How Regions Converge [1]

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Abstract

We present a joint study of the US structural transformation (the decline of agriculture as the dominating sector) and regional convergence (of Southern to Northern average wages). We find that empirically most of the regional convergence is attributable to the structural transformation: the nation-wide convergence of agricultural wages to non-agricultural wages, and the faster rate of transition of the Southern labor force from agricultural to non-agricultural jobs. Similar results describe the Mid-West's catch up to the North-East (but not the relative experience of the West). To explain these observations, we construct a model in which the South (Mid-West) 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) non-agricultural sector. The decline in the agricultural labor force leads to an increase in relative agricultural wages. Both effects benefit the South (Mid-West) 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 inter-regional factor mobility, since in our empirical work we find this channel to be less important than the compositional effects the model emphasizes.

1 Introduction

This paper presents a joint study of two key trends in US economic growth in the last century: structural transformation and regional convergence. The basic facts about the structural transformation are summarized in the top panel of Table 1: the well-known secular decline in the weight of farm goods in US 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 US-wide agricultural labor incomes to non-agricultural labor incomes. Regional convergence is documented in the bottom panel of Table 1. Southern workers experienced a more than doubling of their labor earnings relative to workers in the North. Midwestern workers 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:[2] (i) an income elasticity of the demand for farm products less than 1; (ii) faster total-factor-productivity growth in farming relative to other sectors in the economy. The former implies that as the economy grows the demand for farm goods and, consequently, for farm labor declines. The latter potentially reinforces this effect by further reducing the demand for farm labor, as 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

[1] States in the North are: CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT. States in the South are: AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA, WV. States in the Mid-West are: IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, SD, WI. States in the West are: AZ, CA, CO, ID, MT, NV, NM, OR, UT, WA, WY.

[2] See, e.g., the *Handbook of Development Economics, Vol. 1.*

Table 1: Structural Transformation and Regional Convergence in the USA

Year	1880	1900	1920	1940	1960	1980
Farm Share of GDP[1]	0.27	0.19	0.13	0.09	0.06	0.02
Agricultural Share of Employment[2]	0.50	0.39	0.26	0.20	0.06	0.03
Farm Relative Price (1967=1)[3]	1.20	1.23	1.54	0.99	1.10	1.01
Agricultural Relative Wage[2]	0.20	0.21	0.32	0.35	0.51	0.69
South/North Relative Wage[2]	0.41	0.44	0.59	0.60	0.78	0.90
Midwest/North Relative Wage[2]	0.82	0.89	0.90	0.84	0.96	1.00
West/North Relative Wage[2]	1.28	1.15	1.00	0.99	1.03	1.04

Sources. (1): *Historical Statistics,* series F125, F127; *Economic Report,* Table B-10; (2): see Section 2.2 and Appendix I; (3): *Historical Statistics,* Series E25 and E135, and *Economic Report,* Tables B-60 and B-67 (farm relative price equals the wholesale price index for farm goods divided by the CPI).

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-know 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 relies on shifts in the farm-labor supply curve, so that the decline in farm employment is consistent with the increase in farm wages. We model the industrial composition of the labor force as the result of optimal workers' choices. Farm-born workers face a decision of whether to remain in agriculture or join the urban sector. Sectoral migration involves a cost, such as investment into the differential skills required by urban, non-agricultural employment.[3] The key new mechanism giving rise to the required shifts in the relative supply of farm workers is: (iii) a long-run decline in the relative cost of acquiring non-agricultural 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 transportation, improved quality of education, increased life-expectancy, and school desegregation.[4]

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 non-farm 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 (i)-(iii) push increasing fractions of successive cohorts of Southern workers out of lower-wage farming and into higher-wage manufacturing, while at same time increasing relative wages for those Southern workers remained in farming. Both these features of the structural transformation therefore lead to regional convergence in average labor incomes. In sum, we are able to calibrate a two-region model of commodity trade and factor mobility featuring

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

[4] It should be clear that (i) and/or (ii), although not sufficient, are still necessary to tell the story: (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.

(i)-(iii) so that it closely replicates all of 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 -0.87). It is clear that increasing agricultural wages will therefore favor low-income states disproportionately. Figure 2 plots state per-worker labor income growth 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 where a relatively large fraction of the population moved out of farms (the correlation coefficient is -0.80). 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 farming, account for the bulk of the convergence of the states in the South and the Mid-West to those of the North-East.[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

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

[6]In contrast, these trends do not explain much of the changes in the incomes of the Western states relative to the North-East.

[7]We will not attempt a comprehensive survey of this literature. The classics on this topic include Clark (1940), Nurske (1953), Lewis (1954), and Kuznets (1966). Some recent additions are Matsuyama (1991), Echevarria (1997), Laitner (1997), and Kongsamut, Rebelo and Xie (1998). Matsuyama's paper is the closest to ours, in that he studies a similar overlapping-generation 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 non-agricultural sector - is associated with a decline in the relative agricultural wage.

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 and/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 Kuznets, Miller and Easterlin (1960), Kim (1998), and, especially, Krugman (1991a, 1991b) and Krugman and Venables (1995), all of whom tightly link inter-regional or inter-national convergence or divergence in incomes to convergence or divergence in economic structure.

As applied to the US experience, Krugman's argument is that in the 19^{th} 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 North-East. Subsequently population growth in the other regions made it possible to sustain a manufacturing sector outside of the North-East, 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 farm workers, 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 2 presents our empirical decomposition of the sources of regional convergence. Section 3 discusses the empirical plausibility of assumptions (i)- (iii), that underlie our model. The model's structure, solution, and quantitative results are presented in Sections 4, 5, and 6, respectively. Section 7 surveys alternative explanations and Section 8 offers some concluding remarks.

2 Accounting for Regional Convergence

This section establishes the empirical link between the structural transformation and regional convergence. We will mostly focus on the convergence between the most and the least farm-intensive of the four regions of the US: the South and the North. Convergence of average labor incomes may be due to three possible channels.[8] First, there might be convergence of Southern agricultural wage rates to Northern agricultural wage rates and Southern non-agricultural wage rates to Northern non-agricultural wage rates, i.e. catching up of Southern wages to Northern wages *within* each industry. This channel is the one relied upon by accounts of regional convergence that emphasize the gradual removal of inter-regional frictions preventing factor price equalization (e.g. Wright, 1986; Barro, Mankiw and Sala- i-Martin, 1995). Second, there is convergence of the fraction of the Southern workforce in agriculture to the fraction of the Northern workforce in agriculture (and consequently a convergence of the fraction of the respective workforces in non-agricultural industries). 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, e.g., Krugman (1991a, 1991b), 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 economy-wide average agricultural wage rate to the average non-agricultural wage rate. Since the South has a larger agricultural labor force this also generates convergence. The literature so far has overlooked this *between industry* wage

[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.

convergence channel.

We measure convergence by the quantity

$$\frac{w_t^S - w_t^N}{w_t} - \frac{w_{t-1}^S - w_{t-1}^N}{w_{t-1}} \quad (1)$$

where w_t is the economy-wide average labor income, w_t^S is the average labor income in the South, and w_t^N is the average labor income in the North. Hence, our measure of convergence is the number of percentage points by which the gap between the average Northern income and the average Southern income is reduced between year t and year $t-1$. In Appendix II we show how this measure of convergence can be exactly decomposed into three terms designed to capture the three channels just described. Hence, the "labor reallocation" term asks how much convergence would we 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/non-agriculture 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 agriculture and non-agriculture 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 non-agricultural wage in both regions at the historically observed economy-wide rate. The "within industry" captures the residual convergence, which can be thought of as asking the 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 (holding constant the US-wide average industry wage). How much convergence would we have observed? [9]

[9]Decompositions in a similar spirit are performed in Kuznets, Miller and Easterlin (1960), and Kim (1998).

Carrying out this decomposition requires panel data by region on three variables: agricultural and non-agricultural labor income per worker, and the share of agriculture in employment. 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% (US-wide) of the measure based on service income.[10] If the bias from the inclusion of non-labor, 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 decomposition results separately for the 1940-1990 period.

[10]The US-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% 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.

Appendix I explains the procedures we followed to construct the 1940-1990 panel.[11] [12]

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% of the total) are due to the faster Southern transition out of agriculture. Nationwide convergence of agricultural to non-agricultural incomes generated a 20 percentage-point gain, or 46% of the total. Finally, 8 percentage points of convergence (19% 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% is due to faster movement out of agriculture in the South, and 22.4% is attributable to agricultural wage to non-agricultural wage convergence. Hence, convergence of Southern agricultural and non-agricultural wages to Northern levels accounts for the remaining 42.3% of the gain. Still, the role of the structural transformation remains well above 50%.

[11] In an appendix which is available upon request we discuss alternative data from *Historical Statistics*, 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 farm workers in 1900, and allow for revisions that have been applied to the underlying data since the publication of *Historical Statistics,* a clear positive trend re-emerges, 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.

[12] 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 (1998) 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-North convergence, we think this evidence makes the lack of controls for price differences less troublesome.

Table 2: Decomposition of Convergence in South-North Income per Worker: 1880- 1950.

