in figure 2, the South experienced a comparatively larger reallocation of labor out of low-wage agriculture, leading to some convergence in the industrial composition of the labor force. As implied by the analysis of, for example, Krugman (1991*a,* 1991*b*), this *labor reallocation* channel might be an important source of convergence in average incomes. Finally, as we documented in table 1, there is convergence of the economywide average agricultural wage rate, w_{ft}, to the average nonagricultural wage rate, w_{mt}. Since the South has a larger agricultural labor force, this also generates convergence. The literature so far has overlooked this *between-industry* wage convergence channel.

We measure convergence by the quantity

$$\frac{w_t^S - w_t^N}{w_t} - \frac{w_{t-1}^S - w_{t-1}^N}{w_{t-1}}, \qquad (2)$$

where w_t is the economywide average labor income. In Appendix B we

[8] Labor income constitutes the bulk of personal income. Here we focus on this variable because it allows for a more clear-cut conceptual framework.

show how this measure of convergence can be exactly decomposed into three terms designed to capture the three channels just described.[9]

Carrying out this decomposition requires panel data by region on w^i_{ft}, w^i_{mt}, and L^i_{ft}. We use two data sets that contain this information. The first is provided by Lee et al. (1957) and covers four years: 1880, 1900, 1920, and 1950. The second has been constructed by us using decennial census data from 1940 to 1990. Unfortunately, it is not possible to directly link the two data sets to construct a unique 1880–1990 panel since the definition of labor income is not the same. In particular, the Lee et al. data set provides "service" income, which includes all income from self-employment, and not only the labor component. Our measure for the post-1940 period instead aims at measuring the labor component of agricultural income alone. Since self-employment is particularly prominent among agricultural workers, the measure based on service income is likely to overstate the relative wage of agricultural workers. Indeed, for the overlapping observation in 1950, our measure of the relative agricultural labor income is only 58 percent (U.S.-wide) of the measure based on service income.[10] If the bias from the inclusion of nonlabor, self-employment income is roughly constant over time, the change in the relative service income of agriculture should be a reasonable proxy for the change in the relative labor income of agriculture. This justifies using the Lee et al. data for the 1880–1950 period. Since the two data sets cannot be linked, however, we present the decom-

[9] To be more specific, the "labor reallocation" term asks how much convergence we would have observed if all wages had been fixed at their period average but the labor force in agriculture had shrunk at the historically observed different rates in the South and in the North. Analogously, the "between-industry" term keeps constant the agriculture/nonagriculture allocation of labor in the South and in the North at its average value over time, as well as the percentage difference between the southern agricultural and nonagricultural wage rates from the respective wages in the North and asks how much convergence there would have been had the agricultural wage converged to the nonagricultural wage in both regions at the historically observed economywide rate. The "within-industry" term captures the residual convergence, which can be thought of as asking the following question: Suppose that the allocation of labor had been constant at the period averages but that within each industry the percentage difference between southern wages and northern wages decreased at the rates implied by the data (with the U.S.-wide average industry wage held constant). How much convergence would we have observed? Decompositions in a similar spirit are performed in Kuznets et al. (1960) and Kim (1998).

[10] The U.S.-wide relative wage estimates in table 1 have been obtained for 1880, 1900, and 1920 by assuming that the self-employment bias is constant over time. Hence, they are 58 percent of relative service income. We have not attempted a similar correction for the regional relative wages since for these variables the overlapping observation in 1950 is fairly similar across the two data sets. One implication of this discussion, of course, is that the pre-1940 numbers are rather crude.

TABLE 2
Decomposition of Convergence in South to North Income per Worker, 1880–1950

Period	Total (1)	Labor Reallocation (2)	Between Industry (3)	Within Industry (4)
1880–1950	.440	.156	.201	.084
Percentage of total	100	35.5	45.5	19.1
1940–90	.312	.110	.070	.132
Percentage of total	100	35.3	22.4	42.3

Source.—Authors' calculations. Data sources: service income per worker, 1880–1950: Lee et al. (1957), tables L-4, Y-3, Y-4; labor income per worker, 1940–90: Ruggles and Sobek (1997).

Note.—Col. 1 is the quantity in (2). Col. 2 is the component due to convergence of L^S_{ft} to L^N_{ft}. Col. 3 is the component due to convergence of w_{ft} to w_{mt}. Col. 4 is the component due to convergence of w^S_{ft} to w^N_{ft} and w^S_{mt} to w^N_{mt}. See App. B for more details.

position results separately for the 1940–90 period. Appendix A explains the procedures we followed to construct the 1940–90 panel.[11]

Table 2 reports the results of the decomposition for the two periods. The North-South service income differential declined by 44 percentage points between 1880 and 1950. Of these, about 16 percentage points (35 percent of the total) are due to the faster southern transition of labor out of agriculture. Nationwide convergence of agricultural to nonagricultural incomes generated a 20-percentage-point gain, or 46 percent of the total. Finally, eight percentage points of convergence (19 percent of the total) are accounted for by South-North convergence of within-sector incomes. After 1940 the South pulled off a 31-percentage-point reduction in the labor income gap with the North. The relative contributions of within-industry wage convergence and structural transformation appear more evenly distributed in this period: 35.4 percent is due to faster movement out of agriculture in the South, and 22.4 percent is attributable to convergence from agricultural wages to nonagricultural wages. Hence, convergence of southern agricultural and nonagricultural wages to northern levels accounts for the remaining

[11] In an appendix that is available on request, we discuss alternative data from *Historical Statistics of the United States* (1997), which—contrary to ours—show almost no upward trend in the relative agricultural wage. We show that, once we correct for a mistake in the count of farmworkers in 1900 and allow for revisions that have been applied to the underlying data since the publication of *Historical Statistics,* a clear positive trend reemerges, albeit not as pronounced as the one in our data. We further argue that our samples are more representative, and our methods more transparent, than the ones in the alternative sources.

As in Barro and Sala-i-Martin (1991, 1992), we are unable to correct relative regional wages for regional differences in price levels. In a closely related paper, Mitchener and McLean (1999) attempt to generate time series for regional price levels. One of their conclusions is that convergence in prices explains very little of the shrinking of the South to North and Midwest to North differential, but it plays an important role in the convergence of the West. Since our focus is South to North convergence, we think that this evidence makes the lack of controls for price differences less troublesome.

42.3 percent of the gain. Still, the role of the structural transformation remains well above 50 percent.

In summary, southern incomes converged to northern incomes mainly because agricultural wages converged to nonagricultural wages (between-industry wage convergence) and because southern workers left agriculture at a higher speed (labor reallocation). Explanations of the slow convergence of southern to northern per capita incomes have often emphasized frictions that prevent factor price equalization among regions. In this view, slow convergence results from the gradual removal or overcoming of these frictions. We think that the column "Within Industry" captures this effect. The data confirm that this effect does indeed play a role, and it becomes more important over time. However, they also forcefully suggest that to fully understand convergence, it is necessary to give a close look at changes in the composition of the labor force and in the interindustry (as opposed to interregional) wage structure. We do this in the rest of the paper.[12]

What about the other two regions: the Midwest and the West? We report the detailed results of the Midwest to North and West to North convergence decompositions in an unpublished appendix. When we decomposed changes in the gap between midwestern and northern incomes per worker, we found patterns that closely resemble those characterizing South to North convergence. For service income, the structural transformation actually accounts for 109 percent of the 17-percentage-point convergence between the Midwest and the North between 1880 and 1950. That is, had it not been for its faster rate of agricultural out-migration and the increase in relative agricultural wages, the Midwest would actually have lost further ground relative to the North. For labor incomes in the period 1940–90, however, there is a slight divergence, although this is almost exclusively a consequence of the 1980s. For those periods in which there is convergence, the structural transformation continues to play an important role. Finally, the decomposition of the changes in income differentials between the West and the North clearly shows that the structural transformation is not a universal explanation for regional convergence. For example, between 1880 and 1950, western service income per worker fell 26 percentage points relative to the North. However, none of this decline is explained by the structural transformation. The structural transformation plays a fairly

[12] In an unpublished appendix, we report more detailed results, including greater time disaggregation. Briefly, periods of especially rapid convergence were 1900–1920, the 1940s, and the 1970s. The 1920s and the 1980s were periods of divergence. The relative importance of the various sources of convergence changes across periods, with the proportion of convergence explained by the structural transformation generally declining over time.

important role after 1940, but there is only limited convergence action in this period.[13]

III. The Basic Assumptions

The basic message of this paper is that a model featuring (i) a less than unit income elasticity of farm good demand, (ii) faster total factor productivity (TFP) growth in agriculture, and (iii) declining costs of acquiring nonfarming skills can quantitatively match all the key data on the U.S. structural transformation and regional convergence. In this section we briefly discuss the empirical plausibility of assumptions i–iii.

