

How Regions Converge¹

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Abstract

The process by which per capita income in the South converged to northern levels is intimately related to the structural transformation of the U.S. economy. We find that empirically most of the southern gains are attributable to 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. The 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 factor mobility, since in our empirical work we find this channel to be less important than the compositional effects the model emphasizes.

1 Introduction

Why was the dispersion in per-capita incomes among the U.S. States vastly greater in 1880 than in 1990? Why, over the same period, has the share of agricultural employment fallen from 50 percent to 3 percent, with a corresponding fall in the share of agricultural goods in GDP? In this paper we argue that these two questions are intimately related, and provide an answer for both.

The key fact of per capita income convergence among U.S. states has been well documented by Barro and Sala-i-Martin (1991, 1992). To establish the link between this process and the structural transformation out of agriculture we start by noticing that in 1880 the poor (southern) States produced primarily agricultural goods, and that agricultural wage rates were on average significantly below non-agricultural wage rates. Over the next century the share of agricultural employment in total employment fell dramatically and the agricultural wage rate rose substantially relative to the non-agricultural wage rate. Both the declining wage gap between agricultural and non-agricultural jobs, and the transfer of resources out of farms, benefited the South disproportionately since the South had more agricultural workers. We perform empirical decompositions showing that these two trends in the structural transformation of the U.S. economy account for the bulk of convergence of the states in the South and the Mid-West to those of the North-East.¹

Having made the connection between structural transformation and regional convergence we turn to a joint explanation. We construct a model in which all regions are equally efficient at producing non-agricultural goods, but atmospheric and soil conditions make some regions (the South) more efficient in producing agricultural goods. This leads to an optimum

¹In contrast, these trends do not explain much of the changes in the incomes of the western states (which were relatively unpopulated and richer than the rest of the country in 1880) relative to the North-East.

allocation of resources in which the production of agricultural goods is concentrated in the South. Workers must make an investment in the acquisition of skills before joining the labor force. The required investment is larger in the non-agricultural sector than in the agricultural sector. As a result, the agricultural wage rate is below the non-agricultural wage rate. Per-capita income in the South is then lower because the labor input for agricultural goods is mostly low-skilled workers. One appealing feature of this approach is that it rationalizes the *initial* regional distribution of human capital, production mix, and income at the beginning of the convergence process, instead of taking them as exogenously given.

The centerpiece of our model is the assumption that over time the relative cost of acquiring the skills to become employed in the non-agricultural sector has fallen. The reduction in education costs explains the rise in the agricultural wage rate relative to the non-agricultural wage rate, as more people choose to become non-agricultural workers. Moreover, the rise in the relative cost of producing agricultural goods due to a rise in the relative agricultural wage rate also helps explain the large drop in the production of agricultural goods relative to non-agricultural goods. We are able to calibrate this model so that it closely replicates the quantitative behavior of relative wages, output and employment shares of agriculture, the long-run behavior of the relative price of agricultural goods, and the convergence of Southern to Northern labor incomes.

The main rationale for our assumption of declining learning costs is provided by the joint behavior of the relative agricultural wage (which increased) and the employment share of agriculture (which declined). These trends recommend an explanation based on shifts in the relative supply curve of agricultural labor, rather than shifts in demand. More specifically, we argue that, with an unchanging distribution of the cost of joining the non-agricultural sector, an increase in the employment share of agriculture must almost necessarily be associated

with a decline, not an increase, in the relative agricultural wage. We also discuss some of the possible sources for the decline in the cost of acquiring non-agricultural skills, such as technological progress and scale economies in transportation, improved quality of education, increased life-expectancy, and school desegregation.

We contribute both to the vast literature on structural transformations and to the relatively newer but rapidly growing literature on regional convergence. It seems to us that the former has traditionally emphasized one “leg” of the transformation, namely the long-run decline in the size of the agricultural sector. The other leg, the convergence of agricultural wages to non-agricultural wages, has received comparatively little attention. Our contribution to this literature is to propose a mechanism that accounts for both features.² As for the regional convergence literature, our analysis is particularly close to the commentary in Kuznets, Miller and Easterlin (1960), who also connected regional convergence to the structural transition out of agriculture, and performed an empirical exercise which ours closely resembles (and updates). As already mentioned, the topic of regional convergence has recently been revived by Barro and Sala-i-Martin (1991, 1992), who have used regression techniques to measure the speed of convergence among U.S. states. 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

²We 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.

and theoretically – the sectoral composition of output and the labor force.³ Finally, our analysis shares with much of the recent literature on economic growth an emphasis on human capital accumulation. In our framework, education allows the workforce to move from the low-productivity (agricultural) to the high-productivity (non-agricultural) technology.

Section 2 of this paper presents the key empirical observations on the structural transformation and regional convergence of the U.S. economy from 1880 to 1990; here we establish the connection between the two processes. Section 3 presents the basic idea, discusses a highly simplified example that highlights many of the key features of our model, and surveys alternative explanations. Section 4 develops the model, and section 5 presents the calibration and simulation exercise. Section 6 examines the possible sources of the decline in the cost of education. Section 7 offers some concluding remarks. Appendix I discusses data sources. Appendix II contains empirical results omitted from the text. Appendix III has proofs of theoretical propositions. Appendix IV gives the details of how the model's parameters were selected. An Appendix describing how the model was solved and simulated is available on request.

2 Convergence Facts

2.1 Overall Trends

The first two rows of Table 1 review the well-known secular decline in the weight of farm goods in US output and employment. In 1880 the share of farm goods in US gross GDP was 27% and the share of agricultural employment of the US labor force was 50%. By 1980 the

³A wealth of insightful commentary on South-North convergence is also to be found in Wright (1986).

shares of farming in GDP and of agriculture in employment were, respectively, 2% and 3%.⁴ The third row shows our estimates of relative agricultural labor incomes. We must caution the reader that the pre-1940 numbers are extremely crude (see Section 2.2). However, even allowing for gross mismeasurement before 1940, the conclusion that agricultural workers experienced substantial gains relative to non-agricultural workers is inescapable: the ratio between the agricultural and the non-agricultural wage increased to 69% in 1980 from 35% in 1940, and it may have been as low as 21% in 1880.⁵ The fourth row of Table 1 shows the standard deviation of the logarithm of per-capita personal income of the US states. As also recently documented by Barro and Sala-i-Martin (1991, 1992) the United States experienced considerable convergence in state per-capita personal income during the period.

The last row of Table 1 documents the behavior of the wholesale price index for farm goods relative to the consumer price index from 1880 to 1980.⁶ Despite its highly erratic behavior, the relative price of farm goods does not display a clear trend either downward or

⁴In the national accounts the word "farming" refers to SIC industries 01 (Agricultural Production - Crops), and 02 (Agricultural Production - Livestock), while "agriculture" refers to industries 01, 02 and 07 (Agricultural Services). Our wage and employment data concern "agriculture," but - due to data-availability constraints - our GDP and price data refer to "farming."

⁵As we discuss below, our sources for wage data are Easterlin (1957) and the decennial censuses. 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.

⁶We divide by the CPI, instead of the economy-wide wholesale price index, because the former is continuously available for the whole period. However, using the latter for the periods in which it is available generates an identical pattern.

Table 1: The US Structural Transformation

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
Agricultural Relative Wage ²	0.20	0.21	0.32	0.35	0.51	0.69
US Income Dispersion ³	0.55	0.47	0.33	0.36	0.20	0.13
Farm Relative Price (1967=1) ⁴	1.20	1.23	1.54	0.99	1.10	1.01

Sources. (1): *Historical Statistics*, series F125, F127; *Economic Report*, Table B-10; (2): see Section 2.2 and Appendix I; (3): Easterlin (1957), Table Y-1, Barro and Sala-i-Martin (1991), Kuznets et al. (1960), p. 144. *Historical Statistics*, Series E135, and *Economic Report*, Table B-60; (4) *Historical Statistics*, Series E25 and E135, and *Economic Report*, Tables B-60 and B-67.

upward. This conclusion is confirmed when looking at a variety of possible other measures of the terms of trade of agricultural goods, including prices of specific commodities, such as cotton, tobacco, sugar and rice, in which the South is heavily specialized.

Figure 1 shows that state personal income per capita in 1880 was strongly negatively correlated with the fraction of the state population working in agriculture (the correlation coefficient is -0.90). This suggests that the economy-wide decline in the share of agricultural employment, and the concurrent increase in the relative agricultural wage, can potentially have contributed to the considerable convergence in state per-capita incomes documented in Table 1. As a first check on this hypothesis, Figure 2 plots state per-capita 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 -0.83).⁷

2.2 Accounting for Regional Convergence

In this section we quantify the importance of the structural transformation for regional convergence. In order to perform this exercise, it turns out to be useful to adopt as units of observation the four regions of the United States: South, Mid-West (a.k.a. North-Central), North-East (henceforth just North), and West.⁸ Figure 3, taken from Barro and Sala-i-Martin (1991), vividly illustrates the process of regional convergence. For example, average personal income in the South was about 36% of average personal income in the North-East in 1880. In 1990, Southern personal income was 76% of the Northern level. Also the Midwest went from having 69% to 83% of Northern income. The experience of the West, instead, is quite different: it lost ground and fell behind the North initially, and joined in the convergence process only after 1930.