Period	Total	Labor Reallocation	Between Industry	Within Industry
1880-1950	0.440	0.156	0.201	0.084
% of total	100	35.5	45.5	19.1
1940-1990	0.312	0.110	0.070	0.132
% of total	100	35.3	22.4	42.3

Note: "Total" is the quantity in (1). "Labor Reallocation" is the component due to convergence of the fraction of the Southern labor force in agricultural to the fraction of the Northern labor force in agriculture. "Between Industry" is the component due to convergence of economy-wide average agricultural wage rates to economy-wide average non-agricultural wage rates. "Within Industry" is the component due to convergence of Southern agricultural wages to Northern agricultural wages and Southern non-agricultural wages to Northern non- agricultural wages. See Appendix II for more details. Authors' calculations. Data sources: (1880-1950, service income per worker) Lee et al. (1957), Tables L-4, Y-3 and Y-4; (1940-1990, labor income per worker) Ruggles and Sobek (1997).

To summarize, rising relative agricultural wages and agricultural out-migration can explain 81% of the convergence of Southern to Northern per capita service incomes between 1880 and 1950, and 58% of the convergence of Southern to Northern per capita labor incomes between 1940 and 1990. The South was overwhelmingly farm-intensive and the North largely on its way to industrialization at the inception of the period. Southern incomes converged to Northern incomes mainly because agricultural wages converged to non-agricultural 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 of the column "Within Industry" as capturing this effect. The data confirm that this effect does indeed play a role, and it becomes more and 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 inter-industry (as opposed to inter-regional) wage structure. We do this in the rest of the paper.[13]

What about the other two regions: the Mid-West and the West? We report the results of the Mid-West to North, and West to North convergence decompositions in Appendix II. When we decomposed changes in the gap between Mid-Western and Northern incomes per worker we found patterns that closely resemble those characterizing South-North convergence. For service income, the structural transformation actually accounts for 109% of the 17 percentage-point convergence between Mid-West and 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 Mid-West would actually have lost further ground relative to the North. For labor incomes in the period 1940-1990, however, there is 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

[13] In Appendix II 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 period, with the proportion of convergence explained by the structural transformation generally declining over time.

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 important role after 1940, but there is only limited convergence action in this period.[14]

3 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 TFP growth in agriculture and; (iii) declining costs of acquiring non-farming skills, can quantitatively match all the key data on the US structural transformation and regional convergence. In this section we briefly discuss the empirical plausibility of (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 1 dates back at least to Adam Smith, and has since been observed as an empirical regularity by, e.g. Knogsamut, Rebelo, and Xie (1988) in cross-sections of countries (where richer countries have smaller farm shares of GDP) and in time series data (with declining farm shares as economies grow richer); and by, e.g., Houthakker and Taylor (1970) and Bils and Klenow (1988) 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, among others, by Jorgenson and Gollop (1992), according to whom farm TFP

[14]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 dominated by mining. The period of declining relative Western income coincides with the "normalization" of the region, with increasing population density and raising reliance on agriculture.

growth has historically been 2.5 times as large as non-farm TFP growth. Unfortunately, their estimates are based on post-1947 data. The (very spotty) pre-war evidence from *Historical Statistics* seems to indicate that farm TFP growth might have been slightly slower than non-farm TFP growth. Hence, we take the view that over the century farm productivity *on average* grew faster than non-farm productivity, although not as much faster as implied by the Jorgenson-Gollop figures. In Appendix IV we further elaborate on this point.

The new assumption in the paper is (iii). An Arkansas planter testified in 1900: "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."[15] In this paper we take the Arkansas planter 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 non-agricultural sector ("going to town"). Our key assumption is that skill acquisition has become less costly over time.

If the non-agricultural wage premium reflects a cost of acquiring skills, agriculture should have fewer skill requirements than non-agriculture. 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

[15]Cited in Wright (1986), p. 79. In her study of the "high-school movement" (1910-1940) Goldin (1988) reports that "many state education reports openly acknowledged that the *educated* children of the farm population would leave rural areas" (p. 370, emphasis added). Consistent with the interpretation in this paper she shows that Southern states have historically had lower high-school enrollment and graduation rates than other regions in the country, but also that they experienced a larger increase during the great nationwide expansion of secondary education in the first 40 years of the century.

is considerably larger in agriculture than outside of agriculture.[16] We have also created a ranking - by percent 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.[17]

We can think of at least four distinct sets of reasons why the costs of acquiring non-agricultural skills may have declined. First, there have been extraordinary advances in transportation technology. The bicycle (1885), the automobile (around 1900), and the bus (that 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.[18] By dramatically shortening the duration of the trip to school, better transportation technology has lowered the opportunity cost of education - represented by the foregone 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

[16]This finding is robust to restricting the exercise to those aged between 20 and 30 years of age.

[17]Industries with a lower attainment in at least one year are: fisheries (126), coal mining (216), logging (306), knitting mills (436), dyeing and finishing textiles, except knit goods (437), yarn, thread and fabric (439), apparel and accessories (448), leather: tanned, curried and finished (487), footwear, except rubber (488), leather products, except footwear (489), personal services private households (826), shoe repair services (848). (the numbers are the industry codes in the IPUMS.)

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

have been possible to exploit economies of scale in 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 only 1,800 in 1970.[19] 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-school from exclusively preparatory to college to institutions geared towards 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.[20] 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, blacks constituting a large fraction of the rural popu-

[19] *Historical Statistics,* Series H417.

[20] *Historical Statistics,* Series B126 and B107, and *Statistical Abstract of the United States,* 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.

lation 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.

4 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, subscripts identify goods, and A_j^i is total factor productivity for good j in region i. 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 $A_m^S = A_m^N = A_m$. On the other hand, we will assume that the South enjoys a comparative 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 $A_f^S = A_f > 0$, $A_f^N = 0$, i.e farming activity is only profitable in the South. Clearly, this implies that $F_t^N = L_{ft}^N = T_{ft}^N = K_{ft}^N = 0$, for all t. Total factor productivity grows 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 1, 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, $T^N_{mt} \leq 1 - \omega$. To simplify some of the notation, define $T_{ft} = T^S_{ft}$ and $T_{mt} = T^S_{mt} + T^N_{mt}$, and note that (provided all land is used)

$$T_{ft} + T_{mt} = 1. \tag{2}$$

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

$$K_{ft} + K_{mt} = K_t. \tag{3}$$

The size of the population in each period is 1, 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 $L_{mt} = L^S_{mt} + L^N_{mt}$, and $L_{ft} = L^S_{ft}$. Then:

$$L_{mt} + L_{ft} + L_{et} = 1. \tag{4}$$

The output of the manufacturing sector can either be consumed or invested to add to the capital stock. Denote 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:

$$c_{mt} + K_{t+1} = M_t + (1 - \delta)K_t, \tag{5}$$

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

$$c_{ft} = F_t \tag{6}$$

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. He can either 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 acquire 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 non-farm worker, 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. [21]

We assume that individuals are linked by intergeneration 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,

$$\sum_{t=0}^{\infty} \beta^t u(c^i_{ft}, c^i_{mt}), \tag{7}$$

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

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 inter-temporal discount factor. We also assume that skills are perfectly correlated across generations: the new-born member of generation i inherits the same type ζ^i as the previous member. As it 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 per-period utility function for individual i at time t is

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

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 1 (provided $\gamma > 0$). 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:

$$\sum_{t=0}^{\infty} q_t (c_{ft}^i + p_t c_{mt}^i) = H_0^i. \tag{8}$$

We assume that any financial contract entered into by previous members of a dynasty will be honored by all subsequent members of that dynasty.[22]

[22]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.

5 Competitive Equilibrium

Maximization of (7) subject to (8) implies that the following relations hold for every i and every t:

$$\begin{aligned} \frac{u_2(c^i_{ft}, c^i_{mt})}{u_1(c^i_{ft}, c^i_{mt})} &= p_t, \\ \beta \frac{u_1(c^i_{f,t+1}, c^i_{m,t+1})}{u_1(c^i_{ft}, c^i_{mt})} &= \frac{q_{t+1}}{q_t}. \end{aligned}$$

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}:

$$\frac{u_2(c_{ft}, c_{mt})}{u_1(c_{ft}, c_{mt})} = p_t, \tag{9}$$

$$\beta \frac{u_1(c_{f,t+1}, c_{m,t+1})}{u_1(c_{ft}, c_{mt})} = \frac{q_{t+1}}{q_t}. \tag{10}$$

Note, in particular, that a newborn into 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:

$$F_1(T_{ft}, L_{ft}, K_{ft}, A_{ft}) = a_t, \tag{11}$$

$$F_2(T_{ft}, L_{ft}, K_{ft}, A_{ft}) = w_{ft}, \tag{12}$$

$$F_3(T_{ft}, L_{ft}, K_{ft}, A_{ft}) = r_t, \tag{13}$$

and

$$M_1(T_{mt}, L_{mt}, K_{mt}, A_{mt}) = a_t/p_t, \tag{14}$$

$$M_2(T_{mt}, L_{mt}, K_{mt}, A_{mt}) = w_{mt}/p_t, \tag{15}$$

$$M_3(T_{mt}, L_{mt}, K_{mt}, A_{mt}) = r_t/p_t. \tag{16}$$

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 non-farm 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 $q_t \lambda^t$. Using (10), these equations can be rewritten recursively as:

$$u_1(c_{ft}, c_{mt})h_{mt} = u_1(c_{ft}, c_{mt})w_{mt} + \beta\lambda u_1(c_{f,t+1}, c_{m,t+1})h_{m,t+1}, \tag{17}$$

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

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 manufacture 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 $\zeta^i \leq \overline{\zeta}_t$ choose education and subsequent employment in manufacturing, while all those with $\zeta^i > \overline{\zeta}_t$ 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 non-farm sector. Denote the fraction of generation's 0 time devoted to employment in farming, employment in manufacturing, and training by l^0_{ft}, l^0_{mt}, and l^0_{et}, respectively. Recalling that $\mu(\zeta^i)$ is the frequency of ζ^i, we have:

$$l^0_{et} = \int_0^{\bar{\zeta}_t} \xi_t \zeta^i \mu(\zeta^i) d\zeta^i. \tag{19}$$

$$l^0_{mt} = \int_0^{\bar{\zeta}_t} (1 - \xi_t \zeta^i) \mu(\zeta^i) d\zeta^i. \tag{20}$$

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 $l^0_{ft}(1-\lambda)$ newborn farmers. The fraction of farmers in the total population at time t is then

$$L_{ft} = L_{f,t-1}\lambda + l^0_{ft}(1-\lambda). \tag{21}$$

Similarly,

$$\begin{aligned} L_{mt} &= (L_{m,t-1} + L_{e,t-1})\lambda + l^0_{mt}(1-\lambda), && (22) \\ L_{et} &= l^0_{et}(1-\lambda). && (23) \end{aligned}$$

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 left-hand-side is the return on one unit of capital.