Features i and ii are standard ingredients of accounts of the structural transformation. The observation that the slope of the Engel curve for agricultural products is less than one dates back at least to Adam Smith and has since been observed as an empirical regularity by, for example, Kongsamut et al. (1997) in cross sections of countries (where richer countries have smaller farm shares of gross domestic product) and in time-series data (with declining farm shares as economies grow richer) and by, for example, Houthakker and Taylor (1970) and Bils and Klenow (1998) in cross sections of consumers (where richer individuals devote a smaller share of their income to food consumption). Faster productivity growth in agriculture is documented by, among others, Jorgenson and Gollop (1992), according to whom farm TFP growth has historically been 2.5 times as large as nonfarm TFP growth. Unfortunately, their estimates are based on post-1947 data. The (very spotty) prewar evidence from *Historical Statistics* (1997) seems to indicate that farm TFP growth might have been slightly slower than nonfarm TFP growth. Hence, we take the view that over the century farm productivity, *on average,* grew faster than nonfarm productivity, although not as fast as implied by the Jorgenson-Gollop figures. In Appendix D we further elaborate on this point.

The new assumption in the paper is assumption iii. An Arkansas planter testified in 1900 that "my experience has been that when one of the youngster class gets so he can read and write and cipher, he wants to go to town. It is rare to find one who can read and write and cipher in the field at work" (Wright 1986, p. 79). In her study of the "high school movement" (1910–40), Goldin (1998) reports that "many state education reports openly acknowledged that the *educated* children of the farm population would leave rural areas" (p. 370; emphasis added).

[13] We frankly admit that our story has little relevance to explain the relative experience of the West. Most of the area of this region was still "frontier" territory at the beginning of the century, with almost no population, and economic activities were dominated by mining. The period of declining relative western income coincides with the "filling up" of the region, with increasing population density and rising reliance on agriculture.

In this paper we take these testimonies seriously and build an explanation for the structural transformation on increased availability and improved quality of education and training. Skill acquisition triggers migration to the nonagricultural sector ("going to town"). Our key assumption is that skill acquisition has become less costly over time.

If the nonagricultural wage premium reflects a cost of acquiring skills, agriculture should have fewer skill requirements than nonagriculture. That this may indeed be so is suggested by comparisons of the educational attainment of workers in agriculture and outside of agriculture. Using census data, we have found that in every decade since 1940 the percentage of workers whose educational attainment is an elementary degree or less is considerably larger in agriculture than outside of agriculture. We have also created a ranking—by percentage with an elementary degree or less—of the universe of industries featured in the *Census of Population.* Out of the 119 industries for which we have observations in 1940, there are only two with attainment levels below agriculture. In other years agriculture fares slightly better, but it is consistently among the bottom 10.

We can think of at least four distinct sets of reasons why the costs of acquiring nonagricultural skills may have declined. First, there have been extraordinary advances in transportation technology. The bicycle (1885), the automobile (around 1900), and the bus (which became important after 1920), complemented by advances in road construction and paving, have dramatically reduced the daily time cost of reaching school for rural children.[14] By dramatically shortening the duration of the trip to school, better transportation technology has lowered the opportunity cost of education—represented by the forgone labor on the farm—especially, but by no means exclusively, for children who live outside of walking distance from the school. The bus is clearly the most important of these improvements since it also allows for economies of scale in pupils transported and therefore makes schooling more accessible to low-income children.

Partly as a result of improved transportation, the quality of education should also have risen. With reduced distances, and consequent increased student population, it should have been possible to exploit economies of scale in the construction of educational facilities, again a reduction in educational costs per child, and economies of specialization in teaching assignments. A vivid illustration of this is provided by the virtual disappearance of the "one-teacher school," where all pupils were taught by the same teacher (typically in the same room) independently of grade: there were 200,000 one-teacher public schools in 1916 and

[14] We took the approximate dates for these inventions from Mokyr (1990) and the *Encyclopaedia Britannica.*

only 1,800 in 1970 (*Historical Statistics,* ser. H417). Clear evidence of a long-run improvement in the quality of schools is found in Bishop (1989). He surveys the results of comparable education-affected achievement tests across cohorts of students since 1917 and finds that (controlling for years of schooling) scores have continuously increased for all grades until 1967. After 1967, scores for most grades declined for about 13 years but then started improving again in the 1980s. These large secular gains in average scores are all the more remarkable given the large increase in the student population. Another aspect of the quality of education is the subject matter of instruction: in the 1910s and 1920s, there were widespread changes in the school curricula that transformed high schools from mainly preparatory for college to institutions geared toward giving students the vocational and technical training required by the expanding blue- and white-collar sectors (Goldin 1998). With increased quality of education along these several dimensions, the time cost of attaining a given level of skills should have fallen.

Life expectancy at birth has increased from 42 to 75 years between 1880 and 1990.[15] In terms of the decision to acquire skills, a lengthening of life expectancy is isomorphic to a decline in the time cost of acquiring education, as the horizon over which the investment will pay off is longer. Last but not least, with blacks constituting a large fraction of the rural population in the South, the end of segregation in the school system of that region dramatically improved the access to and the quality of education for the most recent cohorts of southern farm-born children.

IV. The Model

A closed economy has two locations, North (N) and South (S); two goods, farm (F) and manufacturing (M); and three factors of production, land (T), labor (L), and capital (K). The production technologies in the two regions at time t are

$$F_t^i = A_{ft}^i (T_{ft}^i)^{\alpha_T} (L_{ft}^i)^{\alpha_L} (K_{ft}^i)^{1-\alpha_T-\alpha_L}, \quad i = S, N,$$

$$M_t^i = A_{mt}^i (T_{mt}^i)^{\beta_T} (L_{mt}^i)^{\beta_L} (K_{mt}^i)^{1-\beta_T-\beta_L}, \quad i = S, N,$$

where superscripts identify regions and subscripts identify goods; A_{jt}^i is total factor productivity for good j in region i; and α_T, α_L, β_T, and β_L are time-invariant parameters. We assume that North and South are equally good at producing manufactures; hence $A_{mt}^S = A_{mt}^N = A_{mt}$. On the other hand, we shall assume that the South enjoys a comparative

[15] *Historical Statistics,* ser. B126 and B107, and U.S. Bureau of the Census (1997, table 117). The lengthening that is relevant for our purposes is somewhat less pronounced since part of the increased life expectancy derives from decreased infant mortality. For us, what is relevant is life expectancy at age 10.

advantage in the production of farm goods, say because it has better soil and climate. To simplify matters, we take an extreme version of this view and assume that $A_{ft}^S = A_{ft} > 0$ and $A_{ft}^N = 0$; that is, farming activity is profitable only in the South. Clearly, this implies that $F_t^N = L_{ft}^N = T_{ft}^N = K_{ft}^N = 0$ for all t. The productivity parameters A_{ft} and A_{mt} grow in the two sectors at the exogenous factors g_{ft} and g_{mt}, respectively.