We start by quantifying the importance on the structural transformation for convergence between the most and the least farm-intensive of the four regions: the South and the North. Specifically, we perform a decomposition of changes in the log-difference of labor income per worker between the North and the South.⁹ Our goal is to assess the magnitude of the separate contributions of: (i) the faster reallocation of workers out of agriculture in

⁷To see this imagine that the total state population is constant. Then the change in the agricultural-to-total population ratio is just the change in the agricultural population divided by the total population.

⁸States 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. Alaska, Hawaii, and the District of Columbia are excluded from all calculations.

⁹Labor income constitutes the bulk of personal income. Here we focus on this variable because it allows for a more clear-cut conceptual framework.

the South; (ii) the convergence of agricultural wages to non-agricultural wages; and (iii) the convergence of Southern wages to Northern wages.

Call w_t^S (w_t^N) the per-worker labor income in the South (North) in year t . Then:

$$w_t^i = w_{ft}^i l_{ft}^i + w_{mt}^i l_{mt}^i \quad (1)$$

for $i = S, N$, where w_{ft}^i is the per-worker labor income in agriculture in region i and year t (f for “farm”), w_{mt}^i is the per-worker income outside of agriculture (m for “manufacturing”), 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:

$$w_t^i = (w_{ft}^i - w_{ft}) l_{ft}^i + (w_{mt}^i - w_{mt}) l_{mt}^i + w_{ft} l_{ft}^i + w_{mt} l_{mt}^i \quad (2)$$

We can then express the South-North income differential as:

$$\begin{aligned} \frac{w_t^S - w_t^N}{w_t} &= \frac{(w_{ft}^S - w_{ft})}{w_t} l_{ft}^S + \frac{(w_{mt}^S - w_{mt})}{w_t} (1 - l_{ft}^S) \\ &\quad - \frac{(w_{ft}^N - w_{ft})}{w_t} l_{ft}^N - \frac{(w_{mt}^N - w_{mt})}{w_t} (1 - l_{ft}^N) \\ &\quad + \frac{(w_{ft} - w_{mt})}{w_t} (l_{ft}^S - l_{ft}^N) \end{aligned} \quad (3)$$

Where w_t is the North-South average labor income per worker. The first four terms capture the role of differences in Southern and Northern wages from the corresponding aggregate means in generating South-North inequality. The fifth term captures the role of differences between agricultural and non-agricultural wages, and in the share of agriculture in employment.

Our final objective is to decompose the quantity $\frac{w_t^S - w_t^N}{w_t} - \frac{w_{t-1}^S - w_{t-1}^N}{w_{t-1}}$. 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 $\omega_t = (w_{ft} - w_{mt})/w_t$.

To achieve our goal we write the last equation in first differences as:

$$\begin{aligned}
\frac{w_t^S - w_t^N}{w_t} - \frac{w_{t-1}^S - w_{t-1}^N}{w_{t-1}} &= \Delta\omega_{ft}^S \cdot \bar{l}_{ft}^S + \Delta\omega_{mt}^S \cdot (1 - \bar{l}_{ft}^S) - \Delta\omega_{ft}^N \cdot \bar{l}_{ft}^N - \Delta\omega_{mt}^N \cdot (1 - \bar{l}_{ft}^N) \\
&+ \bar{\omega}_t^S \cdot \Delta l_{ft}^S - \bar{\omega}_t^N \cdot \Delta l_{ft}^N \\
&+ \Delta\omega_t \cdot (\bar{l}_{ft}^S - \bar{l}_{ft}^N)
\end{aligned} \tag{4}$$

where $\Delta x_t = x_t - x_{t-1}$ and $\bar{x}_t = (x_t + x_{t-1})/2$. We interpret this decomposition 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.¹⁰

Execution of the above-described exercise 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 Easterlin (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 Easterlin 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

¹⁰Decompositions in a similar spirit are performed in Kuznets, Miller and Easterlin (1960).

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

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

Note: Terms of Equation (4) for sub-periods indicated in first column. The terms a1-a4 correspond to the terms in the first line of (4). 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 source: Easterlin (1957), Tables L-4, Y-3 and Y-4.

measure of the relative agricultural labor income is only 58% (US-wide) of the measure based on service income.¹¹ 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 Easterlin 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. Appendix I explains the procedures we followed to construct the 1940-1990 panel.

¹¹The US-wide relative-wage numbers 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.

Table 2 reports the results of the decomposition for the period 1880-1950, as well as for the three sub-periods for which data are available. The first row shows that the North-South service-income differential declined by 44 percentage points between 1880 and 1950. Of these, about 8 (19% of the total) are accounted for by South-North convergence of within-sector incomes, the sum of the terms in columns a1-a4. About 16 percentage points (35% of the total) are due to the faster transition out of agriculture (columns b1 and b2). Finally, nationwide convergence of agricultural to non-agricultural incomes generated a 20 percentage-point gain, or 46% of the total.

The analysis of sub-periods shows some variation over time in the relative importance of the three sources of convergence. The convergence of agricultural to non-agricultural incomes is the most important source of regional convergence between 1880 and 1900 (54%), and 1900 and 1920 (61%), while the faster structural transformation of the South is the dominant engine of convergence between 1920 and 1950 (69%). Within-industry convergence of Southern to Northern incomes plays an important role only between 1880 and 1900 (48%). However, this is a period of extremely slow convergence. In the subsequent, fast convergence periods the role of within-industry convergence is negligible (4% in 1900-1920) or even negative (-12% in 1920-1950).

Table 3 reports the results of the same exercise on census data from 1940 to 1990. Reading down the column for the Totals, we see that the South pulled off a 31 percentage-point reduction in the labor income gap with the North after 1940. Periods of especially rapid convergence were the 1940s and the 1970s. Most of the gains of the 1970s, however, were lost in the subsequent decade.¹² The relative contributions of within-industry wage

¹²Divergence in the 1980s is also a feature of the distribution of state per capita incomes. Note that the gain in the South in the 1940s according to Table 3 is more than the gain in the 1920-1950 period according to Table 2. This is primarily because the 1920s are a period of divergence in the South-North

Table 3: Decomposition of Convergence in South-North Labor Incomes per Worker: 1940-1990.

Period	Total	a1	a2	a3	a4	b1	b2	c
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 (4) for sub-periods indicated in first column. The terms a1-a4 correspond to the terms in the first line of (4). 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 source: Ruggles and Sobek (1997).

convergence (Columns a1-a4), and structural transformation (b1, b2, and c) appear much more evenly distributed in the post-1940 sample. For the period as a whole, convergence of Southern agricultural and non-agricultural wages to Northern levels accounts for 42.4% of the gain. Another 35.4% is due to faster movement out of agriculture in the South, and the remaining 22.4% is attributable to agricultural wage to non-agricultural wage convergence. Still, the role of the structural transformation remains well above 50%. When looking at the sub-periods, the most interesting aspect is that the proportion of convergence explained by the transformation declines over time. In particular, the structural transformation plays almost no role in the last spurt of convergence in the 1970s, and in the subsequent decade of divergence. The reason is obvious: by the 1970s the structural transformation was essentially completed.

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 (column c), and because Southern workers left agriculture at a higher speed (columns b1-b2). Explanations of the slow convergence of Southern to Northern per capita incomes have often emphasized frictions that prevent factor-price equalization among regions (Wright, 1986, Barro, Mankiw, and Sala-i-Martin, 1995). In this view slow convergence results from the gradual removal or overcoming of these frictions. We think of columns a1-a4 as capturing this effect. The data confirm that this effect does indeed play a role, and it becomes more

income differential, as can be seen from Figure 3.

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.

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 its larger share of agricultural employment, 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 an universal explanation for regional convergence. For example, between 1880 and 1950 Western service income per worker fell 26 percentage points relative to the North (see also Figure 3). 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.¹³

¹³We 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 no or almost no population, and economic activities dominated by mining. The period of declining relative Western income

3 Explaining the Convergence Facts

3.1 The Basic idea

One of the features of the data surveyed in the previous section is that the relative size of the agricultural labor force steadily declined, while at the same time the relative rewards of working in agriculture increased. If one views the industrial composition of the labor force as the result of optimal workers' choices this joint behavior of employment shares and relative wages poses something of a puzzle. To see this, think of a cohort of farm-born workers, each of whom faces a decision of whether to remain in agriculture or join the urban sector. Sectoral migration involves a cost, such as investment into the skills required by urban, non-agricultural employment.¹⁴ In general, workers are heterogeneous in these learning costs, so different workers face different trade-offs between the (wage) gains and (learning) costs of moving out of agriculture. This situation is depicted in Figure 4, where the horizontal axis measures learning costs, and the vertical axis measures their distribution among members of a cohort of workers. The observed non-agricultural/agricultural wage differential then measures this skill-acquisition cost for the individual who is just indifferent between remaining in or moving out of agriculture. All workers facing a higher cost are in agriculture and all workers facing a lower cost are in the non-agricultural sector.