Substitution of eqs. (9), (10), and (13) into the equation just derived leads to

$$u_2(c_{ft}, c_{mt}) = \beta u_2(c_{f,t+1}, c_{m,t+1})(M_3(T_{m,t+1}, L_{m,t+1}, K_{m,t+1}, A_{m,t+1}) + 1 - \delta) \qquad (24)$$

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 manufacture workers: $L_{f,t-1}$ and $L_{m,t-1} + L_{e,t-1}$. The 20 equations that determine these policy functions are 2, 3, 4 (resource constraints), 5 and 6 (market clearing in the two sectors), 9 (intra-temporal optimization in consumption), 11-16 (factor prices), 17 and 18 (recursive definitions of human capital), 19 and 20 (supply of trainees and newborns to the manufacturing sector), 21, 22, 23 (recursive equations for the supply of workers to farming, manufacturing, and education),and 24 (capital accumulation). In Appendix III we prove that there exists a stationary recursive equilibrium to this economy, and that this equilibrium is unique.

6 Estimation 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 non-farming 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 IV. 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. Hence, 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 US economy.[23] 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 total factor productivity growth parameters g_m and g_f. In particular, in the long run the quantities $g_f^{\frac{1}{\alpha_T+\alpha_L}}$ and $g_m^{\frac{1}{\beta_T+\beta_L}}$ must converge to the same value. To meet this requirement in our simulations we assume that g_m is constant, and that $g_f^{\frac{1}{\alpha_T+\alpha_L}}$ is constant in the periods corresponding to the years 1880-1980, and then falls linearly to the value $g_m^{\frac{1}{\beta_T+\beta_L}}$ from 1980 to 2190; after 2190 $g_f^{\frac{1}{\alpha_T+\alpha_L}}$ equals $g_m^{\frac{1}{\beta_T+\beta_L}}$. g_m and the initial constant value of g_f are calibrated based on growth-accounting work for the post-war period.

The parameters discussed so far were set *before* running 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. 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

[23] 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.

Table 3: Parameter Values

Both Models		
parameter	value	description
τ	.01	utility parameter
β	.60	discount factor
α_T	.19	land share in farm.
α_L	.60	labor share in farm.
β_T	.06	land share in manuf.
β_L	.60	labor share in manuf.
δ	.36	depreciation rate
λ	.75	prob. of living another period
$\hat{L}_f$ at $t = 0$	.50	initial farm labor force
g_m	.0840	non-farm tfp growth
g_{f0}	.1680	initial farm tfp growth
ω	.75	land share in South
Model with Constant Education Costs		
parameter	value	description
γ	.2205	utility parameter
$\hat{K}$ at $t = 0$	.0711	initial capital stock
ξ_0 and $\bar{\xi}$	2.0375	constant education cost parameter
Model with Declining Education Costs		
parameter	value	description
γ	.2201	utility parameter
$\hat{K}$ at $t = 0$	.0712	initial capital stock
ξ_0	1.8977	initial education cost parameter
$\bar{\xi}$	.1239	limit of education cost parameter

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).

In the version of the model with constant education costs, we estimate the education cost ξ so that the farm/non-farm wage ratio in the initial period of the model equals the farm/non-farm 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 $\bar{\xi}$. ξ_0 is chosen so that the farm/non-farm wage ratio in the initial period of the model equals the farm/non-farm wage ratio in 1880, and $\bar{\xi}$ is chosen so that the farm/non-farm wage ratio in period 10 in the model (which corresponds to 1980) equals the farm/non-farm wage ratio in 1980.[24]

Finally, to capture the notion that relatively few people require no education to work in the non-farm 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 1, 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 or training past age 10. Naturally this cost is prohibitive and thus high learning-cost individuals – and many others with lower cost – 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, that fall from 15 to 0.96, and from 14 to 0.95 years respectively. Of course the minimum learning cost is 0 throughout.

Table 4, designed to mirror Table 1, reports some key results. Both models capture

[24] 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 non-farm sector. Rather than modeling education as a multi-period investment, we simply think of these people as having to pay an additional cost to acquiring education.

qualitatively the basic story about *quantities*: the declines in the consumption share, c_f/c, and in the employment share, L_f, of farming. 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 looking at *prices*. First, the relative price of farm goods, $1/p$ declines dramatically in the model with constant costs while, 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 farm workers. To reiterate the basic intuition, the model with constant learning costs features declining demand for farm goods and farm workers 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 farm workers.

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 under-predicts the convergence of the South to the North. With the addition of declining learning costs, instead, regional convergence is predicted fairly accurately.[25]

[25]Here is how we computed relative regional labor incomes. Per-worker labor income in the North is w_m, as this region only produces 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. Economy-wide, 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

Table 4: Key Features of the Data and Model Simulations

variable	data	constant cost	declining cost
$(c_f/c)_{1880}$	.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

Note: * = models were fit to these values exactly; ** = model with declining education costs was fit to this value exactly.

Table 5: Additional Features of the Model Simulations

variable (annual growth rates)	const. cost	decl. cost
South-North population ratio	.0036	-.0034
farm capital-labor ratio	-.0069	.0243
farm land-labor ratio	-.0147	.0094
non-farm capital-labor ratio	.0113	.0099
non-farm land-labor ratio	.0038	-.0034

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),[26] which is consistent with historical trends. Conversely, in the model with constant 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 re-equilibrate manufacturing wages

wage income from manufacturing employment in the South is $(\omega - T_f)(L_m/T_m)w_m$. Putting it all together, the ratio of per-worker wage income in the South to that in the North is given by

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

[26] In view of the discussion in the previous footnote the population ratio is:

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

some Northern workers need to migrate South.[27] [28]

7 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 decline in the non-agricultural wage premium may signal a change in the composition of agricultural employment towards 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

[27]The behavior of the land- and capital-labor ratios also directly constitute an additional respect in which the model with declining learning costs dominates the one with constant costs. A rough calculation (based on *Historical Statistics* Series J51, Table 1080 in *Statistical Abstract,* and the agricultural labor force estimates in this paper) shows that farm land per worker increased from 63 to 490 acres per worker 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 non-farm 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.

[28]Kongsamut, Rebelo, and Xie (1998) 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 only varies from .20 to .27, the real interest rate (annualized) varies only from 6.5 to 8 percent, and labor income shares are constant (as labor's share is the same in both sectors). Also, per-capita output growth (annualized, in units of manufacture 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).

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 censi since 1940, although to save space we only report results for 1940 and 1990. The first column of Table 6 reports the results from these regressions when the only explanatory variable is a dummy taking the value of 1 if the worker is employed in agriculture and 0 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 non-agricultural wages grew from -66 to -31 as a percent of the US-wide average wage. In other words, agriculture experienced a 35 percentage-point gain between 1940 and 1990.

In the second column of Table 6 we re-estimate the relation between earnings and the agricultural dummy including controls for a variety of indicators of workers' characteristics and skills: sex, race, age (and age squared), and education. The idea is to isolate the effect of working in agriculture holding constant (observable) skills. The results show that changes in the skill composition of the agricultural labor force do not account for a large fraction of the upward trend in the average relative agricultural wage. Holding skills constant, the agricultural dummy grows from -54 to -27 percent, for an overall gain of 27 percentage points. Hence, changes in the skill composition of the agricultural labor force appear to account for

Table 6: Agriculture Dummy in Earnings Regressions

Year	No Controls	Individual Controls	Industry Controls
1940	-0.656	-0.536	-0.599
(s.e.)	(0.011)	(0.010)	(0.010)
1990	-0.312	-0.268	-0.334
(s.e.)	(0.015)	(0.013)	(0.013)

Note: Coefficients of a dummy variable indicating employment in agriculture. Dependent variable, labor earnings divided by sample mean. Individual Controls: age, age squared, one dummy variable indicating female sex, one dummy variable indicating non-white race, nine dummy variables indicating educational achievement. Industry Controls: individual controls plus nine dummies indicating employment in various industries (mining, utilities, trade, finance, business services, personal services, entertainment and recreation, professional services, public sector). Regressions estimated separately for each year by ordinary least squares. Data source: census microdata samples. See Appendix 1 for more details.

only (35 - 27 =) 8 of the 35 percentage-point gain experienced by agricultural workers. This finding is strongly suggestive that skill-biased technical change in agriculture cannot be the exclusive explanation for the facts we set out to explain in this paper.