At any point in time the economy's resources consist of land, capital, and labor. The economy occupies a fixed area of size one, and a fixed fraction ω of the total supply of land is in the South. In each period, land can be reallocated across sectors. The total use of land in the South must not exceed the supply of land in the South; hence $T_{ft}^S + T_{mt}^S \leq \omega$, and similarly for land in the North, $T_{mt}^N \leq 1 - \omega$. To simplify some of the notation, define $T_{ft} = T_{ft}^S$ and $T_{mt} = T_{mt}^S + T_{mt}^N$, and note that (provided that all land is used)

$$T_{ft} + T_{mt} = 1. \tag{3}$$

Denote by K_t the total supply of capital at time t, and let $K_{ft} = K_{ft}^S$ and $K_{mt} = K_{mt}^S + K_{mt}^N$. Each period capital can be reallocated across sectors, so that

$$K_{ft} + K_{mt} = K_t. \tag{4}$$

The size of the population in each period is one, and each member of the population alive at time t is endowed with one unit of time in that period. Time can be spent working in farming, working in manufacturing, or training. Denote the amount of time spent in training at time t by L_{et}, and define $L_{mt} = L_{mt}^S + L_{mt}^N$ and $L_{ft} = L_{ft}^S$. Then

$$L_{mt} + L_{ft} + L_{et} = 1. \tag{5}$$

The output of the manufacturing sector can be either consumed or invested to add to the capital stock. Denote by c_{jt} the aggregate consumption of good j and by δ the rate of depreciation of the capital stock. Then the following equation constrains the evolution of the capital stock:

$$c_{mt} + K_{t+1} = M_t + (1 - \delta)K_t, \tag{6}$$

where $M_t = M_t^S + M_t^N$ (note that the production functions feature constant returns to scale). On the other hand, only farm goods can be consumed:

$$c_{ft} = F_t. \tag{7}$$

The demographic structure is similar to the one proposed by Blanchard (1985) and Matsuyama (1991). In each period t, there is born a generation of size $1 - \lambda$. For any person alive at time t, the probability of dying in period $t + 1$ is the constant $1 - \lambda$. Define generation j at time t as the generation born at time $t - j$. Then at time t the size of generation j is $(1 - \lambda)\lambda^j$. Note that this assures that the size of the total population is one in every period.

Each generation is constituted by a continuum of individuals, indexed by i. Member i of each newly born generation faces the following choice at (and only at) the beginning of life. Either he can immediately join the farm sector, to which he then supplies one unit of labor for each of the periods in which he remains alive. Or he can devote the first $\xi_t \zeta^i$ periods of his life to acquiring skills and supply one unit of labor to the manufacturing sector for each of the remaining periods he stays alive. We assume that ξ_t is identical across all members of the same cohort but allow it to change over time. On the other hand, we assume that ζ^i is distributed among members of each generation with time-invariant density function $\mu(\zeta^i)$. Hence, ζ^i measures the amount of time it takes for person i to acquire the skills to become a nonfarmworker, relative to other members of the same generation. Instead, ξ_t reflects the overall efficiency of the economy in providing education and training. This efficiency can change across generations. For simplicity, we assume $\xi_t \zeta^i < 1$, for every t and every i. Hence, for those deciding to acquire skills, education never "spills over" into periods of life subsequent to the first.[16]

We assume that individuals are linked by intergenerational altruism. In particular, each individual belongs to one dynasty, and at each point in time a dynasty has one and only one member. Once a person dies, another person is born into that dynasty. Dynastic utility is then given by

$$\sum_{t=0}^{\infty} \beta^t u(c_{ft}^i, c_{mt}^i), \tag{8}$$

where c_{jt}^i is the consumption of good j by the member of dynasty i who is alive at time t, and β is the intertemporal discount factor. We also assume that skills are perfectly correlated across generations: the newborn member of generation i inherits the same type ζ^i as the previous member. As will be apparent below, these assumptions of intergenerational altruism and perfect intergenerational correlation of type greatly simplify the computation of the competitive equilibrium, in that they imply that the economy admits a representative consumer. The utility function per period for individual i at time t is

[16] This assumption is not unduly restrictive: in our numerical work we assume that one period lasts 10 years and that life starts at age 10.

$$u(c_{ft}^i,\ c_{mt}^i) = \frac{[(c_{ft}^i - \gamma)^{\tau}(c_{mt}^i)^{1-\tau}]^{1-\sigma}}{1-\sigma},$$

where $0 < \tau < 1$, $\sigma \geq 0$, and $\gamma \geq 0$. One property of these preferences is that the income elasticity of the demand for farm goods is less than one (provided that $\gamma > 0$). As discussed in the Introduction, this is a key ingredient in any explanation of the structural transformation.

Individuals are assumed to have access to a complete set of contingent claims. Denote by q_t the price at time 0 for delivery of one unit of the farm good in period t. Denote by H_0^i the wealth of an individual (dynasty) of type i at time $t = 0$. This consists of any initial assets and the discounted value of labor income of current and future members of the dynasty to which the individual belongs. The present-value budget constraint is then

$$\sum_{t=0}^{\infty} q_t(c_{ft}^i + p_t c_{mt}^i) = H_0^i. \tag{9}$$

We assume that any financial contract entered into by previous members of a dynasty will be honored by all subsequent members of that dynasty.[17]

V. Competitive Equilibrium

Maximization of (8) subject to (9) implies that the following relations hold for every i and every t:

$$\frac{u_2(c_{ft}^i,\ c_{mt}^i)}{u_1(c_{ft}^i,\ c_{mt}^i)} = p_t,$$

$$\beta\frac{u_1(c_{f,t+1}^i,\ c_{m,t+1}^i)}{u_1(c_{ft}^i,\ c_{mt}^i)} = \frac{q_{t+1}}{q_t}.$$

Given our assumptions on preferences and the dynastic structure of the economy, the same equations must hold in equilibrium when evaluated at the aggregate quantities for the consumption of farm and manufacture goods, c_{ft} and c_{mt}:

$$\frac{u_2(c_{ft},\ c_{mt})}{u_1(c_{ft},\ c_{mt})} = p_t \tag{10}$$

and

[17] Both land and capital are owned by individuals, who rent them out to firms. Since this model permits aggregation, however, for examining resource allocation and per capita wage income, the distribution of land and capital is irrelevant. Hence, we do not keep track of the distribution of assets.

$$\beta \frac{u_1(c_{f,t+1},\ c_{m,t+1})}{u_1(c_{ft},\ c_{mt})} = \frac{q_{t+1}}{q_t}. \tag{11}$$

Note, in particular, that a newborn of a dynasty will choose the same level of consumption that the retiring old member would have consumed had he remained alive. It is this feature, along with the functional form assumption on preferences, that yields the aggregation result just mentioned.

Maximization of profits by farms and manufacturing firms leads to the standard factor pricing equations:

$$F_1(T_{ft},\ L_{ft},\ K_{ft},\ A_{ft}) = a_t, \tag{12}$$

$$F_2(T_{ft},\ L_{ft},\ K_{ft},\ A_{ft}) = w_{ft}, \tag{13}$$

$$F_3(T_{ft},\ L_{ft},\ K_{ft},\ A_{ft}) = r_t, \tag{14}$$

and

$$M_1(T_{mt},\ L_{mt},\ K_{mt},\ A_{mt}) = \frac{a_t}{p_t}, \tag{15}$$

$$M_2(T_{mt},\ L_{mt},\ K_{mt},\ A_{mt}) = \frac{w_{mt}}{p_t}, \tag{16}$$

$$M_3(T_{mt},\ L_{mt},\ K_{mt},\ A_{mt}) = \frac{r_t}{p_t}, \tag{17}$$

where a_t is the rental rate per unit of land, w_{ft} is the wage rate for farm labor, r_t is the rental rate per unit of capital, and w_{mt} is the nonfarm wage rate (all three rates are in units of farm goods). Note that we are using the fact that land and capital can be costlessly moved across sectors.