What Figure 4 makes clear is that a fall in the non-agricultural wage premium should be accompanied by an increase, and not a decline, in the agricultural employment share. When the wage differential declines the "marginal worker" is one with a lower cost of skill

coincides with the "normalization" of the region, with increasing population density and raising reliance on agriculture.

¹⁴Alternative interpretations include utility costs from living in towns (e.g. because they are insalubrious), or acquisition of urban-survival skills.

acquisition. If the distribution of this cost is unchanging over time, this necessarily implies that the fraction of the labor force joining the non-agricultural sector has declined: there are fewer workers who have a learning cost smaller than the indifferent individual. But as we have seen, the opposite is true in the historical experience: the fraction joining the non-agricultural sector has increased dramatically, despite a narrowing of the wage differential.

We propose to solve this puzzle by postulating that the relative cost of acquiring non-agricultural skills has declined across subsequent cohorts of farm-born individuals. In terms of Figure 4, this amounts to a left-ward shift of the distribution of learning costs, with points closer to the origin acquiring a larger mass over time. It is clear that this is consistent with the decline in agricultural employment in the face of increasing agricultural wages. Indeed, the theoretical work in the sections to follow shows that increasing agricultural wages and declining agricultural employment both follow from a decline in non-agricultural skill-acquisition costs.

3.2 An Example

Our objective is to show that a model featuring declining costs of acquiring non-agricultural skills can replicate the key quantitative features of US economic growth since 1880. This exercise, which we perform in the next section, requires a fairly rich model of the economy. This section sets the stage for the quantitative work by analyzing qualitatively a much simpler example. This preliminary analysis gives insight and intuition on the economic forces driving the results of the numerical exercise.

Imagine a static, closed economy with: two locations, North (N) and South (S); two goods, farm (F) and manufacturing (M); and two factors of production, land (T) and labor

(L).¹⁵ The production technologies in the two regions are:

$$F^i = A_f^i (T_f^i)^\alpha (L_f^i)^{1-\alpha} \quad i = S, N$$

$$M^i = A_m^i (T_m^i)^\beta (L_m^i)^{1-\beta} \quad i = S, N$$

where superscripts identify regions, subscripts identify goods, and A_j^i is total factor productivity for good j in region i . 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 $F^N = L_f^N = T_f^N = 0$.

The economy occupies an area of size 1. Define $T_j = T_j^S + T_j^N$. Thus, $T_f + T_m = 1$. A Fraction ω of the land is in the South. The economy is also populated by a continuum of identical (for now) individuals. Workers who desire to be employed in the non-farm sector must spend a fraction ξ of their time learning the corresponding skills. On the other hand, all workers can enter the farming sector at no cost. The size of the population is also 1. Define $L_j = L_j^S + L_j^N$. Hence, $L_f + (1 + \xi)L_m = 1$.

We assume that the economy admits a representative consumer, whose preferences are summarized by the utility function $(c_f)^\tau (c_m)^{1-\tau}$, where c_f (c_m) measures consumption of good F (M).¹⁶ All markets are perfectly competitive, and there is free trade and free labor mobility between North and South. Our explanation for the trends in Table 1 is that over time the cost of acquiring non-farm skills has declined. Hence, the exercise now consists in

¹⁵For ease of exposition in the theoretical parts of the paper we drop the distinctions between “farming” and “agriculture,” and “manufacturing” and “non-agriculture.”

¹⁶This also implies that we don’t need to worry about who owns the land.

performing comparative statics with respect to a fall in ξ . This yields an increase in the farm wage relative to the non-farm wage, a decline in relative farm employment, regional convergence, and South-North migration.

The first result is immediate. Calling w_f (w_m) the farm (non-farm) wage (in units of the farm good), the assumption that all workers are identical implies that

$$w_f = (1 - \xi)w_m \quad (5)$$

Namely, in equilibrium workers must be indifferent between supplying their labor to the farm sector, and earn w_f , or spending a fraction ξ of their time training and the remaining $(1 - \xi)$ using their newly acquired skills in the manufacturing sector, a strategy that yields an income of $(1 - \xi)w_m$. Clearly, equilibrium requires that a fall in ξ be matched by an increase in w_f/w_m . Conversely, it is clear that a fall in training costs is a necessary condition for a decline in the non-farm wage premium.¹⁷

The second result is also easily obtained from other equilibrium conditions. Since the economy is closed equilibrium requires $c_f = F = A_f T_f^\alpha L_f^{1-\alpha}$, and $c_m = M^S + M^N = A_m T_m^\beta L_m^{1-\beta}$, where the last equality follows from the fact that production functions feature constant returns to scale. One can therefore take the first order conditions for the representative consumer's problem and write:

$$p = \frac{1 - \tau}{\tau} \frac{c_f}{c_m} = \frac{1 - \tau}{\tau} \frac{A_f T_f^\alpha L_f^{1-\alpha}}{A_m T_m^\beta L_m^{1-\beta}} \quad (6)$$

¹⁷We want to emphasize that this conclusion is in no way sensitive to the assumption that all workers are identical. For example, we could assume that the cost of learning is $\xi\zeta$, where ξ is identical across individuals and ζ is distributed in the population according to an arbitrary density function $\mu(\zeta)$, which is the case depicted in Figure 4. Indeed, this is what we do in the next section. This alternative model has exactly the same comparative static implications with respect to a fall in ξ as the simpler one we are analyzing.

where p is the price of manufactures in units of farm goods. Given our assumptions on market structure landowners receive the marginal product of land. To avoid arbitrage opportunities this requires that the marginal productivity of land (in units of the same good) is equalized in the two sectors. This condition can be written as:

$$p = \frac{\alpha A_f T_f^{\alpha-1} L_f^{1-\alpha}}{\beta A_m T_m^{\beta-1} L_m^{1-\beta}} \quad (7)$$

Combining the last two equations we get:

$$\frac{T_f}{T_m} = \frac{\alpha \tau}{\beta(1-\tau)} \quad (8)$$

Finally, labor also earns its marginal product. This means that equation (5) can be rewritten as:

$$(1-\xi) = \frac{(1-\alpha)A_f T_f^\alpha L_f^{-\alpha}}{p(1-\beta)A_m T_m^\beta L_m^{-\beta}} \quad (9)$$

Substituting (7) and (8) into (9) we get:

$$(1-\xi) = \frac{\tau(1-\alpha)}{(1-\tau)(1-\beta)} \frac{L_m}{L_f} \quad (10)$$

This shows that the employment share of manufacturing increases as the cost of acquiring skills decline.

To see how the example generates regional convergence notice that 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, recall that ω is the amount of land in the South, and $1-\omega$ is the amount of land in the North. Since the North only produces non-farm goods, the amount of land used for manufacturing in the South is $T_m - (1-\omega) = \omega - T_f$. Because manufacturing

wages must be equalized between North and South, the labor-land ratio is the same in both regions, and it is therefore equal to L_m/T_m . Hence, manufacturing employment in the South is $(\omega - T_f)L_m/T_m$ and wage income from manufacturing employment in the South is $(\omega - T_f)(L_m/T_m)w_m$. Putting it all together, the ratio of per-worker wage income in the South to that in the North is given by

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

Or:

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

Now notice from equations (5) and (9) that the quantity $\frac{L_f}{L_m} \frac{w_f}{w_m}$ is independent of ξ . On the other hand, the quantity $\frac{L_f}{L_m}$ falls as ξ falls. This generates the desired convergence result.

It is also worth pointing out that this simple example may be used to think about inter-regional migration. To study migration we compute the ratio of the Southern to the Northern population, and we interpret a decline in this ratio as indicating positive net migration from the South to the North, and viceversa.¹⁸ In view of the discussion above the population ratio is:

$$\frac{L_f T_m + (\omega - T_f) L_m}{(1 - \omega) L_m} \tag{11}$$

Since we have established that L_f/L_m falls as ξ falls, we have that the Southern to Northern population ratio declines during the converge process, i.e. there is migration from the South to the North. The intuition is that as Southern rural workers abandon the countryside, the labor-land ratio increases in the manufacturing sector. But this increase must take place both in the North and in the South, to prevent arbitrage opportunities. Given that the

¹⁸A more precise definition of migration would require us to take a stand on whether the learning cost ξ is paid by migrating non-farm workers before or after they locate in the new region.