Another potential alternative explanation is suggested by the increasing importance of the service sector. Specifically, one could imagine a situation in which employment in agriculture and services is subject to identical skill requirements, relative to manufacturing. One could further assume that the income elasticity of services is greater than one, potentially leading to increasing demand for service workers. This might generate over time a continuous flow of low skill workers from agriculture into services. This flow would be accompanied by an increase in the agriculture/non-agriculture relative wage, as the composition of the non-agricultural sector becomes more skewed towards service, low-skill jobs. This wage convergence would take place even if the cost of acquiring non-agricultural skills was constant over time. We address this alternative explanation with the regressions in the last column of table 6. These regressions include the same controls as those in the second column, 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 we just outlined would lead us to expect such 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 the previous two columns.

8 Conclusions

The joint behavior of relative agricultural wages and relative agricultural employment suggest that the relative cost of acquiring non-farming skills has declined over the last century. This paper has constructed on this observation an explanation for several features of US economic growth, including the structural transformation out of agriculture and the interregional convergence of per-capita incomes.

In our exposition we have tightly linked our argument to the historical experience of the U.S., but the methods and ideas developed in this paper have a natural applicability to the current cross-country distribution of per capita incomes. If one plots the farm share of employment against per capita incomes for a cross-section of countries today, one sees even more pronounced a negative relationship than we found for the US states in 1880.

The interpretation of these cross-country correlations suggested by our work is that in some countries human-capital acquisition is so costly that only a small fraction of the population can migrate from the low-productivity, low-skill sector to the high- productivity, high-skill sector. Their poverty is therefore a consequence of impediments to the accumulation of skills. One piece of evidence that supports this interpretation is provided by Parente, Gollin and Rogerson (1998), who show that countries that have most of their workforce in agriculture also have the highest productivity differential between the non-agricultural and agricultural sectors. Parente, Gollin and Rogerson view this as a puzzle: why do countries specialize in agriculture if their comparative advantage is in producing non-agricultural goods? But in the context of our paper this is not a paradox, since in our framework the farm-nonfarm productivity differential is precisely a measure of the cost of acquiring non-farming skills.

We have also tightly linked our argument to issues related to the production of agricultural goods versus non-agricultural goods. However, skill requirements also vary among more disaggregated industry definitions. Changes in the relative costs of skill acquisition among industries within a broad sector may have implications for the dynamics of growth analogous to those explored here. Similarly, we have limited our focus on the choice of industry by workers. However, an equally important issue is one of choice of technology within an industry. In particular, if more productive technologies require greater investments in skills, the cost of acquiring skills becomes a crucial ingredient in an explanation of growth in per-capita income across countries, even holding constant industry structure (see Caselli, 1999, for a model with some of these features). Pursuing these insights may help clarifying the mechanism through which human-capital accumulation affects economic growth.

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Appendix I: 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 public-use micro-data samples of the US 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.[29] 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, 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.

i. Wages. To compute average agricultural and non-agricultural 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.

ii. 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.

iii. Table 1. The US-wide numbers for the relative agricultural wage in Table 1 are obtained by constructing the US wide agricultural and non- agricultural labor income per worker as the

[29]Except for 1950, where 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.

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 non-agricultural wages.

iv. 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 non-white 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, 1-3 years of college, 4+ years of college).

Appendix II. Convergence Decompositions: South, Mid-West and West (Detailed Results).

For $i = S, N$ we have:

$$w_t^i = w_{ft}^i L_{ft}^i + w_{mt}^i L_{mt}^i, \tag{25}$$

where w_{ft}^i is the per-worker labor income in agriculture in region i and year t, w_{mt}^i is the per-worker income outside of agriculture, L_{ft}^i is the share of the labor force that is employed in agriculture, and $L_{mt}^i = 1 - L_{ft}^i$. Now define $w_{ft}(w_{mt})$ as the aggregate agricultural (non-agricultural) income per worker of South and North together. By adding and subtracting the quantity $w_{ft}L_{ft}^i + w_{mt}L_{mt}^i$ we can rewrite w_t^i as:

$$w_t^i = (w_{ft}^i - w_{ft})L_{ft}^i + (w_{mt}^i - w_{mt})L_{mt}^i + w_{ft}L_{ft}^i + w_{mt}L_{mt}^i. \tag{26}$$

Using equation (26) we can express the South-North income differential as:

$$\begin{aligned} \frac{w_t^S - w_t^N}{w_t} &= \frac{(w_{ft}^S - w_{ft})}{w_t} L_{ft}^S + \frac{(w_{mt}^S - w_{mt})}{w_t}(1 - L_{ft}^S) \\ &- \frac{(w_{ft}^N - w_{ft})}{w_t} L_{ft}^N - \frac{(w_{mt}^N - w_{mt})}{w_t}(1 - L_{ft}^N) \\ &+ \frac{(w_{ft} - w_{mt})}{w_t}(L_{ft}^S - L_{ft}^N) \end{aligned} \tag{27}$$

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

$$\frac{w_t^S - w_t^N}{w_t} - \frac{w_{t-1}^S - w_{t-1}^N}{w_{t-1}} = \Delta\omega_{ft}^S \cdot \overline{L}_{ft}^S + \Delta\omega_{mt}^S \cdot (1 - \overline{L}_{ft}^S) - \Delta\omega_{ft}^N \cdot \overline{L}_{ft}^N - \Delta\omega_{mt}^N \cdot (1 - \overline{L}_{ft}^N)$$

$$+\overline{\omega}_t^S \cdot \Delta L_{ft}^S - \overline{\omega}_t^N \cdot \Delta L_{ft}^N$$
$$+\Delta\omega_t \cdot (\overline{L}_{ft}^S - \overline{L}_{ft}^N) \tag{28}$$

where $\Delta x_t = x_t - x_{t-1}$ and $\overline{x}_t = (x_t + x_{t-1})/2$. This decomposition can be interpreted as follows. The four terms on the first line represent the contribution to North-South convergence of North-South convergence of incomes within the agricultural and non-agricultural industries. The two terms on the second line capture the role of the faster Southern transfer of resources out of agriculture. The term in the third line captures the convergence of agricultural incomes to non-agricultural incomes. Hence, in Table 2 "Total" is the left hand side of (28). "Within Industry" is the quantity in the first line of (28). "Labor Reallocation" is the second line. "Between Industry" is the third line. In the remainder of this appendix we provide tables with the more detailed decomposition reflecting all 7 terms of (28) for South-North, as well as for Midwest-North and West-North convergence, and for the various sub-periods for which we have available data.

Appendix III: The Equivalence of Efficient and 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"

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

In maximizing this utility, the planner chooses sequences for c_{ft}, c_{mt}, K_t, K_{ft}, K_{mt}, T_{ft}, T_{mt}, l_{ft}^0, l_{mt}^0, l_{et}^0, L_{ft}, L_{mt}, L_{et}, and $\bar{\zeta}_t$. 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 over the 11 policy variables and is subject – with hats replacing time subscripts as appropriate – to (2)-(6), (19)-(23). 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 computing first-order and envelope conditions the solution is shown to satisfy (24),

$$u_1(c_f, c_m)F_1(T_f, L_f, K_f, A_f) = u_2(c_f, c_m)M_1(T_m, L_m, K_m, A_m), \tag{29}$$

and

$$u_1(c_f, c_m)F_3(T_f, L_f, K_f, A_f) = u_2(c_f, c_m)M_3(T_m, L_m, K_m, A_m). \tag{30}$$

Denote by φ_f the multiplier for eq. (21) and denote by φ_m the multiplier for eq. (22); both multipliers are functions of the state vector $(A_f, A_m, K, \xi, \hat{L}_f, \hat{L}_m + \hat{L}_e)$. These functions must satisfy the two equations:

$$\varphi_f = u_1(c_f, c_m)F_2(T_f, L_f, K_f, A_f) + \beta\lambda\varphi_f', \tag{31}$$

$$\varphi_m = u_2(c_f, c_m)M_2(T_m, L_m, K_m, A_m) + \beta\lambda\varphi_m'. \tag{32}$$

Note that λ enters these equations because of its role in determining the evolution of farm and manufacture workers over time. Finally, using the Fundamental Theorem of Calculus, the solution must also satisfy the equation

$$\bar{\zeta} = \frac{1}{\xi}\frac{\varphi_m - \varphi_f}{u_2(c_f, c_m)M_2(T_m, L_m, K_m, A_m)}. \tag{33}$$

A necessary and sufficient condition for a solution to be a social optimum is if 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 (2)-(6), (19)-(24), (??)-(33).