Denote the present value of wages in sector j by h_{jt}:

$$h_{jt} = \sum_{s=t}^{\infty} \frac{q_s}{q_t} \lambda^{s-t} w_{js}, \quad j = f,\ m.$$

Note that the present value of wages must take into account the probability of remaining alive. Put differently, the price at time 0 for delivery of w_{ft} units of the farm good at time *t, conditional* on being alive (and working), is $q_t\lambda^t$. From (11), these equations can be rewritten recursively as

$$u_1(c_{ft}, c_{mt})h_{mt} = u_1(c_{ft}, c_{mt})w_{mt} + \beta\lambda u_1(c_{f,t+1}, c_{m,t+1})h_{m,t+1} \tag{18}$$

and

$$u_1(c_{ft}, c_{mt})h_{ft} = u_1(c_{ft}, c_{mt})w_{ft} + \beta\lambda u_1(c_{f,t+1}, c_{m,t+1})h_{f,t+1}. \tag{19}$$

Recall that members of generation 0 (the current newly born) are distributed according to the amount of time $\xi_t\zeta^i$ it takes to acquire the skills to work in the manufacturing sector. Clearly, all individuals with a type ζ^i such that

$$h_{mt} - \xi_t\zeta^i w_{mt} \geq h_{ft}$$

will invest in skill acquisition. Thus we can define

$$\bar{\zeta}_t = \frac{1}{\xi_t}\frac{h_{mt} - h_{ft}}{w_{mt}}$$

as the cutoff value such that all newborns with $\zeta^i \leq \bar{\zeta}_t$ choose education and subsequent employment in manufacturing, whereas all those with $\zeta^i > \bar{\zeta}_t$ choose farming. Note that, for *given* prices such as the wage rate and interest rate, a decline in the cost of schooling, ξ_t, leads to an increase in the share of the incoming generation who decide to acquire skills and join the nonfarm sector. Denote the fraction of generation 0's time devoted to employment in farming, employment in manufacturing, and training by l_{ft}^0, l_{mt}^0, and l_{et}^0, respectively. Recalling that $\mu(\zeta^i)$ is the frequency of ζ^i, we have

$$l_{et}^0 = \int_0^{\bar{\zeta}_t} \xi_t\zeta^i\mu(\zeta^i)d\zeta^i \tag{20}$$

and

$$l_{mt}^0 = \int_0^{\bar{\zeta}_t} (1 - \xi_t\zeta^i)\mu(\zeta^i)d\zeta^i, \tag{21}$$

where we made use of the fact that each individual is endowed with one unit of time per period.

The evolution of the distribution of workers into the three sectors has a particular recursive structure. Note that of the farm population at time $t-1$, a fraction λ is still alive at time t. In addition, there are $l_{ft}^0(1-\lambda)$ newborn farmers. The fraction of farmers in the total population at time t is then

$$L_{ft} = L_{f,t-1}\lambda + l_{ft}^0(1 - \lambda). \tag{22}$$

Similarly,

$$L_{mt} = (L_{m,t-1} + L_{e,t-1})\lambda + l_{mt}^0(1 - \lambda) \tag{23}$$

and

$$L_{et} = l^0_{et}(1 - \lambda). \tag{24}$$

The evolution of the population into the various sectors is completely determined by choices over time for l^0_{ft}, l^0_{mt}, and l^0_{et}.

Since this economy features a full set of contingent securities, the return to holding capital (and land) must be consistent with the prices of contingent claims to goods in various periods and states of the world. Capital acquired in period t at the price p_t in units of farm goods can be held until the next period and rented at the rate r_{t+1}; the undepreciated amount $1 - \delta$ can be sold at the price p_{t+1}. Removal of arbitrage then requires that this return equal the return implied on the state-contingent securities. The no-arbitrage condition is thus

$$\frac{q_t}{q_{t+1}} = \frac{p_{t+1}}{p_t}\left(\frac{r_{t+1}}{p_{t+1}} + 1 - \delta\right),$$

where the left-hand side is the gross return on a one-period bond and the right-hand side is the return on one unit of capital.

Substitution of equations (10), (11), and (17) into the equation just derived leads to

$$u_2(c_{ft}, c_{mt}) = \beta u_2(c_{f,t+1}, c_{m,t+1}) \times [M_3(T_{m,t+1}, L_{m,t+1}, K_{m,t+1}, A_{m,t+1}) + 1 - \delta]. \tag{25}$$

We could proceed in a similar fashion to establish a no-arbitrage condition between land and capital (or, equivalently, between land and a portfolio of contingent claims). This no-arbitrage condition would dictate a time path for the price of land. Given the aggregation properties of the model, this exercise can be left implicit.

A stationary recursive competitive equilibrium consists of 20 time-invariant policy functions that determine the evolution of p_t, a_t, w_{ft}, w_{mt}, r_t, h_{ft}, h_{mt}, T_{ft}, T_{mt}, c_{ft}, c_{mt}, K_{t+1}, K_{ft}, K_{mt}, l^0_{ft}, l^0_{mt}, l^0_{et}, L_{ft}, L_{mt}, and L_{et}. These policy functions are functions of the variables that summarize the state of the economy at a point in time. The state variables consist of the two current productivity levels, A_{ft} and A_{mt}; the current level of efficiency in providing education, ξ_t; the current capital stock, K_t; as well as variables that summarize the distribution of the old population into farm and manufacturing workers: $L_{f,t-1}$ and $L_{m,t-1} + L_{e,t-1}$. The 20 equations that determine these policy functions are (3), (4), and (5) (resource constraints); (6) and (7) (market clearing in the two sectors); (10) (intratemporal optimization in consumption); (12)–(17) (factor prices); (18) and (19) (recursive definitions of human capital); (20) and (21) (supply of trainees and newborns to the manufacturing sector); (22), (23), and (24) (recursive equations for the supply of workers to farming, manufacturing, and education); and (25) (capital accumulation). In Appen-

TABLE 3
PARAMETER VALUES

Parameter	Value	Description
		Both Models
τ	.01	Utility parameter
β	.60	Discount factor
α_T	.19	Land share in farming
α_L	.60	Labor share in farming
β_T	.06	Land share in manufacturing
β_L	.60	Labor share in manufacturing
δ	.36	Depreciation rate
λ	.75	Probability of living another period
$\hat{L}_f$ at $t = 0$	.50	Initial farm labor force
g_m	.0840	Nonfarm TFP growth
g_{f0}	.1680	Initial farm TFP growth
ω	.75	Land share in South
		Model with Constant Education Costs
γ	.2205	Utility parameter
K at $t = 0$	.0711	Initial capital stock
ξ_0 and $\bar{\xi}$	2.0375	Constant education cost parameter
		Model with Declining Education Costs
γ	.2201	Utility parameter
K at $t = 0$	.0712	Initial capital stock
ξ_0	1.8977	Initial education cost parameter
$\bar{\xi}$	.1239	Limit of education cost parameter

dix C we prove that there exists a stationary recursive equilibrium to this economy and that this equilibrium is unique.

VI. Calibration and Simulation of the Model

We quantitatively examine two versions of the model. Both models feature preferences such that the farm share of consumption declines with income and faster technological progress in farming than outside of farming. As discussed, these are the standard ingredients of conventional explanations of the structural transformation. The models differ in the dynamic behavior of the cost of acquiring nonfarming skills. In the first version we assume that education costs are constant over time, and in the second version we allow education costs to fall over time. We show that the model with declining costs of acquiring skills better fits the historical experience than the model featuring only the standard ingredients.

Table 3 reports the parameter values used in the simulations of the model. A detailed description of how we made these choices is given in Appendix D. Here we provide a brief summary. The utility parameter

τ in the model equals the steady-state ratio of the consumption of farm goods to the consumption of all goods. We use national account time-series data to generate a prediction of this long-run value. The discount factor β is set to match the average return to capital observed historically. The output shares α_T, α_L, β_T, β_L and the depreciation rate δ are calibrated on direct estimates for these parameters for the U.S. economy.[18] The probability of remaining alive for another period, λ, is set to match data on life expectancy. The value of $\hat{L}_f$ at $t = 0$ (1880) is taken directly from table 1.