North only produces manufactures, it can only experience an increasing labor-land ratio if it absorbs additional workers from the South. This is another important dimension in which the model matches the historical experience.

There are, however, three important qualitative features of the data that are at odds with our simple example. First, as shown in Table 1, the output share of farming has declined dramatically in the last century. Because this is a closed economy with Cobb-Douglas preferences, however, output shares cannot change over time (see equation 6). Second, historically there has been no clear trend in the relative price of farm goods. On the other hand, our example predicts a long-run increase in the relative price of farm goods. The easiest way to see this is to look again at equation (6): Since the amount of resources devoted to farming is falling, c_f is falling (again, the closed economy assumption) and c_m is increasing, which requires p to fall. Clearly these two deficiencies of our example are strictly connected. The third fact our analysis does not take into account is that, as we discuss below, there is some evidence that total factor productivity has grown at a faster speed in the farm sector than in the non-farm sector, at least in the post-World War II period. Here, on the other hand, we have implicitly assumed that technological progress is equally fast in the two sectors.

To solve these difficulties the model in the next section features a more general utility function, and calibrates the rates of total factor productivity growth in and out of agriculture on the available evidence. The utility function we adopt has the “Stone-Geary” form: $(c_f - \gamma)^\tau (c_m)^{1-\tau}$. One property of these preferences is that the share of farm goods in consumption (hence in output) declines with the level of income. That preferences exhibit this property has been confirmed by a wealth of both macro and micro evidence on Engel’s curves.¹⁹ Clearly this allows us to eliminate the first qualitative discrepancy between the facts and the

¹⁹A recent contribution in this vein is Bils and Klenow (1998).

model. Furthermore, with these modifications it is no longer necessary for the relative price of farm goods to exhibit a trend.

It is instructive to explore this issue further, to gain some more insight on the workings of the model. Combining (7) with (9) we get:

$$\frac{T_f/L_f}{T_m/L_m} = \frac{\alpha(1-\beta)}{\beta(1-\alpha)}(1-\xi) \quad (12)$$

This implies that, as ξ falls, the relative land-intensity of farming increases. The reason is that a fall in ξ represents an increase in net income for manufacturing workers. Since workers must be indifferent between employment in farming and in manufacturing, farm workers must be compensated with a relative increase in their land endowment. Approximately, the difference between the rates of growth of the land-labor ratios in the two sectors is equal to the rate of decline of the cost of acquiring skills.

Now imagine, for argument's sake, that the share of labor in output is approximately the same in both sectors.²⁰ Then we can substitute equation (12) in equation (7) to get:

$$p = \frac{\alpha A_f}{\beta A_m} (1-\xi)^{\alpha-1} \quad (13)$$

This equation shows that when labor shares in output are roughly the same across sectors the relative price of non-farm goods can remain roughly constant, in the face of a decline in

²⁰Using the first three rows of table 1 one could back out for each period an estimate of the ratio between 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 roughly similar labor share in the two sectors is only realistic for the later decades. We nonetheless make this assumption because it greatly simplifies the exposition, here, and the numerical work, in the next section. As we discuss below, roughly equal labor shares in and out of agriculture in recent decades have been independently estimated in the growth-accounting literature.

the cost of acquiring skills, if total factor productivity growth in farming is sufficiently fast relative to manufacturing. As we have seen, a decline in learning costs leads to an increase in the relative land-intensity of farming. This tends to depress the marginal productivity of farm land relative to land used in manufacturing. On the other hand, faster total factor productivity growth boosts the relative productivity of farming. The elimination of arbitrage opportunities requires that the value marginal productivity of land is always equalized among the two sectors: the price level adjusts to bring this about. In our numerical exercise we calibrate the rates of TFP growth using the literature on sectoral growth accounting, and we calibrate the rate of decline in the cost of acquiring skills on features of the income distribution at the end and at the beginning of the century. It turns out that these numbers generate a dynamic path for the economy on which the relative price of farm goods is roughly constant.²¹

3.3 Alternative Explanations

The literature on the structural transformation has typically emphasized the inferiority of agricultural goods and faster rates of total factor productivity growth in agriculture as key elements of an explanation of the structural transformation. The above discussion suggests that these features are important in order to fit some aspects of the historical experience, such as the declining share of farming in output and the absence of a long-run trend in relative prices. However, theories of the structural transformation that rely exclusively on the form of the utility function and on growth in agricultural productivity cannot explain

²¹Note that with identical TFP growth rates in both sectors it is inevitable for the relative price of manufacturing goods to decline as learning costs decline. Hence, Stone-Geary preferences are necessary but not sufficient to avoid a trend in farm prices.

the observed joint behavior of the relative agricultural wage and agricultural employment. This is why we have postulated a declining cost of acquiring non-agricultural skills.

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.²² 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 outside of agriculture. In fact, one could presumably write down a model in which skill biased technical change in agriculture increases the average agricultural wage (because the average agricultural worker becomes more skilled), and reduces the employment share of agriculture (because fewer agricultural workers are required in agriculture).

In order to assess the potential quantitative importance of the skill-biased technical change explanation we have used our census data to perform a battery of Mincer-like regressions of workers' earnings. In these regressions the unit of observation is a worker, and the dependent variable is a worker's earnings (relative to the sample average). A separate regression is estimated for each of the decennial censuses since 1940. The first column of Table 4 reports the results from these regressions when the only explanatory variable is a dummy variable 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

²²Actually the two hypotheses are not mutually exclusive, so this is best described as a complementary explanation.

Table 4: Agriculture Dummy in Earnings Regressions

Year	No Controls	With Controls
1940	-0.656	-0.536
(s.e.)	(0.011)	(0.010)
1950	-0.605	-0.551
(s.e.)	(0.010)	(0.009)
1960	-0.479	-0.422
(s.e.)	(0.014)	(0.012)
1970	-0.365	-0.325
(s.e.)	(0.015)	(0.013)
1980	-0.305	-0.275
(s.e.)	(0.015)	(0.013)
1990	-0.312	-0.268
(s.e.)	(0.015)	(0.013)

Note: Coefficients of a dummy variable indicating employment in agriculture. Dependent variable, labor earnings divided by sample mean. Controls: age, age squared, one dummy variable indicating female sex, one dummy variable indicating non-white race, nine dummy variables indicating educational achievement. Regressions estimated separately for each year by ordinary least squares. Data source: census microdata samples. See Appendix 1 for more details.

other words, agriculture experienced a 35 percentage-point gain between 1940 and 1990.

In the second column of Table 4 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 only $(35 - 27 =) 8$ of the 35 percentage-point gain experienced by agricultural workers.²³ 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.

Skill-biased technical change does seem to be very important in the 1940s, where the agricultural dummy actually increases in absolute value once skills are held constant. This is consistent with historical accounts of the 1940s as being characterized by the continuation of a strong drive, initiated in the 1930s, towards the mechanization of agriculture. Unfortunately, we do not have individual-level data to perform a similar assessment of the skill-biased technical change explanation for the pre-1940 period. The historical literature, however, does not convey the impression of diffusion of major technological breakthroughs in agriculture before the mechanization drive of the 1930s and 1940s. This suggests that the long-run role of skilled-bias technical change in raising the relative wage of agricultural workers may have been even smaller before than after 1940.

²³The only change when the dependent variable is in natural logarithms (instead of percentage of the national average) is that the agricultural dummy increases in absolute value in the 1940s, even when there are no controls.

4 The Model

This section develops the model that we use to explain the structural transformation and regional convergence. The model generalizes the example of the previous section by adding: dynamics, in the form of an overlapping-generation demographic structure; heterogeneity among individuals in the cost to be borne to join the manufacturing sector; and capital in the production functions for both goods. As we discussed, the model also features Stone-Geary preferences in order to accommodate the behavior of the output share of farming and the relative price of agricultural goods. After describing the model we define a competitive equilibrium. Proofs of existence and uniqueness of a competitive equilibrium are given in Appendix III.

4.1 The Technology

With the addition of capital (and time subscripts) the production functions become:

$$F(T_{ft}, L_{ft}, K_{ft}, A_{ft}) = A_{ft} T_{ft}^{\alpha_T} L_{ft}^{\alpha_L} K_{ft}^{1-\alpha_T-\alpha_L},$$

$$M(T_{mt}, L_{mt}, K_{mt}, A_{mt}) = A_{mt} T_{mt}^{\beta_T} L_{mt}^{\beta_L} K_{mt}^{1-\beta_T-\beta_L},$$

where K_{jt} denotes the capital input in sector j , and α_T , α_L , β_T and β_L are time-invariant parameters. Note that we continue to assume that total factor productivity in farming is sufficiently higher in the South that all farm production takes place in this region, and that the two regions enjoy the same level of total factor productivity in manufacturing, A_{mt} . The production function F exhibits constant returns to scale in land, labor, and capital. Total factor productivity grows in the two sectors at the exogenous factors g_{ft} and g_{mt} , respectively.