It is straightforward to show that the allocations in a competitive equilibrium coincide with the efficient allocations as defined above. Combine eqs. (9), (11), and (14) to show that the allocations in a competitive equilibrium must satisfy eq. (29) and combine eqs. (9), (13), and (16) to show that the allocations in a competitive equilibrium must satisfy eq. (30). Also, note that the solution φ_f to eq. (31) equals the solution $u_1 h_f$ to eq. (18), and the solution φ_m to eq. (32) equals the solution $u_1 h_m$ to eq. (17). These results show that eq. (33) 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 IV: 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 non-farm GDP less gross investment. In 1996, e.g., Farm GDP/(Farm GDP + Non-farm 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 $s_{t+1} = a_0 + a_1 * s_t$ 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: Economic Report of the President, Tables B1 and 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 billions, and the average size of farm GDP was 5.8 billion (both figures expressed in 1929 dollars). The ratio of gross fixed non-residential 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 + Non-farm 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, as the latter refer to the farm share in gross GDP. Data: Historical Statistics of the United States, Series F125 and 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 non-farm 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 Non-farm 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 nyse 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: Economic Report of the President, and Center for Research in Security Prices.

α: α_T, α_L, β_T, β_L are chosen as follows. Jorgensen and Gollop report data on the relative rental costs in production, for both the farm and non-farm 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. BLS report the rental cost of land as a fraction of the rental cost of all types of capital plus land for the farm and non-farm sectors. For the farm sector, the rental cost of land as a fraction of the total rental cost of capital is .4754. For the non-farm sector, this fraction is .1444. We use these numbers to estimate .19 = .4754*.4 as land's share in the farm sector, and .06 = .1444*.4 as land's share in the non-farm sector. Data: Jorgenson and Gollop, inferred from Tables 9.2 and 9.4, and BLS, Tables NFB5a and F5a.

δ: Christensen and Jorgenson, 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 (depr. = .200, weight = .21), Nonresidential Structures (depr. = .056, weight = .22), Producer Durables (depr. = .138, weight = .20), and Residential Structures (depr. = .039, weight = .37). The weighted average depreciation rate is .0964. This implies a value of $\delta = .36$/decade. Data: Christensen and Jorgenson, Tables 5.11 and 5.12.

g_m: According to Jorgenson and Gollop, the average total factor productivity (tfp) growth rate in the non-farm sector from 1947-85 was .0081/year (this value is not adjusted for the changing quality of inputs; adjusted for quality this estimate is .0044). As reported in the Historical Statistics of the U.S., the average tfp growth rate in the non-farm 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 (due to 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/decade ($g_m = .0840$). Data: Jorgenson and Gollop, Tables 9.2 and 9.4, and Historical Statistics of the U.S., Series W8.

g_{f0}: As estimated by Jorgenson and Gollop, the average tfp growth rate in the farm sector from 1947-85 was .0206/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/year). As reported in the Historical Statistics of the U.S., the average tfp growth in the farm sector from 1929 to 1948 was .0144/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/year, which implies a value of .1345/decade. As noted by Jorgenson and Gollop, their procedure for computing farm tfp generates a substantial growth in tfp from 1947-85 (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 fn. 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/decade, which is simply twice the value of our estimate of non-farm tfp growth (In Jorgenson and Gollop's estimates for the 1947-85 time period, farm tfp growth is 2.54 times the non-farm tfp growth rate). Data: Gollop and Jorgenson, Tables 9.2 and 9.4, and the Historical Statistics of the U.S., Series W7.

ξ_0: Set to match the farm/non-farm wage ratio in 1880, which is .20. Data: Table 1.

$\bar{\xi}$: Set to match the farm/non-farm wage ration 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 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 4 decades. This implies a value of $\lambda = .75$. Historical Statistics of the United States, Series B126 and B107; Statistical Abstract of the United States (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 farm workers in 1880, which is .50. Data: Table 1.

ω: The value of ω is chosen to match the ratio of per-worker labor income 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.

Table A.1: Decomposition of Convergence in South-North Incomes per Worker.

Period	Total	a1	a2	a3	a4	b1	b2	c
1880-1950	0.440	0.037	0.070	0.021	-0.044	0.280	-0.124	0.201
% of total	100	8.4	15.8	4.9	-10.1	63.6	-28.2	45.6
1880-1900	0.059	0.029	0.006	0.008	-0.015	0.072	-0.072	0.032
% of total	100	49.2	10.2	13.6	-25.4	122.0	-122.0	54.2
1900-1920	0.252	-0.009	0.048	-0.02	0.019	0.098	-0.037	0.153
% of total	100	-3.6	19.0	-7.9	7.5	38.9	-14.7	60.7
1920-1950	0.129	0.019	0.001	0.016	-0.051	0.104	-0.015	0.055
% of total	100	14.7	0.8	12.4	-39.5	80.6	-11.6	42.6
1940-1990	0.312	0.002	0.102	0.005	0.023	0.130	-0.020	0.070
% of total	100	0.6	32.7	1.7	7.4	41.7	-6.4	22.4
1940-1950	0.216	0.000	0.068	0.001	0.047	0.084	-0.011	0.027
% of total	100	0.0	31.4	0.5	21.7	38.8	-5.1	12.5
1950-1960	0.033	-0.003	-0.003	-0.001	-0.016	0.053	-0.006	0.009
% of total	100	-9.0	-9.0	-3.0	-47.8	158.5	-17.9	26.9
1960-1970	0.051	0.000	0.019	0.001	0.004	0.021	-0.002	0.008
% of total	100	0.0	37.4	2.0	7.9	41.4	-3.9	15.8
1970-1980	0.111	0.002	0.054	0.002	0.047	0.005	-0.001	0.002
% of total	100	1.8	48.8	1.8	42.5	4.5	-0.9	1.8
1980-1990	-0.099	-0.001	-0.039	-0.001	-0.060	0.001	0.000	0.000
% of total	100	1.0	39.4	1.0	60.6	-1.0	0.0	0.0

Note: Terms of Equation (28) for sub-periods indicated in first column. The terms a1-a4 correspond to the terms in the first line of (28). The terms b1 and b2 correspond to the terms in the second line. The term c is the term in the third line. Authors' calculations. Data sources: (1880-1950, service income per worker) Lee et al. (1957); (1940-1990, labor income per worker) Ruggles and Sobek (1997).

Table A.2: Decomposition of Convergence in Midwest-North Incomes per Worker

Period	Total	a1	a2	a3	a4	b1	b2	c
1880-1950	0.176	0.017	-0.031	0.023	-0.024	0.196	-0.100	0.095
% of total	100	9.7	-17.6	13.1	-13.7	111.6	-56.9	54.1
1880-1900	0.079	0.015	-0.013	0.016	-0.009	0.096	-0.056	0.030
% of total	100	19.0	-16.5	20.3	-11.4	121.5	-70.9	38.0
1900-1920	0.010	-0.013	-0.033	-0.014	-0.034	0.066	-0.03	0.066
% of total	100	-130.0	-330.0	-140.0	-340.0	660.0	-300.0	660.0
1920-1950	0.086	0.011	0.022	0.011	0.020	0.027	-0.012	0.007
% of total	100	12.8	25.6	12.8	23.3	31.4	-14.0	8.1
1940-1990	-0.006	0.001	-0.048	0.002	-0.057	0.082	-0.018	0.032
% of total	100	-16.7	800.0	-33.3	950.0	-1366.7	300.0	-533.3
1940-1950	0.093	0.001	0.022	0.001	0.022	0.045	-0.01	0.012
% of total	100	1.1	23.7	1.1	23.7	48.4	-10.8	12.9
1950-1960	0.028	0.000	-0.002	0.000	-0.002	0.027	-0.005	0.009
% of total	100	0.0	-7.1	0.0	-7.1	96.4	-17.9	32.1
1960-1970	-0.013	0.001	-0.017	0.001	-0.018	0.016	-0.002	0.007
% of total	100	-7.7	130.8	-7.7	138.5	-123.1	15.4	-53.8
1970-1980	0.040	0.000	0.018	0.000	0.018	0.004	0.000	0.000
% of total	100	0.0	45.0	0.0	45.0	10.0	0.0	0.0
1980-1990	-0.154	-0.001	-0.077	0.000	-0.08	0.002	0.000	0.001
% of total	100	0.6	50.0	0.0	51.9	-1.3	0.0	-0.6

Note: Terms of Equation (28) for sub-periods indicated in first column. The terms a1-a4 correspond to the terms in the first line of (28). The terms b1 and b2 correspond to the terms in the second line. The term c is the term in the third line. Authors' calculations. Data sources: (1880-1950, service income per worker) Lee et al. (1957); (1940-1990, labor income per worker) Ruggles and Sobek (1997).