Existence of a balanced growth path for our model imposes a restriction on the TFP growth parameters g_m and g_f.[19] In particular, in the long run the quantities $g_f^{1/(\alpha_T+\alpha_L)}$ and $g_m^{1/(\beta_T+\beta_L)}$ must converge to the same value. To meet this requirement in our simulations, we assume that g_m is constant and that $g_f^{1/(\alpha_T+\alpha_L)}$ is constant in the periods corresponding to the years 1880–1980 and then falls linearly to the value $g_m^{1/(\beta_T+\beta_L)}$ from 1980 to 2190; after 2190, $g_f^{1/(\alpha_T+\alpha_L)} = g_m^{1/(\beta_T+\beta_L)}$. The rate of productivity growth g_m and the initial constant value of g_f are calibrated on the basis of growth accounting work for the postwar period.

The parameters discussed so far were set *before* we ran the simulations. Some additional parameters had to be estimated *from* the simulations. These are the land share of the South, ω; the "Stone-Geary" utility parameter, γ; the initial capital stock, $\hat{K}$, at $t = 0$; and the parameters describing the behavior of the learning cost, ξ_t. These parameters are clearly estimated jointly, but it is useful to think of them as being chosen to match particular moments in the data. Land share ω is set so that the ratio of South/North per capita wage income in the initial period of the model equals the one observed in 1880 (the value of this parameter estimated for the model with declining education costs is also used for the model with constant education costs). The utility parameter γ is chosen so that the consumption of farm goods relative to total consumption in 1880 equals the observed one. The initial capital stock $\hat{K}$ at $t = 0$ is chosen so that the return to capital in 1880 equals the return to capital in the steady state (the return to capital does not show any strong trend in the data).

[18] Using the first three rows of table 1, one could back out for each period an estimate of the ratio of the labor share in agricultural GDP to the labor share in total GDP. This implied ratio grows from about 0.54 in 1880 to about 1 in 1980. While these numbers should be treated with great caution because of the poor quality of the data in the first part of the sample and because of the mismatch in industry definitions (farming vs. agriculture), they suggest that the assumption of a constant labor share in the two sectors is not realistic. We nonetheless make this assumption because it greatly simplifies the numerical work.

[19] Here these growth rates are given exogenously. Caselli (1999) provides an argument in which a fall in the cost of acquiring skills may be a crucial ingredient in explaining growth in per capita income.

TABLE 4
KEY FEATURES OF THE DATA AND MODEL SIMULATIONS

Variable	Data	Constant Costs	Declining Costs
$(c_f/c)_{1880}$	.31*	.31	.31
$(c_f/c)_{1980}$	.014	.03	.08
$(L_f)_{1880}$	.50*	.50	.50
$(L_f)_{1980}$	.03	.33	.10
p_{1880}/p_{1980}	≈1.0	.16	1.14
$(w_f/w_m)_{1880}$	.20*	.20	.20
$(w_f/w_m)_{1980}$	.69†	.03	.69
$(w^S/w^N)_{1880}$	.41*	.41	.41
$(w^S/w^N)_{1980}$	.90	.56	.97

* Models were fit to these values exactly.
† Model with declining education costs was fit to this value exactly.

In the version of the model with constant education costs, we estimate the education cost ξ so that the farm/nonfarm wage ratio in the initial period of the model equals the farm/nonfarm wage ratio in 1880. In the version of the model with declining education costs, we assume that ξ begins at ξ_0 in 1880 and falls linearly to $\bar{\xi}$ in 1980; after 1980, ξ remains at the value $\bar{\xi}$. The value of ξ_0 is chosen so that the farm/nonfarm wage ratio in the initial period of the model equals the farm/nonfarm wage ratio in 1880, and $\bar{\xi}$ is chosen so that the farm/nonfarm wage ratio in period 10 in the model (which corresponds to 1980) equals the farm/nonfarm wage ratio in 1980.[20]

Finally, to capture the notion that relatively few people require no education to work in the nonfarm sector, we assume that the distribution function μ is given by $\mu(\zeta) = 3\zeta^2$ for $0 \leq \zeta \leq 1$. Because the maximum value of ζ is one, table 3 implies that the maximum learning cost (i.e., for the individual who is least adept at learning) in 1880 is 1.9, or 19 years of training past age 10. Naturally this cost is prohibitive, and thus individuals with high learning costs—and many others with lower costs—will choose to stay in farming. By the end of the period the highest learning cost is 1.2 years past age 10. Clearly then by the end of the century most people will choose to leave farming. It is straightforward to compute the median and the mean cost of learning, which fall from 15 to 0.96 and from 14 to 0.95 years, respectively. Of course the minimum learning cost is zero throughout.

Table 4, designed to mirror table 1, reports some key results. Both models capture qualitatively the basic story about *quantities:* the declines

[20] For these parameter values, during the simulations it sometimes occurs that $\xi_t\zeta^i > 1$ for some households. Recall that $\xi_t\zeta^i$ is the fraction of the initial period that person i must spend in the education sector so that he may subsequently work in the nonfarm sector. Rather than modeling education as a multiperiod investment, we simply think of these people as having to pay an additional cost to acquire education.

in the consumption share, c_f/c, and in the employment share of farming, L_f. Quantitatively, the model with constant learning costs outperforms the model with declining learning costs on the consumption share dimension and is outperformed on the employment share dimension. The key difference between the two models emerges, however, when one looks at *prices*. First, the relative price of farm goods, $1/p$, declines dramatically in the model with constant costs, whereas, consistent with the evidence, it remains roughly constant in the model with declining costs. Second, the model with constant costs of learning predicts a vast and counterfactual *decline* in the relative wage of farmworkers. To reiterate the basic intuition, the model with constant learning costs features declining demand for farm goods and farmworkers through the less than unitary income elasticity of the demand for farm goods and increasing supply through faster TFP growth in farming. The model with declining costs of learning features an offsetting decline in the supply of farmworkers.

Table 4 also shows that the model with declining costs of learning also outperforms the model with constant costs on the regional convergence dimension. Because it features slower reallocation of labor out of low-wage agriculture *and* because it features a declining farm wage, the model with constant training costs wildly underpredicts the convergence of the South to the North. With the addition of declining learning costs, instead, regional convergence is predicted fairly accurately.[21]

Table 5 reports additional features of the simulations. In the model with declining learning costs, migration flows from the South to the North (as captured by a falling South-North population ratio),[22] which is consistent with historical trends. Conversely, in the model with con-

[21] Here is how we computed relative regional labor incomes. Labor income per worker in the North is w_m since this region produces only manufacturing goods. Total labor income in the South consists of all wage income paid in the farm sector, $L_f w_f$, plus the wage income paid to manufacturing workers located in the South. Economywide, wage income for the manufacturing sector is given by $w_m L_m$. To compute the fraction of this received by southerners, note that the amount of land used for manufacturing in the South is $T_m - (1 - \omega) = \omega - T_f$. No-arbitrage conditions require that the labor/land ratio is the same in both regions, and it is therefore equal to L_m/T_m. Hence, manufacturing employment in the South is $(\omega - T_f)L_m/T_m$ and wage income from manufacturing employment in the South is $(\omega - T_f)(L_m/T_m)w_m$. When all of this is put together, the ratio of wage income per worker in the South to that in the North is given by

$$\frac{L_f w_f + (\omega - T_f)(L_m/T_m)w_m}{[L_f + (\omega - T_f)(L_m/T_m)]w_m}.$$

[22] In view of the discussion in n. 22, the population ratio is

$$\frac{L_f T_m + (\omega - T_f)L_m}{(1 - \omega)L_m}.$$

TABLE 5
ADDITIONAL FEATURES OF THE MODEL SIMULATIONS

Variable (Annual Growth Rates)	Constant Costs	Declining Costs
South/North population ratio	.0036	−.0034
Farm capital/labor ratio	−.0069	.0243
Farm land/labor ratio	−.0147	.0094
Nonfarm capital/labor ratio	.0113	.0099
Nonfarm land/labor ratio	.0038	−.0034

stant education costs, migration counterfactually flows from the North to the South. The remaining rows shed light on the reasons. With declining learning costs, workers are reallocated from farming to manufacturing faster than the other factors of production, leading to increasing labor intensity outside of farming. To prevent the southern manufacturing wage from falling relative to the northern manufacturing wage, some of the southerners leaving the farms need to head to manufacturing centers in the North. Instead, with constant learning costs, workers leave farming at a slower speed than the other factors, leading to falling labor intensity in manufacturing. To reequilibrate manufacturing wages, some northern workers need to migrate South.[23]