As before, total land endowment is fixed at unity, and in each period land can be

reallocated across sectors. Hence, the only constraint on land usage is

$$T_{ft} + T_{mt} = 1. \quad (14)$$

A fixed fraction ω of the total supply of land is in the South. Denote by K_t the total supply of capital at time t . Each period capital can be reallocated across sectors, so that

$$K_{ft} + K_{mt} = K_t. \quad (15)$$

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} . Then:

$$L_{mt} + L_{ft} + L_{et} = 1. \quad (16)$$

The output of the manufacturing sector can either be consumed or invested to add to the capital stock. Denote by δ the rate of depreciation of the capital stock. Then, the following equation constrains the evolution of the capital stock:

$$c_{mt} + K_{t+1} = M(T_{mt}, L_{mt}, K_{mt}, A_{mt}) + (1 - \delta)K_t. \quad (17)$$

On the other hand, farm goods can only be consumed:

$$c_{ft} = F(T_{ft}, L_{ft}, K_{ft}, A_{ft}) \quad (18)$$

Note that we are implicitly assuming that the economy is closed.

4.2 Population Dynamics

The demographic structure is similar to the one proposed by Blanchard (1985) and Matsuyama (1991). In each period t there is born a population of size $1 - \lambda$. For any person

alive at time t , the probability of dying in period $t + 1$ is the constant $1 - \lambda$. Hence, at time t the size of any generation j , where $j = 0$ is the current newborn generation, $j = 1$ is the generation born last period, and so on, is $(1 - \lambda)\lambda^j$. Note that this assures that the size of the total population is one in every period.

Each new-born 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 that ξ_t perhaps changes 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. These individuals, therefore, spend a fraction of their first period of life in school and/or training. The remainder of that period, as well as any other period in which they are alive, are spent working in the manufacturing sector.²⁴

The evolution of the distribution of workers into the three sectors has a particular

²⁴This assumption is not unduly restrictive: in our numerical work we assume that one period lasts ten years, and that life starts at age 10.

recursive structure. Denote the fraction of generation's 0 time devoted to employment in farming, employment in manufacturing, and training by l_{ft}^0 , l_{mt}^0 , and l_{et}^0 , respectively. Note that of the population at any point in time, λ were born in a previous period and $1 - \lambda$ were born in the current period. Hence, $L_{f,t-1}\lambda$ of the population in period t are old (not newborn) farmers and $l_{ft}^0(1 - \lambda)$ are newborn farmers. The fraction of the total population at time t that are farmers is then

$$L_{ft} = L_{f,t-1}\lambda + l_{ft}^0(1 - \lambda). \quad (19)$$

Similarly,

$$L_{mt} = (L_{m,t-1} + L_{e,t-1})\lambda + l_{mt}^0(1 - \lambda), \quad (20)$$

$$L_{et} = l_{et}^0(1 - \lambda). \quad (21)$$

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

4.3 Preferences

Individual i has preferences defined over her consumption of farm goods and manufacture goods. As discussed in the previous section the per-period utility function of a member i of generation j is

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

where $0 < \tau < 1$ and $\sigma \geq 0$. Lifetime utility is then given by (aside from some (finite) constant),

$$\sum_{s=t}^{\infty} (\beta\lambda)^{s-t} u(c_{fs}^{i,j+s-t}, c_{ms}^{i,j+s-t}). \quad (22)$$

Where β is the inter-temporal discount factor. Here, clearly consumption is contingent on states in which a person is alive. Recall that λ is each person's probability of survival from one period to the next.

4.4 Markets and Budget Constraints

We assume that people can trade in a complete set of contingent claims. For any person, denote by q_t the price at time 0 for delivery of one unit of the farm good in period t , contingent on that person being alive in period t . Since everybody faces the same constant probability of dying, everybody trades at the same state-contingent price q_t . Denote by y_t^{ij} the labor income of person i of generation j at time t ; labor income is conditional on that person being alive in time t . People are born with no assets. The present-value budget constraint, for any person of generation $j = 0$ and any time $t \geq 0$, can be written as

$$\sum_{s=t}^{\infty} \frac{q_s}{q_t} (c_{f,s}^{i,j+s-t} + p_s c_{m,s}^{i,j+s-t}) = \sum_{s=t}^{\infty} \frac{q_s}{q_t} y_s^{i,j+s-t}. \quad (23)$$

Note that the delivery of consumption goods is always conditional on the person being alive.²⁵ Coupled with the existence of a complete set of contingent securities, this implies that two members of generation j who have the same ζ^i will share identical consumption patterns in all periods in which they are both alive.

²⁵Equivalently, Blanchard (1985) assumes the existence of a competitive market in life-insurance contracts. Here, the contract would be such that a person promises to pay the insurer one unit of one of the goods upon his death, and in exchange the insurer promises to pay $(1 - \lambda)/\lambda$ units of goods in any period in which the person is alive.

4.5 Competitive Equilibrium

4.5.1 Preferences and the Price of Goods

Each person maximizes his utility, given by (22), subject to his budget constraint, given by (23). As a consequence of utility maximization, the following relations hold for every i , every j , and every t :

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

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

Given our assumptions on preferences, 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} :

$$\frac{u_2(c_{ft}, c_{mt})}{u_1(c_{ft}, c_{mt})} = p_t, \quad (24)$$

$$\beta\lambda \frac{u_1(c_{f,t+1}, c_{m,t+1})}{u_1(c_{ft}, c_{mt})} = \frac{q_{t+1}}{q_t}. \quad (25)$$

4.5.2 Production and the Price of Inputs

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

$$F_1(T_{ft}, L_{ft}, K_{ft}, A_{ft}) = a_t, \quad (26)$$

$$F_2(T_{ft}, L_{ft}, K_{ft}, A_{ft}) = w_{ft}, \quad (27)$$

$$F_3(T_{ft}, L_{ft}, K_{ft}, A_{ft}) = r_t, \quad (28)$$

and

$$M_1(T_{mt}, L_{mt}, K_{mt}, A_{mt}) = a_t/p_t, \quad (29)$$

$$M_2(T_{mt}, L_{mt}, K_{mt}, A_{mt}) = w_{mt}/p_t, \quad (30)$$

$$M_3(T_{mt}, L_{mt}, K_{mt}, A_{mt}) = r_t/p_t. \quad (31)$$

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.

4.5.3 Time and the Distribution of Skills

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

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

Note that, using (25), this can be rewritten recursively as:

$$u_1(c_{ft}, c_{mt})h_{mt} = u_1(c_{ft}, c_{mt})w_{mt} + \beta\lambda u_1(c_{f,t+1}, c_{m,t+1})h_{m,t+1} \quad (32)$$

$$u_1(c_{ft}, c_{mt})h_{ft} = u_1(c_{ft}, c_{mt})w_{ft} + \beta\lambda u_1(c_{f,t+1}, c_{m,t+1})h_{f,t+1}, \quad (33)$$

Recall that members of generation 0 are distributed according 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 value ζ^i such that

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

will invest in education. 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 new borns with $\zeta^i \leq \bar{\zeta}_t$ choose education and subsequent employment in manufacturing, while all those with $\zeta^i > \bar{\zeta}_t$ choose farming. Note that, for

given prices such as the wage rate and interest rate, a decline in the cost of schooling, ξ_t , leads to an increase in the share of the incoming generation who decide to acquire skills and join the non-farm sector. Recall that $\mu(\zeta^i)$ is the frequency of ζ^i , and that l_{et}^0 and l_{mt}^0 are, respectively, the fractions of generation 0's endowment of time in period t spent, respectively, learning and working in manufacturing. Thus, we have:

$$l_{et}^0 = \int_0^{\bar{\zeta}^i} \xi_t \zeta^i \mu(\zeta^i) d\zeta^i. \quad (34)$$

$$l_{mt}^0 = \int_0^{\bar{\zeta}^i} (1 - \xi_t \zeta^i) \mu(\zeta^i) d\zeta^i. \quad (35)$$

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

4.5.4 Ownership of Assets

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.

4.5.5 Capital Accumulation

Since this economy features a full set of contingent securities, it is important that the returns to holding capital (and land) are consistent with the prices of contingent claims to goods in various periods and states of the worlds. 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} . The gross one-period return to

capital purchased in period t , in units of the farm good, is thus

$$\frac{p_{t+1}}{p_t} \left(\frac{r_{t+1}}{p_{t+1}} + 1 - \delta \right).$$

Note that the one-period return to capital we have just computed is unconditional, i.e. it is independent of the event of death of the person acquiring the capital.