Table A.3: Decomposition of Convergence in West-North Incomes per Worker

Period	Total	a1	a2	a3	a4	b1	b2	c
1880-1950	-0.255	0.014	-0.266	0.031	-0.036	0.068	-0.093	0.028
% of total	100	-5.5	104.3	-12.2	14.1	-26.7	36.5	-11.0
1880-1900	-0.119	0.011	-0.080	0.007	-0.006	-0.005	-0.051	0.003
% of total	100	-9.2	67.2	-5.9	5.0	4.2	42.9	-2.5
1900-1920	-0.147	-0.014	-0.161	0.003	-0.030	0.020	-0.028	0.065
% of total	100	9.5	109.5	-2.0	20.4	-13.6	19.0	-44.2
1920-1950	0.011	0.014	0.002	0.009	0.000	-0.004	-0.012	0.002
% of total	100	127.3	18.2	81.8	0.0	-36.4	-109.1	18.2
1940-1990	-0.046	-0.003	-0.059	-0.001	-0.031	0.051	-0.017	0.013
% of total	100	6.5	128.3	2.2	67.4	-110.9	37.0	-28.3
1940-1950	0.045	0.003	0.005	0.001	0.007	0.030	-0.009	0.008
% of total	100	6.7	11.1	2.2	15.6	66.7	-20.0	17.8
1950-1960	-0.016	-0.005	-0.016	-0.002	-0.004	0.015	-0.005	0.001
% of total	100	31.3	100.0	12.5	25.0	-93.8	31.3	-6.3
1960-1970	-0.025	0.000	-0.022	0.000	-0.011	0.008	-0.002	0.002
% of total	100	0.0	88.0	0.0	44.0	-32.0	8.0	-8.0
1970-1980	0.037	0.001	0.019	0.001	0.014	0.001	0.000	0.001
% of total	100	2.7	51.4	2.7	37.8	2.7	0.0	2.7
1980-1990	-0.088	-0.001	-0.049	-0.001	-0.038	0.001	0.000	0.000
% of total	100	1.1	55.7	1.1	43.2	-1.1	0.0	0.0

Note: Terms of Equation (28) for sub-periods indicated in first column. The terms a1-a4 correspond to the terms in the first line of (28). The terms b1 and b2 correspond to the terms in the second line. The term c is the term in the third line. Authors' calculations. Data sources: (1880-1950, service income per worker) Lee et al. (1957); (1940-1990, labor income per worker) Ruggles and Sobek (1997).

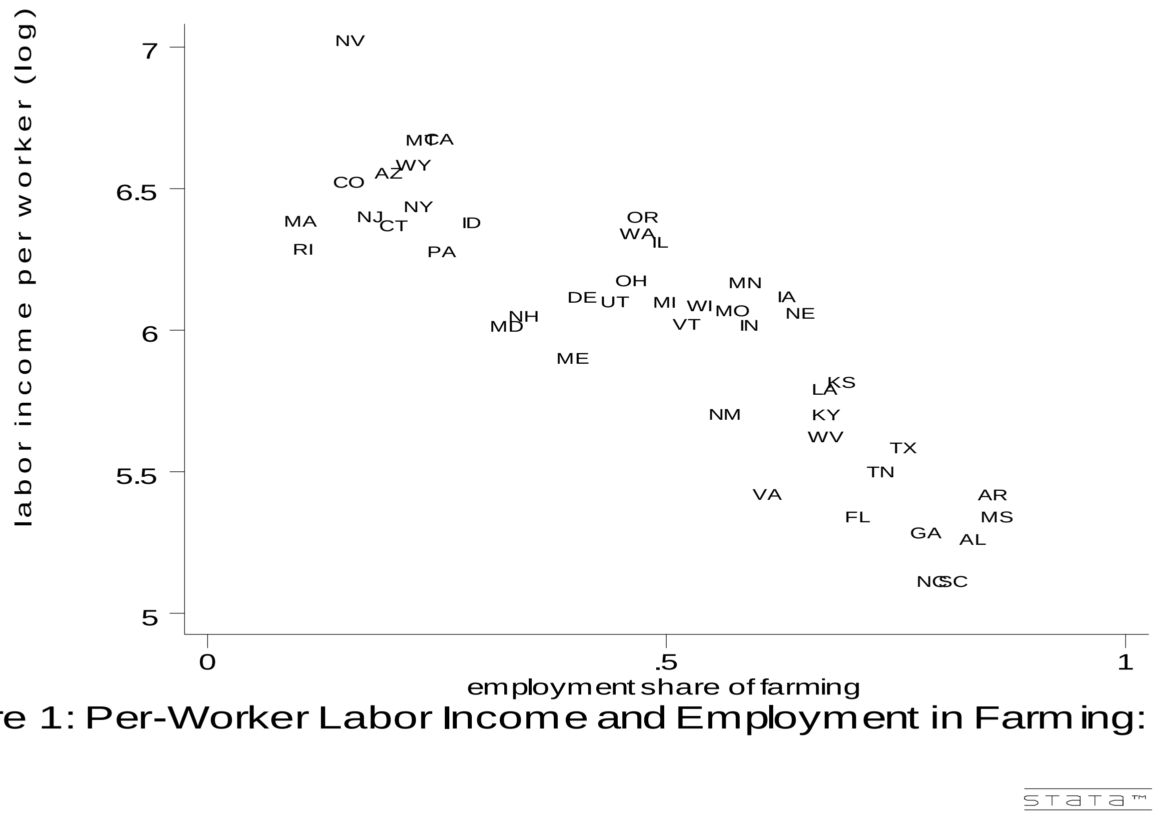

Figure 1: Per-Worker Labor Income and Employment in Farming: 1880

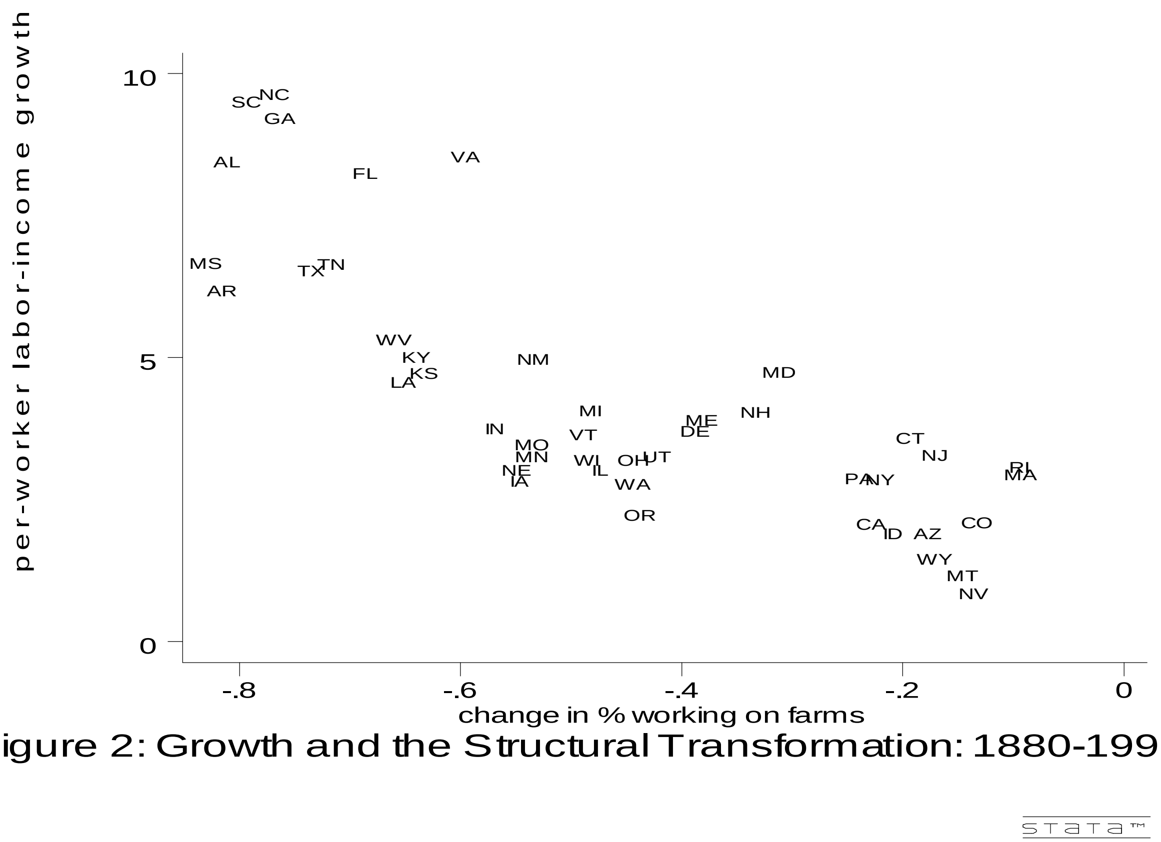

Figure 2: Growth and the Structural Transformation: 1880-1990

How Regions Converge: Solving the Model

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This note describes how we numerically solved the model in Caselli and Coleman (1998). As derived in Appendix III of that paper, the solution to the model consists of 16 policy functions 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, $\bar{\zeta}$, and for the multipliers φ_f and φ_m, that satisfy the following 16 equations:

$$
\begin{aligned}
c_f &= F(T_f, L_f, K_f, A_f), && (1)\\
c_m + K' &= M(T_m, L_m, K_m, A_m) + (1-\delta)K, && (2)\\
K &= K_f + K_m, && (3)\\
1 &= T_f + T_m, && (4)\\
1 &= l_e^0 + l_m^0 + l_f^0, && (5)\\
l_e^0 &= \int_0^{\bar{\zeta}} \xi \zeta^i \mu(\zeta^i) d\zeta^i, && (6)\\
l_m^0 &= \int_0^{\bar{\zeta}} (1 - \xi\zeta^i) \mu(\zeta^i) d\zeta^i, && (7)\\
L_f &= \hat{L}_f \lambda + l_f^0 (1-\lambda), && (8)\\
L_m &= (1 - \hat{L}_f)\lambda + l_m^0 (1-\lambda), && (9)\\
L_e &= l_e^0 (1-\lambda). && (10)\\
u_1(c_f, c_m) F_1(T_f, L_f, K_f, A_f) &= u_2(c_f, c_m) M_1(T_m, L_m, K_m, A_m), && (11)\\
u_1(c_f, c_m) F_3(T_f, L_f, K_f, A_f) &= u_2(c_f, c_m) M_3(T_m, L_m, K_m, A_m). && (12)\\
u_2(c_f, c_m) &= \beta u_2(c_f', c_m')(M_3(T_m', L_m', K_m', A_m') + 1 - \delta). && (13)\\
\varphi_f &= u_1(c_f, c_m) F_2(T_f, L_f, K_f, A_f) + \beta\lambda\varphi_f', && (14)\\
\varphi_m &= u_2(c_f, c_m) M_2(T_m, L_m, K_m, A_m) + \beta\lambda\varphi_m'. && (15)\\
\bar{\zeta} &= \frac{1}{\xi} \frac{\varphi_m - \varphi_f}{u_2(c_f, c_m) M_2(T_m, L_m, K_m, A_m)}. && (16)
\end{aligned}
$$

Each function depends on the state vector $(A_f, A_m, K, \xi, \hat{L}_f)$.