VII. Alternative Explanations

Our discussion so far assumes that workers in agriculture all receive the same wage. One important alternative explanation arises if agricultural workers of different skill levels receive different wages. In this case, a

[23] The behavior of the land/ and capital/labor ratios also directly constitutes an additional respect in which the model with declining learning costs dominates the one with constant costs. A rough calculation (based on *Historical Statistics,* ser. J51; U.S. Bureau of the Census [1997, table 1080]; and the agricultural labor force estimates in this paper) shows that farmland per worker increased from 63 to 490 acres between 1880 and 1992. Since these changes are mainly driven by changes in agricultural employment, it seems exceedingly likely that the land/labor ratio outside of agriculture declined. Also, as reported by Jorgenson and Gollop (1992), in agriculture the capital/labor ratio has grown by .0264 per year from 1947 to 1985, and in the nonfarm sector this ratio has grown by .0225 per year. Both ratios grew in the model with declining education costs, but the farm capital/labor ratio fell in the model with constant education costs.

Kongsamut et al. (1997) construct a model of the structural transformation that is designed to match the "Kaldor facts": roughly constant time profiles of the capital/output ratio, the real interest rate, the share of labor in income, and the growth of output. Our model (with declining education costs) is also broadly consistent with these facts. In the simulations, the capital/output ratio varies only from .20 to .27, the real interest rate (annualized) varies only from 6.5 to 8 percent, and labor income shares are constant (since labor's share is the same in both sectors). Also, per capita output growth (annualized, in units of manufacturing goods) begins close to 0 percent, rises to 2.6 percent over the subsequent 50 years, and then falls to around 1.2 percent; this hump-shaped pattern of output growth is broadly consistent with the U.S. experience during the last century (although output growth in the model in the initial period is a bit low).

TABLE 6
Agriculture Dummy in Earnings Regressions

Year	No Controls (1)	Individual Controls (2)	Industry Controls (3)
1940	−.656	−.536	−.599
	(.011)	(.010)	(.010)
1990	−.312	−.268	−.334
	(.015)	(.013)	(.013)

Source.—Census microdata samples. See App. A for more details.
Note.—Standard errors are in parentheses. Coefficients are dummy variables indicating employment in agriculture. The dependent variable is labor earnings divided by the sample mean. Individual controls are age, age squared, one dummy variable indicating female sex, one dummy variable indicating a nonwhite race, and nine dummy variables indicating educational achievement. Industry controls are individual controls plus nine dummies indicating employment in various industries (mining, utilities, trade, finance, business services, personal services, entertainment and recreation, professional services, and public sector). Regressions were estimated separately for each year by ordinary least squares.

decline in the nonagricultural wage premium may signal a change in the composition of agricultural employment toward more skilled individuals, even if the cost of moving across sectors is unchanged. This could arise, for example, as a consequence of technical change that is relatively more skilled-biased in agriculture than outside of agriculture. In fact, one could presumably write down a model in which skill-biased technical change in agriculture increases the average agricultural wage (because the average agricultural worker becomes more skilled) and reduces the employment share of agriculture (because fewer agricultural workers are required in agriculture).

In order to assess the potential quantitative importance of the skill-biased technical change explanation, we have used our census data to perform a battery of Mincer-like regressions of workers' earnings. In these regressions the unit of observation is a worker, and the dependent variable is a worker's earnings (relative to the sample average). A separate regression is estimated for each of the decennial censuses since 1940, although to save space we report results only for 1940 and 1990. Column 1 of table 6 reports the results from these regressions when the only explanatory variable is a dummy taking the value of one if the worker is employed in agriculture and zero otherwise. Comparing the coefficient on this dummy across years is just another way of documenting the upward trend in the relative agricultural wage: the differential between agricultural and nonagricultural wages grew from −66 to −31 as a percentage of the U.S.-wide average wage. In other words, agriculture experienced a 35-percentage-point gain between 1940 and 1990.

Another potential alternative explanation is that wage convergence is driven by changes in the skill composition of the nonagricultural sector (say, from high-skill manufacturing to low-skill services). We address this alternative explanation with the regressions in column 3 of table 6. These regressions include the same controls as those in column 2 but add a set of nine industry dummies to the already-present indicator for agriculture. The eleventh industry, omitted from the regression, is manufacturing. Hence, the coefficient on the agriculture dummy reported in the table now captures the "cost" of being in agriculture—individual characteristics being held constant—*relative to manufacturing*. The alternative explanation would lead us to expect such a cost to be constant over time. Instead, consistent with our explanation, the decline in the agriculture dummy is comparable in magnitude to the one in columns 1 and 2.

VIII. Summary

In 1880 the various states that constitute the United States exhibited substantial differences in their per capita income, but by 1980 this difference largely vanished. In this paper we found that the initial disparity in per capita incomes could be explained by the variation across states in the fraction of employment devoted to agriculture (poor states devoted a large fraction of employment to agriculture, and in 1880 agricultural wage rates were well below nonagricultural wage rates). Also, we decomposed the subsequent convergence of per capita incomes into (i) a part due to regional differences in wage rates for agricultural and nonagricultural workers and (ii) a part due to the rapid fall in the share of southern employment in agriculture along with the U.S.-wide rise in the wage rate of agricultural workers relative to nonagricultural workers (which is a new fact that we seem to have documented). Our finding that the bulk of convergence is due to the latter suggests that a larger share of the historical regional convergence is due to the structural transformation out of agriculture than to the removal of interregional obstacles to factor mobility.

We base our model of the structural transformation on the fact that the relative wage rate for agricultural workers has risen whereas their relative supply has fallen. These facts suggest that the relative cost of acquiring nonagricultural (manufacturing) skills has declined over the last century. On this observation we construct an explanation for several features of U.S. economic growth, including the initial disparity of per capita incomes in 1880, the subsequent structural transformation out of agriculture, and the interregional convergence of per capita incomes. As agriculture is the predominant form of economic activity in developing countries and regional imbalances are widely diffused across the world, we hope our analysis of the U.S. experience may shed light on broader issues of growth and cross-country income differences.

Appendix A

Labor Income and Employment by State and Industry

The estimates of labor income and employment by state and industry for the years 1940, 1950, 1960, 1970, 1980, and 1990 have been made from the integrated public-use microdata series (IPUMS) of the U.S. *Census of Population,* as made available by the IPUMS project of the University of Minnesota (Ruggles and Sobek 1997 [http://www.ipums.umn.edu/]). Specifically, individual-level information has been extracted from the following samples: 1940 General, 1950 General, 1960 General, 1970 Form 1 State (5% State), 1980 1% Metro (B Sample), and 1990 1% Unweighted. The size of these samples varies from approximately 1.35 million persons in 1940 to 2.49 million in 1990. To reduce computer time, we have done most of the work using smaller random samples containing about one-third of the observations of the original ones.[24] Extensive checks have showed that, beyond this size, the results are in no appreciable way sensitive to further enlargement of the samples.

For each year and for each individual in our samples, we have extracted the variables describing age (AGE), wage income (INCWAGE), employment status (EMPSTAT), industry (IND1950), number of weeks worked (WKSWORK2), state of residence (STATEFIP), and sampling weight (SLWT for 1950, PERWT for all other years). We dropped all individuals who were not employed, whose age was less than 16, and who had worked less than 50 weeks in the previous year. We then created a dummy variable for all individuals employed in agriculture.

Wages.—To compute average agricultural and nonagricultural wages by state, we first calculated total wage income by state and industry as the sum of all the wages paid to workers in agriculture and outside of agriculture, respectively. To convert this to a per worker basis, we computed by state and industry the total number of individuals who received positive wages in that industry. In both the computation of the total wage bill and the number of wage earners, each individual's contribution is proportional to his or her sampling weight.