To find the corresponding unconditional return from a portfolio of contingent securities, recall that q_t is the price a person needs to pay at time 0 for a claim to a unit of farm goods delivered in period t , conditional on that person being alive at time t . Recall, also, that the event of dying is independent across people, and the probability that a person will be alive in time s , given that he is alive in period $t \leq s$, is λ^{s-t} . The price in time 0 for a unit of farm good delivered in period t , without any conditions, is then simply q_t/λ^t . Hence, the gross return from investing one unit of the farm good in this portfolio is: $\lambda q_t/q_{t+1}$. Removal of arbitrage then requires that

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

Substitution of eqs. (24), (25), and (28) into the equation just derived leads to

$$u_2(c_{ft}, c_{mt}) = \beta u_2(c_{f,t+1}, c_{m,t+1}) (M_3(T_{m,t+1}, L_{m,t+1}, K_{m,t+1}, A_{m,t+1}) + 1 - \delta) \quad (36)$$

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.

4.5.6 Equilibrium Conditions

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_{ft}^0 , l_{mt}^0 , l_{et}^0 , 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. The remaining state variables are then $L_{f,t-1}$ and $L_{m,t-1} + L_{e,t-1}$. A policy function is then a function of these state variables, so that c_{ft} , for example, is given by the function $c_f(A_{ft}, A_{mt}, \xi_t, K_t, L_{f,t-1}, L_{m,t-1} + L_{e,t-1})$

The 20 equations that determine these policy functions are 14, 15, 16 (resource constraints), 17 and 18 (market clearing in the two sectors), 19, 20, 21 (recursive equations for the supply of workers to farming, manufacturing, and education), 24 (intra-temporal optimization in consumption), 26-31 (factor prices), 32 and 33 (recursive definitions of human capital), 34 and 35 (supply of trainees and newborns to the manufacturing sector), and 36 (capital accumulation).

In the appendix we prove that there exists a stationary recursive equilibrium to this economy, and that this equilibrium is unique. The proof essentially shows the existence and uniqueness of an efficient allocation of resources, and then establishes an equivalence between an efficient allocation and the allocation of resources in a competitive equilibrium.

5 Estimation and Simulation of the Model

In this section 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. These are the standard ingredients of conventional explanations of the structural transformation. The models differ in the behavior of education costs. 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 calibrate both versions to match key features of the data, and then ask on which dimensions the model with declining education costs is better able to match the data.

5.1 Selection of Parameter Values

To simulate the model we need to specify how g_m , g_f , and ξ evolve over time, and we need to specify the distribution function μ . We assume that g_m is constant. In the data we find that g_f is roughly twice g_m , which is clearly an important fact for explaining convergence. However, in the long run the existence of a steady state for the model requires that $g_f^{\frac{1}{\alpha_T + \alpha_L}}$ and $g_m^{\frac{1}{\beta_T + \beta_L}}$ eventually converge to the same value. We thus assume that $g_f^{\frac{1}{\alpha_T + \alpha_L}}$ is constant for the simulations that correspond to the period from 1880 to 1990, and then falls linearly to the value $g_m^{\frac{1}{\beta_T + \beta_L}}$ from 1990 to 2190; after 2190 $g_f^{\frac{1}{\alpha_T + \alpha_L}}$ equals $g_m^{\frac{1}{\beta_T + \beta_L}}$. In the model with declining education costs, we assume that ξ begins at ξ_0 in 1880 and falls linearly to $\bar{\xi}$ in 1990; after 1990 ξ remains at the value $\bar{\xi}$. In the model with constant education costs, we assume that ξ is constant at ξ_0 . We assume that the distribution function μ is given by $\mu(\zeta) = 3\zeta^2$ for $0 \leq \zeta \leq 1$ (we chose a convex function to capture the notion that relatively few people require no education to work in the non-farm sector).

To simulate the model we thus need to specify values for the following parameters: τ , γ , β , α_T , α_L , β_T , β_L , δ , g_m , g_{f0} , ξ_0 , $\bar{\xi}$, λ , \hat{k} at $t = 0$, \hat{L}_f at $t = 0$, and ω . Most of the parameter values are directly calibrated to match certain features of the data, and are calibrated independent of the version of the model that is considered. The utility parameter τ equals the long-run value of the ratio of the consumption of farm goods to the consumption of all goods, which we estimate from the data. The discount factor β is set to match the average return to capital. The production parameters α_T , α_L , β_T , β_L are set to match the

fraction of costs of production of farm and non-farm goods due to land, labor, and capital.²⁶ The depreciation rate δ is set to match an estimate of the depreciation rate on capital. The total factor productivity growth rates g_m and g_{f0} are set to match estimates of total factor productivity growth rates for the non-farm and farm sectors. The probability λ of remaining alive for another period is set to match an estimate of the average lifetimes of people. The value of \hat{L}_f at $t = 0$ is set to match estimates of the fraction of the labor force in farming in 1880. In this way the parameters τ , β , α_T , α_L , β_T , β_L , δ , g_m , g_{f0} , λ , and \hat{L}_f at $t = 0$ were estimated directly from observations of the data; a more detailed description of how these parameter values were chosen is in the Appendix. Table 5 reports the values of these parameters.

The remaining parameters that need to be specified are γ , \hat{K} at $t = 0$, ξ_0 , $\bar{\xi}$, and ω . These parameters are chosen so that simulations of the model match various features of the data. The parameters are clearly estimated jointly, but in essence we will think of them as being chosen to match particular moments in the data. The utility parameter γ is chosen so that the consumption of farm goods relative to total consumption in 1880 equals that observed in the data. The initial capital stock \hat{K} at $t = 0$ is chosen so that the return to capital in 1880 in the model 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 calibrate education costs so that the farm/non-farm wage ratio in the initial period in the model equals the farm/non-farm wage ratio in 1880 in the data. In the version of the model with declining education costs, we calibrate the initial education cost so that the farm/non-farm wage ratio in the initial period in the model equals the

²⁶We reiterate the caveat from the previous section: our Cobb-Douglas technologies greatly simplify the model, but they prevent us from capturing the trend in the labor share in agriculture, relative to the rest of the economy, that seems to be suggested by Table 1.

Table 5: 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
g_m	.0840	non-farm tfp growth
g_{f0}	.1680	initial farm tfp growth
λ	.75	prob. of living another period
\hat{L}_f at $t = 0$	.50	initial farm labor force
ω	.69	land share in South
Model with Constant Education Costs		
parameter	value	description
γ	.2204	utility parameter
ξ_0 and $\bar{\xi}$	2.0375	constant education cost parameter
\hat{K} at $t = 0$	.0711	initial capital stock
Model with Declining Education Costs		
parameter	value	description
γ	.2201	utility parameter
ξ_0	1.9130	initial education cost parameter
$\bar{\xi}$	.1223	limit of education cost parameter
\hat{K} at $t = 0$	.0712	initial capital stock

farm/non-farm wage ratio in 1880, and we calibrate the decline in education costs so that the farm/non-farm wage ratio in period 11 in the model (which corresponds to 1990) equals the farm/non-farm wage ratio in 1990 in the data. The value of ω is set so that the ratio of South/North per-capita wage income equals that in the initial period of the model (the value of this parameter estimated for the model with declining education costs is also used for the model with constant education costs). The values of the parameters that require simulations are also reported in Table 5.²⁷

5.2 Quantitative Features of the Model

Table 6 reports key features of the data, simulations of the model with constant education costs, and simulations of the model with declining education costs.

In the data the relative price of farm goods does not show much of a trend from 1880 to 1990. The agricultural/non-agricultural wage ratio rises sharply from .20 in 1880 to .68 in 1990, and the agricultural/total labor force ratio falls from .50 in 1880 to .024 in 1990. Similarly, the ratio of consumption of farm goods to total consumption falls from .31 in 1880 to .014 in 1990.

The model with a constant education cost exhibits a sharp fall in the price of farm goods relative to non-farm goods (the relative price falls to roughly one-third its initial value). The farm/non-farm wage ratio falls, despite the rise in total factor productivity of farming. The productivity gains of farmers in the model are more than offset by the fall in the price of farm goods. The farm/non-farm labor force ratio falls over 110 years

²⁷For these parameter values, during the simulations it sometimes occurs that $\xi_i \zeta^i > 1$ for some households. Recall that $\xi_i \zeta^i$ 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.