We wish to compute optimal choices over time for an economy that starts with a particular value of the state vector. To compute such an optimal time path, we first solved for approximate optimal policy functions that characterize choices at each time for arbitrary values of the endogenous state variables, but only for values of the exogenous state variables that would be observed. We then used these optimal policy functions to simulate an optimal time path for some given initial values of the state vector.

We assumed that A_f and A_m grew without bound over time at rates given by g_f and g_m, respectively. To solve for functions that are bounded, we used the following change of variables. First, define $\tilde{A}_f = A_f^{\frac{1}{1-\alpha_{fk}}}$, $\tilde{A}_m = A_m^{\frac{1}{1-\alpha_{mk}}}$, $\tilde{g}_f = g_f^{\frac{1}{1-\alpha_{fk}}}$, and $\tilde{g}_m = g_m^{\frac{1}{1-\alpha_{mk}}}$, then define

$$\tilde{c}_f = \frac{c_f}{\tilde{A}_f},\ \tilde{K}_f' = \frac{K_f'}{\tilde{A}_f},\ \tilde{c}_m = \frac{c_m}{\tilde{A}_m},\ \tilde{K}_m' = \frac{K_m'}{\tilde{A}_m},\ \tilde{K}' = \frac{K'}{\tilde{A}_m}.$$

Additionally, we also used the following change of variables:

$$1 - \tilde{\delta} = \frac{1-\delta}{\tilde{g}_m},\ \tilde{\gamma} = \frac{\gamma}{\tilde{A}_f},\ \theta = \frac{\tilde{A}_f}{\tilde{A}_m}.$$

With these transformations the total factor productivity levels A_f and A_m no longer entered the equations, but rather only the growth rates $\tilde{g}_m$ and $\tilde{g}_f$, and the transformed variables $\tilde{\gamma}$ and θ entered the equations (for the assumed functional form assumptions on preferences and production). We assumed that the growth rates were such that θ is finite and bounded away from zero ($\tilde{g}_f$ and $\tilde{g}_m$ converge to the same number after a finite amount of time). Policy functions in these transformed variables are thus bounded.

For the transformed variables the endogenous state variables are $\tilde{K}$ and $\hat{L}_f$, and the exogenous state variables are $\tilde{g}_f$, $\tilde{\gamma}$, θ, and ξ (we assumed $\tilde{g}_m$ is constant). For some $\bar{t} > 0$ the variables $\tilde{g}_f$, θ, and ξ become constant for $t \geq \bar{t}$. The value of $\tilde{\gamma}$, however, converges to zero, but never attains zero in finite time.

Our first approximation begins with an assumption on the evolution of $\tilde{\gamma}$. We assumed that $\tilde{\gamma}$ falls at the rate $\tilde{g}_f$ for $0 \leq t \leq t^*$ for some value of $t^* \geq \bar{t}$, but that $\tilde{\gamma} = 0$ for $t > t^*$. In practice we chose t^* such that $\tilde{\gamma}$ at t^* was very close to zero. This assumption amounted to assuming that policy functions for this economy for $t > t^*$ are close to the policy functions in the limit when t is arbitrarily large.

To compute an equilibrium, we first computed the equilibrium policy functions for any time $t > t^*$. Note that for $t > t^*$ all the exogenous state variables are constant, so we need only compute the policy functions for all possible values of the endogenous state variables $\tilde{K}$ and $\hat{L}_f$. Note first that using the static eqs. (1)-(12), all the policy functions for $\tilde{c}_f$, $\tilde{K}'$, $\tilde{K}_f$, $\tilde{K}_m$, T_f, T_m, ℓ_f^0, ℓ_m^0, ℓ_e^0, L_f, L_m, and L_e can be written as functions of only $\tilde{c}_m$, $\bar{\zeta}$, and the state variables (the ratio of eq. (11) to eq. (12) gives $\tilde{K}_f$ and $\tilde{K}_m$ as exact closed-form functions of $\tilde{K}$ and T_f).[1] We thus need only compute policy functions for $\tilde{c}_m$, $\bar{\zeta}$, φ_f, and φ_m. We started with initial guesses of these policy functions, say $\tilde{c}_m'$, $\bar{\zeta}'$, φ_f', and φ_m', and updated to policy functions $\tilde{c}_m$, $\bar{\zeta}$, φ_f, and φ_m using the time-iterative procedure for iterating on policy functions as descibed in Coleman (1990).

We then constructed the policy functions for each time period $0 \leq t \leq t^*$ as follows. We first constructed the policy function for $t = t^*$ for the values of the exogenous state variables for that period, and for every value (on the grid) of the two endogenous state variables. In computing this policy function, we used the fact that agents will find it optimal to use the (stationary) policy functions that we already computed for $t > t^*$. Given the policy function for $t = t^*$, we computed the policy function for $t = t^* - 1$, and so on. Note that successively computing these policy functions does not require any procedure that iterates on policy functions; given the optimal policy function for $t > t^*$, one simply backs out optimal policy functions for $t = t^*$, $t = t^* - 1$, and so on until $t = 0$.

In the following way we simulated an optimal time path for this economy. Starting

[1]Note that all variables except T_f could be computed as closed-form functions of c_m and $\bar{\zeta}$.

with values for the state variables, we computed optimal decisions using the policy functions for $t = 0$. This implies values for the state variables for $t = 1$. We then computed optimal decisions using the policy functions for $t = 1$, which implies values for the state variables for $t = 2$, and so on. For time periods $t > t^*$, we repeatedly use the policy functions for $t = t^* + 1$.

Note: For the most part this algorithm worked well. One drawback was that the algorithm computed a lot of information that was not needed to compute an optimal path. In some sense the algorithm computed an optimal path for each possible value of the initial endogenous state variables, but in the end we were only interested in one path associated with a particular value of the initial endogenous state variable. This was done for the convenience of computing the solution by starting at $t = t^* + 1$ and then working back in time. This caused no problems, with one exception. Sometimes it was difficult to compute the optimal decision close to $t = 0$ (for which $\tilde{\gamma}$ is high) and for low values of $\hat{L}_f$. Clearly this information would not be used along an optimal path (that starts with a high value of $\hat{L}_f$), hence this complication was in some sense unnecessary. Other algorithms, though, may have experienced related problems.

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How Regions Converge: Alternative Data Sources[1]

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[1]We thank Ellen McGrattan for bringing to our attention the alternative data sources, and four USDA and three BEA economists and statisticians for explanations of the sources and methods underlying these data.

Abstract

Caselli and Coleman (1998) use data from Easterlin (1957) and the microdata samples of the US census of population to document a large increase in annual earnings of agricultural workers relative to non-agricultural workers. This appendix discusses alternative data sources, and argues that the upward trends in the relative farm wage is indeed a robust finding.

The first two columns of Table 1 report the series for the US-wide relative agriculture/non-agriculture wage generated by the data used in Caselli and Coleman (1998). Recall that our sources are Easterlin (1957) for the 1880-1950 period, and the microdata files from the US Census for the 1940-1990 period (also recall from Section 2.2 that, as a means of correcting for the difference in income concepts, we have forced the two series to coincide in 1950). The methods underlying these series are detailed in Section 2.2 and in Appendix 1 of Caselli and Coleman (1998).

An alternative series for the US-wide relative agricultural wage can be constructed from *Historical Statistics,* which provide historical average annual earnings per full-time employee in agriculture (Series D739) and the other major industries (D Series 740, 741, 745, 746, 750, 753, 754, 755, and 761). The latter can be combined with the corresponding employment figures (D Series 128, 129, 130, 133, 134, 137, 138, 139) to create a weighted average non-agricultural annual wage. It is then possible to obtain a measure of the relative farm wage by dividing the agricultural wage in Series D739 by the non-agricultural wage. The resulting series is presented in Table 1, under the column heading "Hist. Stat." It is immediately apparent that the alternative series based on the *Historical Statistics* data differs markedly from ours. In particular, it features no (or very little) upward trend in the relative farm wage. The rest of this appendix investigates the causes of this discrepancy.

According to the accompanying notes in *Historical Statistics*, the wage data in series D739-D761 originate in Table A-16 in Lebergott (1964) for the period 1900-1929, and in National Income and Product Account publications for the post-1929 period. Accordingly, we discuss the discrepancy in Table 1 separately for the these two sub-periods.