Employment.—Employment in agriculture and outside of agriculture in each state is simply given by the number of people employed in each sector in that state, each contributing in proportion to his or her sampling weight.

Table 1.—The U.S.-wide numbers for the relative agricultural wage in table 1 are obtained by constructing the U.S.-wide agricultural and nonagricultural labor income per worker as the means, weighted by the number of workers, of the state-level numbers. For the employment share of agriculture we simply summed the numbers of workers in the two sectors across states. The regional wages were constructed by computing by region the average—weighted by employment share—of the agricultural and nonagricultural wages.

Wage regressions.—The individuals included in the regressions are those with positive wage income. Controls: SEX, AGE, and AGE squared are included directly. RACE, which originally allows for various nonwhite options, is transformed to a binary variable. The nine education dummies correspond to the nine values taken by the variable EDUCREC (no schooling, grades 1–4, 5–8, 9, 10, 11, 12, one to three years of college, and four or more years of college).

[24] Except for 1950, when only about one-quarter of the respondents had been queried on earnings. Hence, for this year our sample contains all the individuals responding to the earnings questions.

Appendix B

Convergence Decompositions: Analytics

By adding the quantity $w_{ft}L^i_{ft} + w_{mt}L^i_{mt}$ to equation (1) and subtracting, we can rewrite w^i_t as

$$w^i_t = (w^i_{ft} - w_{ft})L^i_{ft} + (w^i_{mt} - w_{mt})L^i_{mt} + w_{ft}L^i_{ft} + w_{mt}L^i_{mt}. \tag{B1}$$

Using equation (B1), we can express the South-North income differential as

$$\begin{aligned}\frac{w^S_t - w^N_t}{w_t} = {} & \frac{w^S_{ft} - w_{ft}}{w_t}L^S_{ft} + \frac{w^S_{mt} - w_{mt}}{w_t}(1 - L^S_{ft}) \\ & - \frac{w^N_{ft} - w_{ft}}{w_t}L^N_{ft} - \frac{w^N_{mt} - w_{mt}}{w_t}(1 - L^N_{ft}) \\ & + \frac{w_{ft} - w_{mt}}{w_t}(L^S_{ft} - L^N_{ft}).\end{aligned} \tag{B2}$$

Define $\omega^i_{jt} = (w^i_{jt} - w_{jt})/w_t$, $i = S, N$, $j = f, m$. Also, let $\omega^i_t = (w^i_{ft} - w^i_{mt})/w_t$ and $\omega_t = (w_{ft} - w_{mt})/w_t$. We can now write equation (B2) in first differences as

$$\begin{aligned}\frac{w^S_t - w^N_t}{w_t} - \frac{w^S_{t-1} - w^N_{t-1}}{w_{t-1}} = {} & \Delta\omega^S_{ft} \cdot \bar{L}^S_{ft} + \Delta\omega^S_{mt} \cdot (1 - \bar{L}^S_{ft}) \\ & - \Delta\omega^N_{ft} \cdot \bar{L}^N_{ft} - \Delta\omega^N_{mt} \cdot (1 - \bar{L}^N_{ft}) \\ & + \bar{\omega}^S_t \cdot \Delta L^S_{ft} - \bar{\omega}^N_t \cdot \Delta L^N_{ft} \\ & + \Delta\omega_t \cdot (\bar{L}^S_{ft} - \bar{L}^N_{ft}),\end{aligned} \tag{B3}$$

where $\Delta x_t = x_t - x_{t-1}$ and $\bar{x}_t = (x_t + x_{t-1})/2$. In table 2, column 1 is the left-hand side of (B3), column 4 is the quantity in the first and second lines of (B3), column 2 is the third line, and column 3 is the fourth line.

Appendix C

Existence, Uniqueness, and Efficiency of Equilibrium Allocations

We first characterize the efficient allocation of resources for our model economy. We then show that the efficient allocation coincides with the allocation in a competitive equilibrium.

Consider a central planner interested in maximizing the utility of the "representative dynasty"

$$v_0 = \sum_{t=0}^{\infty} \beta^t \frac{[(c_{ft} - \gamma)^{\tau}(c_{mt})^{1-\tau}]^{1-\sigma}}{1 - \sigma}.$$

In maximizing this utility, the planner chooses sequences for c_{ft}, c_{mt}, K_t, K_{ft}, K_{mt}, T_{ft}, T_{mt}, l^0_{ft}, l^0_{mt}, l^0_{et}, L_{ft}, L_{mt}, L_{et}, and ξ_t. Assume that all exogenous variables evolve according to time-invariant recursive laws of motion. The social planner's problem can be solved as a dynamic program. Let a hat denote a value of a variable in the previous period. The state variables consist of A_f, A_m, K, ξ, $\hat{L}_f$, and $\hat{L}_m + \hat{L}_e$. The stationary recursive solution to the efficient allocation problem consists of time-invariant policy functions that are functions of the state of the system.

The policy functions are for c_f, c_m, K', K_f, K_m, T_f, T_m, l_f^0, l_m^0, l_e^0, L_f, L_m, L_e, and $\bar{\zeta}$. The value function v and policy functions must satisfy the Bellman equation

$$v(A_f, A_m, K, \xi, \hat{L}_f, \hat{L}_m + \hat{L}_e) = \max\{u(c_f, c_m) + \beta v(A'_f, A'_m, K', \xi', L_f, L_m + L_e)\},$$

where the max is taken over the 11 policy variables and is subject—with hats replacing time subscripts as appropriate—to (3)–(7) and (20)–(24). Standard theorems on solutions to concave dynamic programming problems can be used to prove the existence and uniqueness of a solution to this problem.

By computation of the first-order and envelope conditions, the solution is shown to satisfy (25):

$$u_1(c_f, c_m)F_1(T_f, L_f, K_f, A_f) = u_2(c_f, c_m)M_1(T_m, L_m, K_m, A_m) \tag{C1}$$

and

$$u_1(c_f, c_m)F_3(T_f, L_f, K_f, A_f) = u_2(c_f, c_m)M_3(T_m, L_m, K_m, A_m). \tag{C2}$$

Denote by φ_f the multiplier for equation (22), and denote by φ_m the multiplier for equation (23); both multipliers are functions of the state vector (A_f, A_m, K, ξ, $\hat{L}_f$, $\hat{L}_m + \hat{L}_e$). These functions must satisfy the two equations

$$\varphi_f = u_1(c_f,\ c_m)F_2(T_f,\ L_f,\ K_f,\ A_f) + \beta\lambda\varphi'_f \tag{C3}$$

and

$$\varphi_m = u_2(c_f,\ c_m)M_2(T_m,\ L_m,\ K_m,\ A_m) + \beta\lambda\varphi'_m. \tag{C4}$$

Note that λ enters these equations because of its role in determining the evolution of farming and manufacturing workers over time. Finally, from the fundamental theorem of calculus, the solution must also satisfy the equation

$$\bar{\zeta} = \frac{1}{\xi}\frac{\varphi_m - \varphi_f}{u_2(c_f,\ c_m)M_2(T_m,\ L_m,\ K_m,\ A_m)}. \tag{C5}$$

A necessary and sufficient condition for a solution to be a social optimum is that the choices c_f, c_m, K, K_f, K_m, T_f, T_m, L_f, L_m, L_e, and $\bar{\zeta}$ satisfy (3)–(7), (20)–(25), and (C1)–(C5).

It is straightforward to show that the allocations in a competitive equilibrium coincide with the efficient allocations as defined above. Combine equations (10), (12), and (15) to show that the allocations in a competitive equilibrium must satisfy equation (C1), and combine equations (10), (14), and (17) to show that the allocations in a competitive equilibrium must satisfy equation (C2). Also, note that the solution φ_f to equation (C3) equals the solution u_1h_f to equation (19), and the solution φ_m to equation (C4) equals the solution u_1h_m to equation (18). These results show that equation (C5) holds. Hence, the allocations coincide. Because of this equivalence, the existence and uniqueness of a solution to the planner's problem that were established for the efficient allocation also carry over to establish the same properties for the competitive equilibrium.