Table 6: Key Features of the Data and Model Simulations

variable	data	const. educ.	decl. educ.
p_{1880}/p_{1990}	≈ 1.0	.15	1.06
$(w_f/w_m)_{1880}$	.20*	.20	.20
$(w_f/w_m)_{1990}$	.68**	.03	.68
$(z_s/z_n)_{1880}$	.36*	.36	.36
$(z_s/z_n)_{1990}$	.76	.56	.97
$(c_f/c)_{1880}$	.31*	.31	.31
$(c_f/c)_{1990}$	.014	.02	.07
$(L_f)_{1880}$	.50*	.50	.50
$(L_f)_{1990}$	.024	.29	.06

Note: * = models were fit to these values exactly; ** = model with declining education costs was fit to this value exactly. z_i = per-capita wage income in region i for the model, and per-capita income for region i in the data.

from .50 to .18, and the South/North ratio of per-capita income rises from .36 to .73. Both features are roughly consistent with the data; however, both features are intimately related to the model's incorrect prediction for the behavior of the relative price of farm goods. If the relative price were constant (suppose there was no sharp fall in the demand for farm goods, or that in an open-economy version of the model the international relative price was constant), then it seems likely that relative farm employment would rise. The overall effect of convergence is then unclear. Finally, in the model the ratio of consumption of farm goods to total consumption falls from .31 to .03.

The model with declining education costs exhibits almost no change in the relative price of farm goods, and also matches all other key aspects of the data. By construction, the farm/non-farm wage ratio rises sharply from .21 to .71 over 110 years. The farm/non-farm labor force falls from .50 to .08, and the model predicts a rise in South/North ratio of per-capita income from .36 to .97. The model clearly overstates the convergence of per-capita income, which is due to the fact that the model abstracts from other frictions that prevent an equalization of wage rates within an industry. Finally, in the model the ratio of consumption of farm goods to total consumption falls from .31 to .08.

Evidently the model with constant education costs predicts a sharp drop in the relative price of farm goods and no change in the relative wage rate of farmers. Both features are inconsistent with what is observed in the data. On the other hand, the model with declining education costs is able to explain the roughly constant price of farm goods along with the sharp increase in the farm wage rate relative to the non-farm wage rate. The model is also consistent with the vast reduction of resources devoted to farming that has taken place over the last century.

Table 7 reports additional features of the simulations. In the model with declining

education costs, migration flows from the South to the North, which is consistent with historical trends. Conversely, in the model with constant education costs, migration flows from the North to the South. In both models the capital-labor ratio rises in the non-farm sector. In the model with declining education costs the capital-labor ratio rises in the farm sector whereas in the model with constant education costs this ratio falls. In the model with declining education costs, the farm land-labor ratio rises and the non-farm land-labor ratio falls, whereas in the model with constant education costs the farm land-labor ratio falls and the non-farm land-labor ratio rises. It is obvious that these are additional respects 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.

6 Interpreting the Non-Farm Wage Premium

“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

Table 7: Additional Features of the Model Simulations

variable (annual growth rates)	const. educ.	decl. educ.
South-North population ratio	.0032	-.0017
farm capital-labor ratio	-.0064	.0236
non-farm capital-labor ratio	.0114	.0102
farm land-labor ratio	-.0142	.0087
non-farm land-labor ratio	.0033	-.0030

the field at work.”. Thus says an Arkansas planter in 1900.²⁸ In this paper we have taken the Arkansas planter seriously, and have built 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”). We have assumed that skill acquisition has become cheaper 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 Table 8, where we compare the educational attainment of workers in agriculture and outside of agriculture. The first two columns show that the percentage of workers whose educational attainment is an elementary degree or less is considerably larger in agriculture than outside of agriculture. One may suspect that this finding may be an artificial feature of the age distribution of the population, but when we restrict the exercise to those aged between 20 and 30 years of age, i.e. in some sense the “incoming” cohort of each decade, we still find that educational achievement is considerably less in agriculture. In order to

²⁸Cited in Wright (1986), p. 79.

Table 8: Percentage of Workers with At Most An Elementary Education

Year	Agriculture (All Ages)	Non-Agriculture (All Ages)	Agriculture Age 20-30	Non-Agriculture Age 20-30	Rank of Agriculture	No. of Industries
1940	0.77	0.47	0.65	0.30	3	119
1950	0.68	0.36	0.54	0.21	3	147
1960	0.57	0.27	0.42	0.14	6	145
1970	0.41	0.16	0.23	0.06	4	144
1980	0.23	0.08	0.11	0.03	10	141
1990	0.17	0.04	0.15	0.02	4	141

Note: Authors' calculations. Data source: Ruggles and Sobek (1997).

provide a more disaggregated comparison, Table 8 also shows the position of the agricultural industry in a ranking - by percent with an elementary degree or less - of the universe of industries featured in the Census of Population. So, for example, 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 10.²⁹

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

²⁹Industries 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.)

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.³⁰ 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 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 1970.³¹ 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-year, 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

³⁰We took the approximate dates for these inventions from Mokyr (1990) and *Encyclopedia Britannica*.

³¹*Historical Statistics, Series H417.*

the student population. With increased quality of education, 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 1990.³² 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 population in the South, the end of segregation in the school system of that region dramatically improved the access to and the quality of education for the most recent cohorts of Southern farm-born children.

7 Conclusions

The joint behavior of relative agricultural wages and relative agricultural employment suggest that the costs of acquiring the skills required by non-agricultural employment relative to agricultural employment have declined over the last century. This paper has constructed on this observation an explanation for several of the main features of the dramatic structural transformation and regional convergence that has occurred in the U.S. economy.

In our exposition we have tightly linked our argument to the U.S. experience. The structural transformation, however, is a near universal phenomenon for countries experiencing growth in per-capita income. A natural question for further research is therefore whether our explanation is also applicable to the structural transformation of other countries. If so, then different rates of change across countries in the costs of acquiring non-agricultural skills could have important consequences for a variety of international issues, such as the chang-

³² *Historical Statistics*, Series B126 and B107, and *Statistical Abstract of the United States*, Table 117.

ing pattern of international trade and the convergence or lack of convergence of per-capita incomes across countries.

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, as well as for the patterns of trade. Indeed, in a world in which the types of skills constantly change over time, how complementary new skills are to old skills may affect the costs of acquiring new skills, and thereby may provide important insights to the ever evolving structural transformation of various countries.

We have also 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. Pursuing this insight may help clarifying the mechanism through which human-capital accumulation affects economic growth.³³

³³A possible way to do this would be to combine the one-sector model in Caselli (1998) with the one in this paper.

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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.³⁴ 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. US-wide numbers. 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

³⁴Except 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.

Table A.1: Occupational Groups of Agricultural Workers

Year	Farmers	Other Self-Employed	Paid Farm Laborers	Other Paid Workers
1940	0.311	0.004	0.577	0.109
1950	0.451	0.006	0.407	0.136
1960	0.326	0.008	0.482	0.184
1970	0.242	0.049	0.454	0.256
1980	0.140	0.090	0.407	0.364
1990	0.084	0.139	0.265	0.513

Note: Authors' calculations. Data source: Ruggles and Sobek (1997).

as the means, weighted by the number of workers, of the state-level numbers. For the employment share of agriculture we simply summed the numbers of workers in the two sectors across states.

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 different non-white race, 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).

The above-described procedure for estimating the agricultural and non-agricultural wages is extremely straightforward. Essentially, we take the average wage of all full-time employees who, within each industry (and state) report a strictly positive wage income. For agriculture, these positive-wage earners can be subdivided into four groups: farmers (almost all of whom are self-employed), paid farm laborers, other paid workers, other self-employed workers; the "other" categories include a wide variety of professionals and laborers providing services to farm establishments. Table A.1 shows how the weights of the four groups in the overall number of positive-wage earners changes over time.

Two potential issues of robustness arise in connection with the composition of the agricultural workforce. The first potential problem concerns the interpretation of the wage income of the agricultural self-employed, whether farmers or "other". The self-employed can be "incorporated" or "not incorporated". The incorporated receive wages as official employees of their businesses, and

therefore are expected to report positive wage income. Hence, they legitimately contribute to our measure of agricultural labor income. The not incorporated, instead, are expected to report all their income associated with their business as business income (INCBUSFM or INCFARM), and nothing as wage income (INCWAGE). Instead, we found that some not incorporated agricultural self-employed did report wage income, and therefore contributed to our measure of the agricultural wage. There are two possible interpretations of the positive wage incomes reported by not incorporated self-employed. First, they could be trying to assess the labor component of their overall business income. If this were the case, their contribution to our measure of labor income would be legitimate. Second, they could be reporting wages from a "second-job" outside of their business, in which case these wages should not be included in our estimates. The obvious solution to this potential robustness problem would be to repeat the empirical exercises of this paper with an alternative measure of agricultural labor earnings that omits the not-incorporated self-employed. However, the incorporated/not-incorporated distinction is only made in 1970, 1980, and 1990, so this robustness check can only be performed for these three years. When this is done, the results are almost indistinguishable from those reported in the paper. The reason is that the number of not-incorporated self-employed with positive wages is fairly small, and their reported wages are fairly close to those of the incorporated. It is plausible to expect that the same applies to 1940, 1950, and 1960. We conclude that our methods are robust to the exclusion of not incorporated self-employed workers.