Table 1: Different Series for the Relative Farm Wage

Year	Easterlin[1]	Census[2]	Hist. Stat.[3]	NIPA[4]
1880	0.20			
1900	0.21		0.35	
1910			0.34	
1920	0.32		0.37	
1930			0.26	0.31
1940		0.35	0.29	0.36
1950	0.39	0.39	0.41	0.49
1960		0.51	0.34	0.41
1970		0.64	0.40	0.54
1980		0.69		0.54
1990		0.68		0.60

Sources. (1): Computed by the authors from data in Easterlin (1957) as described in Section 2.2 of Caselli and Coleman (1998); (3): Computed by the authors using the micro data files from the population census, as described in Appendix 1 of Caselli and Coleman (1998); (3): Computed by the authors from data in *Historical Statistics,* as described in this appendix; (4) Computed by the authors from data in *National Income,* as described in this appendix.

Pre-1929: Lebergott vs. Easterlin

It is clear that for this sub-period the only relevant discrepancy between our data – from Easterlin (1957) – and those in *Historical Statistics* – from Lebergott (1964) – concerns the year 1900. It turns out that the 1900 Lebergott estimate of the agricultural wage is obtained by dividing total "Labor Expenditures" from the 1900 Census of Agriculture by the number of "Farm and Plantation Laborers" from the 1900 Census of Population.[1] The latter number is 2.047 millions. The problem with this estimate is that it greatly undercounts the number of hired laborers in farming, and thus overstates the farm wage in 1900. The reason is that, as discussed by Brainerd and Miller (1957), a very large number of farm laborers are included, in the same table from the Population Census, under the heading "Laborers (not specified)," whose total number is 2.588 millions. Hence, the correct number of farm laborers is the number used by Lebergott *plus* the fraction of the 2.588m unspecified laborers that is deemed to work in the agricultural sector. Brainerd and Miller's best estimate for this fraction is 40.3 percent, i.e. about 1 million. When we correct Lebergott's estimate of the farm wage using this figure, the relative farm wage falls to 0.23, which is remarkably close to the figure we independently computed from Easterlin's numbers. Miller and Brainerd also report attempts by previous authors to estimate the share of "not-specified" laborers who work in farming. The lowest published estimate of this share is 17 percent, and it implies a relative farm wage of 29 percent. In conclusion, after correcting the 1900 *Historical Statistics* figures for Lebergott's undercount of farm laborers the relative farm wage is *at most* 29 percent and, using the most recent estimate, 23 percent.

[1] Specifically, the first figure is in *Twelfth Census,* Volume 5, Agriculture, Part I, Table 12, p. 145; the second figure is in *Twelfth Census,* Volume 2, Population, Part II, Table 91, p. 505.

Post-1929: Census vs. NIPA

For dates after 1929 the sources for the *Historical Statistics* data are National Income and Product Accounts (NIPA) publications by the Bureau of Economic Analysis (BEA). It turns out that BEA has considerably revised its historical series for agricultural earnings since the publication of *Historical Statistics.* In the last column of table 1 we report the relative agricultural wage as it can be estimated from the most recent version of the National Accounts, which supersedes the version in *Historical Statistics.*[2] The revised NIPA numbers go some way towards reconciling the original *Historical Statistics* numbers with our estimates based on census data, and they do re-establish the impression of an upward trend in the relative agricultural wage. However, there is still a substantial discrepancy.

Recall that for the period 1940-1990 our figures are obtained from direct estimation of the agricultural and non-agricultural annual wage from the census microdata files, as documented in Appendix 1. A close comparison of the wage series reveals that, as for the pre-1929 period – the discrepancy is entirely due to the agricultural wage: our non-agricultural wage estimate differs from the one desumed from *National Accounts* by only 2 percent in 1960, 4 percent in 1980, 1 percent in 1990, and less than 1 percent in the other years. Instead, our farm wage series is 14 percent below the corresponding series from *National Accounts* in 1950, and more than 20 percent above in each of the subsequent decadal observations.

Agricultural wages are obtained in the NIPA with procedures that are quite different from

[2]Specifically, for each year we divide the Agriculture, forestry and fishery wage and salary figure from Table 6.6 of *National Income* by a weighted average of the figures for Mining, Construction, Manufacturing, Transportation and public utilities, Wholesale trade, Retail trade, Finance, insurance, and real estate, Services, and Government, where the weights are the corresponding full-time equivalent employment numbers in Table 6.5.

those underlying the data for almost all other industries. Wages and salaries for non-agricultural industries are normally computed using payroll information submitted by employers to State Unemployment Insurance Agencies. This insures that there is extremely wide coverage, as well as consistency of definition and sources across non-agricultural industries.

In this respect, it is very reassuring that our non-agricultural wage and the one obtained from payroll records are so close. On the other hand, the agricultural sector is not as well covered by Unemployment Insurance, so that the NIPA agricultural wage is constructed using a variety of alternative sources. We devote the rest of this appendix to a description of the sources and procedures for the NIPA agricultural wage but it is already clear that our census-based measures has the advantage over the NIPA measure of sharing the same source and the same methods underlying the non-agricultural wage.

We have devoted considerable time and effort to an attempt of establishing the origin of the discrepancy in the agricultural wage series between *National Accounts* and our own census-based estimates.[3] Written documentation for the agricultural wages in *National Accounts* is scarce and fragmentary. The following description is based mainly on verbal communications with several BEA and USDA officers. (For a description of our own census-based series we again refer the reader to Appendix 1 in the paper).

The NIPA measure of the agricultural wage – wage and salary per full-time equivalent employee in Agriculture, forestry and fishery - is an employment-weighted average of the earnings of two groups of workers: (i) employees of Farms, and (ii) employees in the Agricultural services, Forestry and Fishing industries.

[3] One difference is that the former is actually for "Agriculture, forestry, and fisheries," while ours is only for agriculture. Clearly, however, this cannot be the source of the large discrepancy.

(i) Employees of farms. The source of these data is the United States Department of Agriculture (USDA). USDA annualy surveys a sample of farming establishments and collects data on a variety of farm expenditures, including various forms of compensation paid to employees.[4] Sample weights are then used to construct an estimate of the US-wide bill for each form of compensation. This information is then conveyed to BEA, where a national farm wage bill is computed that essentially includes all cash wages and in-kind payments made to employees. In certain years BEA also made some further adjustments for underreporting associated with tax evasion, and an estimate of the voluntary 401(k) contributions paid by workers, but these adjustments are always minuscule. The resulting total wage and salary bill - Wage and Salary Accruals by Industry – appears in *National Income* in Table 6.3. USDA also provides an estimate of the number of full-time and part-time employees of Farms, which is computed from a separate survey of farm establishments.[5] BEA combines these data with information on hours worked by part-time workers to convert these numbers into estimates of full-time equivalent employees, which appears in Table 6.5 of *National Accounts*. Wage and Salaries for full-time equivalent employees of farms are obtained by dividing the wage and salary bill by the number of full-time equivalent employees.

(ii) Agricultural services, forestry, and fishing wages are computed by BEA using a variety of sources. For forestry and fishing the methodology is the same as for the typical non-agricultural industry. Namely, total wage and salary bill and employment numbers come from payroll data filed by employers with the authorities overseeing State Unemployment Insurance programs. This is also true for some, but not all categories of workers in

[4] The survey has changed name several times. Currently it is known as the Agricultural Resource Management Survey. Previous incarnations include the Farm Costs and Returns survey, and the Farm Production and Expenditure survey.

[5] The Agricultural Labor Survey?

agricultural services. For those categories of agricultural-service workers for which there is insufficient coverage in Unemployment-Insurance records BEA resorts once again to special estimates and calculation by USDA.

One important caveat is that this reconstruction of the agricultural wage numbers applies to the most recent years. We have found that the "institutional memory" on how these data were constructed as recently as the 1970s is fragmentary at best, so we are less than certain that the same methods and criteria applied in the past.[6] That qualification aside, however, our reconstruction does not reveal any basic conceptual difference between our definition of the agricultural wage and the one implied by the (recent) NIPA methodology. This suggests that ultimately an evaluation of the relative merit of the two measures must rest on a judgement of the quality of the underlying data. In this respect, it seems to us that there is a basis to deem our census-based estimates more satisfactory. First, our estimates are based on worker-level information, which is intrinsically more appropriate for a study of labor earnings, while the NIPA figures are based on establishment-level surveys. Second, our source being the census of population, there is no possible question as to whether the sample is representative. Instead, USDA surveys appear not to have been based on probability sampling until 1974, and at any rate they have a limited coverage. Third, because workers in the census report exactly the figure we are interested in estimating, we did not need to resort to the battery of judgmental modifications, additions and subtractions, that have been imposed in the NIPA. Lastly, our census data have the advantage of deriving from a unique source, while the NIPA figures require to combine several separate data sources.

[6]The lack of an institutional memory, as well as the essential absence of written documentation, are probably attributable to the high degree of fragmentation in the data construction process, with responsibility for various stages of data handling divided between several different individuals at both USDA and BEA.

As a last remark it is also important to note that the above constructed *Historical Statistics* and *National Income*-based relative farm wage series appear to be in conflict with other information in *Historical Statistics*. For example, according to Series D697 compensation per man-hour in all industries grew 68 percent between 1950 and 1960, while according to series D698 compensation per man-hour in non-farm industries only increased 63 percent. Given the small weight of farm employment, this seems to indicate a large increase in relative farm wages (consistent with our data) and not a large decline as implied by the NIPA series in Table 1. This should cast further skepticism on the quality of the NIPA farm wages, or at the very least on the implausibly large agricultural wage estimate they imply for 1950.