Appendix D

The Choice of Parameter Values

This Appendix describes how we chose the values for the model's parameters. Each period in the model consists of 10 years, and we think of the initial period of the model as corresponding to 1870–80. The method for choosing each parameter is as follows.

τ: The value of $c_f/(c_f + pc_m)$ in the model converges to τ as γ/c_f converges to zero. In the data we measure c_f as farm GDP and pc_m as nonfarm GDP less gross investment. In 1996, for example, farm GDP/(farm GDP + nonfarm GDP − gross fixed private nonresidential investment) = .013. Denote $s = c_f/(c_f + pc_m)$. Using data from 1959 to 1996, we estimate the process $s_{t+1} = a_0 + a_1 \times s_t$ using the Cochrane-Orcutt procedure and estimate the long-run value of s_t as $a_0/(1 - a_1)$. We obtain an estimate for this long-run value of 0.01 and thus use it as our estimate of τ. Data: 1998 *Economic Report of the President,* tables B1, B10.

γ: We chose a value of γ so that the value of $c_f/(c_f + pc_m)$ observed in the data in 1880 equals the value of this ratio predicted in the initial period in the model. The average level of GDP between 1879 and 1888 was $21.2 billion, and the average size of farm GDP was $5.8 billion (both figures expressed in 1929 dollars). The ratio of gross fixed nonresidential investment to GDP between 1881 and 1890 was, on average, 12.2. From these figures we derive an estimate in 1880 for the quantity farm GDP/(farm GDP + nonfarm GDP − gross investment) = .31. Note that the farm share numbers we are giving here and in the previous paragraph differ from those in table 1 since the latter refer to the farm share in gross GDP. Data: *Historical Statistics of the United States* (1997), series F125, F127; Maddison (1991), table 2.3.

σ: We assume log utility, which implies $\sigma = 1.0$.

β: Denote the real return to capital by R, and denote the real per capita consumption growth of nonfarm goods by g. In the model the discount factor β is related to these two variables as $\beta = (1 + g)/(1 + R)$. In 1929, per capita nonfarm GDP − gross investment = $629.9 (1929 dollars). In 1996 this number is $24,223.1 (1996 dollars). This represents an annual nominal growth rate of .0551. The average nominal return on the value-weighted New York Stock Exchange from 1929 to 1995 is .1147. This implies an annual $\beta_a = .95$. We think of a period in the model as consisting of 10 years, which leads to a value $\beta = .60$. Data: 1998 *Economic Report of the President;* Center for Research in Security Prices.

α: α_T, α_L, β_T, and β_L are chosen as follows. Jorgenson and Gollop (1992) report data on the relative rental costs in production, for both the farm and nonfarm sectors, of using labor, capital (inclusive of land), energy, and materials (a KLEM decomposition). The labor/capital ratio in both sectors is roughly 60/40, so we assign .6 to the use of labor and .4 to the use of capital plus land. The Bureau of Labor Statistics reports the rental cost of land as a fraction of the rental cost of all types of capital plus land for the farm and nonfarm sectors. For the farm sector, the rental cost of land as a fraction of the total rental cost of capital is .4754. For the nonfarm sector, this fraction is .1444. We use these numbers to estimate $.19 = .4754 \times .4$ as land's share in the farm sector, and $.06 = .1444 \times .4$ as land's share in the nonfarm sector. Data: Jorgenson and Gollop (1992), inferred from tables 9.2, 9.4; Bureau of Labor Statistics, unpublished data obtained by direct query.

δ: Christensen and Jorgenson (1995), citing the *Capital Stock Study,* report the following annual depreciation rates (table 5.11) and relative values of the capital stock (table 5.12): consumer durables (depreciation .200, weight .21), nonresidential structures (depreciation .056, weight .22), producer durables (depreciation .138, weight .20), and residential structures (depreciation .039, weight .37). The weighted average depreciation rate is .0964. This implies a value of $\delta = .36$ per decade. Data: Christensen and Jorgenson (1995), tables 5.11, 5.12.

g_m: According to Jorgenson and Gollop (1992), the average TFP growth rate in the nonfarm sector from 1947 to 1985 was .0081 per year (this value is not adjusted for the changing quality of inputs; adjusted for quality, this estimate is .0044). As reported in *Historical Statistics,* the average TFP growth rate in the nonfarm sector from 1929 to 1948 was .0161, and the average TFP growth rate from 1889 to 1929 was .0163. The earlier TFP growth rates are larger than the later ones, but as argued by Jorgenson and Gollop, estimates such as these overstate the TFP growth rate (because of various errors of aggregation). Getting a reasonably accurate estimate of average TFP growth from 1880 to 1990 is somewhat challenging. In the end we chose to use the Jorgenson-Gollop estimate of .0081 for the entire 1880–1990 period, which implies an average growth rate of .0840 per decade ($g_m = .0840$). Data: Jorgenson and Gollop (1992), tables 9.2, 9.4; *Historical Statistics,* series W8.

g_{f0}: As estimated by Jorgenson and Gollop (1992), the average TFP growth rate in the farm sector from 1947 to 1985 was .0206 per year (as above, this number is not adjusted for the changing quality of inputs; with such an adjustment the average farm TFP growth rate was .0158 per year). As reported in *Historical Statistics,* the average TFP growth in the farm sector from 1929 to 1948 was .0144 per year, and the average TFP growth rate from 1889 to 1929 was .0043. This implies an average farm TFP growth rate from 1889 to 1985 of .0127 per year, which implies a value of .1345 per decade. As noted by Jorgenson and Gollop, their procedure for computing farm TFP generates a substantial growth in TFP from 1947 to 1985 (hence various biases due to aggregation do not explain the high farm TFP growth rates), and indeed their estimate is much higher than the estimates of farm TFP growth for earlier time periods (which do not control for these biases). We are somewhat concerned about the accuracy of the early farm TFP numbers, especially since they are very sensitive to estimates of farm employment, which are highly suspect for the early period (see n. 11). Instead of totally discounting the earlier estimates of TFP growth, we took them into account and chose a farm TFP growth rate of .1680 per decade, which is simply twice the value of our estimate of nonfarm TFP growth (in Jorgenson and Gollop's estimates for the 1947–85 time period, farm TFP growth is 2.54 times the nonfarm TFP growth rate). Data: Gollop and Jorgenson (1992), tables 9.2, 9.4; *Historical Statistics,* series W7.

ξ_0: Set to match the farm/nonfarm wage ratio in 1880, which is .20. Data: table 1.

$\bar{\xi}$: Set to match the farm/nonfarm wage ratio in 1980, which is .69. Data: table 1.

λ: The expected lifetime of people is $1/(1 - \lambda)$. In the data, the life expectancy at birth for each decade from 1880 to 1990 is 42, 43, 47, 50, 54, 60, 63, 68, 70, 71, 74, and 75. To adjust for the fact that in some sense the bulk of the population from 1880 to 1980 was born closer to 1880 than to 1980, we chose an expected lifetime corresponding to that in 1910, which is 50. We think of the model as starting when people are 10 years old (from 10 to 20 they make their education decision) and hence expect to live another four decades. This implies a value of $\lambda = .75$. Data: *Historical Statistics,* series B126, B107; U.S. Bureau of the Census (1997), table 117.

K_0: The initial capital stock, K_0, is set so that the initial return to capital equals the return to capital in the steady state (the return to capital does not seem to show any pronounced trend in U.S. data).

$\hat{L}_f$: $\hat{L}_f$ at $t = 0$ is set to match the fraction of the population that were farmworkers in 1880, which is .50. Data: table 1.

ω: The value of ω is chosen to match the ratio of labor income per worker in the South to that in the North in 1880 for the version of the model with declining education costs (the estimated value for the model with constant education costs is almost identical in any event). In the data this ratio is .41. Data: our calculations based on Lee et al. (1957), table Y-1.

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