The second potential question has to do with changes in the weight of the four occupational groups. Table A.1 shows that the percentage of farmers has increased between 1940 and 1950, but then it has declined steadily since 1950. Similarly, paid farm laborers have declined, although all the decline is concentrated in the two decades after 1940 and after 1980. The two "other" categories have both shared in the gain. The question then arises whether our wage data - and especially the US-wide upward trend in the relative agricultural wage - are driven by these large changes in the composition of the agricultural labor force (and, if yes, if this is a problem). To investigate this issue, we have separately re-estimated the wages of each of the four sub-groups. The results are reported in Table A.2 which also includes, in the last column, the aggregate of the four groups (i.e. our baseline data). From these data, it emerges that in the long run all four groups shared in the upward trend in the relative agricultural wage. However, changes in the occupational

Table A.2: Agricultural Relative Wages by Occupational Group

Year	Farmers	Other Self-Employed	Paid Farm Laborers	Other Paid Workers	All
1940	0.39	0.79	0.33	0.66	0.35
1950	0.36	0.46	0.45	0.54	0.39
1960	0.59	1.76	0.41	0.70	0.51
1970	0.73	1.00	0.47	0.77	0.64
1980	0.67	1.19	0.51	0.80	0.69
1990	0.55	1.06	0.50	0.72	0.68

Note: Authors' calculations. Data source: Ruggles and Sobek (1997).

composition seem to have played a role, as in general the change in the overall relative agricultural wage is more pronounced than the changes for the individual groups. These compositional effects seem particularly pronounced in the 1940s. While we believe that our comprehensive definition of agricultural labor is the one that best captures the spirit of this paper, readers must keep in mind that some of the quantitative - but not qualitative - results might change if a narrower definition was adopted.

Appendix II. Convergence Decompositions: Mid-West and West.

Table A.3: 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 (4) for sub-periods indicated in first column. The terms a1-a4 correspond to the terms in the first line of (4). 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) Easterlin (1957); (1940-1990, labor income per worker) Ruggles and Sobek (1997).

Table A.4: 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 (4) for sub-periods indicated in first column. The terms a1-a4 correspond to the terms in the first line of (4). 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) Easterlin (1957); (1940-1990, labor income per worker) Ruggles and Sobek (1997).

Appendix III: The Equivalence of Efficient and Equilibrium Allocations

This appendix characterizes the efficient allocation of resources for the economy developed in this paper. Given the particular utility function people are assumed to have, we will then show that the efficient allocation coincides with the allocation in a competitive equilibrium.

The Efficient Allocation of Resources

Consider the allocation of resources by a central planner interested in maximizing overall social welfare, defined as any one person's utility (recall that the utility function is the same for everybody) evaluated at the aggregate levels of consumption of each of the two goods.

Denote the aggregate consumption of farm goods by c_{ft} and denote the aggregate consumption of manufacture goods by c_{mt} . To compute the efficient allocation of resources, the planner is assumed to maximize aggregate utility given by

$$v_0 = \sum_{t=0}^{\infty} \beta^t u(c_{ft}, c_{mt}),$$

where

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

Note that while any individual's utility is uncertain, due to the probability of dying, utility defined over aggregate consumption is certain. Hence, computing utility over aggregate consumption does not require averaging over states of dying and not dying. In maximizing utility, the planner chooses sequences for c_{ft} , c_{mt} , K_t , K_{ft} , K_{mt} , N_{ft} , N_{mt} , l_{ft}^0 , l_{mt}^0 , l_{et}^0 , L_{ft} , L_{mt} , L_{et} , and $\bar{\zeta}_t$ subject to the above constraints. 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 , N_f , N_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 to

$$c_f = F(N_f, L_f, K_f, A_f), \quad (37)$$

$$c_m + K' = M(N_m, L_m, K_m, A_m) + (1 - \delta)K, \quad (38)$$

$$K = K_f + K_m, \quad (39)$$

$$1 = N_f + N_m, \quad (40)$$

$$1 = l_e^0 + l_m^0 + l_f^0, \quad (41)$$

$$l_e^0 = \int_0^{\bar{\zeta}} \xi \zeta^i \mu(\zeta^i) d\zeta^i, \quad (42)$$

$$l_m^0 = \int_0^{\bar{\zeta}} (1 - \xi \zeta^i) \mu(\zeta^i) d\zeta^i, \quad (43)$$

$$L_f = \hat{L}_f \lambda + l_f^0 (1 - \lambda), \quad (44)$$

$$L_m = (\hat{L}_m + \hat{L}_e) \lambda + l_m^0 (1 - \lambda), \quad (45)$$

$$L_e = l_e^0 (1 - \lambda). \quad (46)$$

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, it is straightforward to show that necessary and sufficient conditions for the solution to be an optimum is if the policy functions satisfy the following equations, in addition to eqs. (37) - (46). First, the solution must satisfy

$$u_1(c_f, c_m) F_1(N_f, L_f, K_f, A_f) = u_2(c_f, c_m) M_1(N_m, L_m, K_m, A_m), \quad (47)$$

and

$$u_1(c_f, c_m) F_3(N_f, L_f, K_f, A_f) = u_2(c_f, c_m) M_3(N_m, L_m, K_m, A_m). \quad (48)$$

Second, the solution must satisfy

$$u_2(c_f, c_m) = \beta u_2(c'_f, c'_m) (M_3(N'_m, L'_m, K'_m, A'_m) + 1 - \delta). \quad (49)$$

Denote by φ_f the multiplier for eq. (44) and denote by φ_m the multiplier for eq. (45); 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:

$$\varphi_f = u_1(c_f, c_m)F_2(N_f, L_f, K_f, A_f) + \beta\lambda\varphi'_f, \quad (50)$$

$$\varphi_m = u_2(c_f, c_m)M_2(N_m, L_m, K_m, A_m) + \beta\lambda\varphi'_m. \quad (51)$$

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

$$\bar{\zeta} = \frac{1}{\xi} \frac{\varphi_m - \varphi_f}{u_2(c_f, c_m)M_2(N_m, L_m, K_m, A_m)}. \quad (52)$$

A necessary and sufficient condition for a solution to be a social optimum is if the choices $c_f, c_m, K, K_f, K_m, N_f, N_m, L_f, L_m, L_e$, and $\bar{\zeta}$ satisfy eqs. (37) - (52).

Equivalence

It is straightforward to show that the allocations in a competitive equilibrium coincide with the efficient allocations as defined above. Combine eqs. (24), (26), and (29) to show that the allocations in a competitive equilibrium must satisfy eq. (47) and combine eqs. (24), (28), and (31) to show that the allocations in a competitive equilibrium must satisfy eq. (48). Clearly the allocations in a competitive equilibrium must satisfy eq. (49). Also, note that the solution φ_f to eq. (50) equals the solution $u_1 h_f$ to eq. (33), and the solution φ_m to eq. (51) equals the solution $u_1 h_m$ to eq. (32). These results show that eq. (52) 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

$$\beta = \frac{1 + g}{1 + R}.$$

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 : $\alpha_T, \alpha_L, \beta_T, \beta_L$ 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 $.19 = .4754 \cdot .4$ as land's share in the farm sector, and $.06 = .1444 \cdot .4$ 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 $\delta = .36/\text{decade}$. 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. 5). 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). In the model we assume that g_f starts at this value of g_{f0} , remains at this value for 11 periods (110 years), and then falls linearly over 20 periods (200 years) so that $g_f^{\frac{1}{\alpha_L + \alpha_T}}$ equals $g_m^{\frac{1}{\beta_L + \beta_T}}$; it is then expected to remain at this value forever (this evolution of g_f is not recursive, but our method for constructing the solution can handle time-dependent policy functions). Data: Gollop and Jorgenson, Tables 9.2 and 9.4, and the Historical Statistics of the U.S., Series W7.

ξ_0 : The initial value of ξ , which is ξ_0 , is set to match the farm/non-farm wage ratio in 1880, which is .21. Data: Table 1.

$\bar{\xi}$: For the model with declining education costs, over 110 years we assume that ξ falls linearly from ξ_0 to $\bar{\xi}$, and then remains permanently at this level. The value of $\bar{\xi}$ is set to match the steady-state farm/non-farm wage ratio to what this value seems to be trending to in the data. There is not sufficient data to reliably estimate this limit. For each decade from 1950 to 1990, the value of this ratio is .39, .51, .64, .69, and .68. The change in this ratio is very slow in the last three decades relative to earlier decades. Based on these value we simply chose a limit of .8. Data: Appendix I.

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 1990 was born closer to 1880 than 1990, 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-capita 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 .36. Data: our calculations based on Lee, et.al. (1957), Table Y-1.

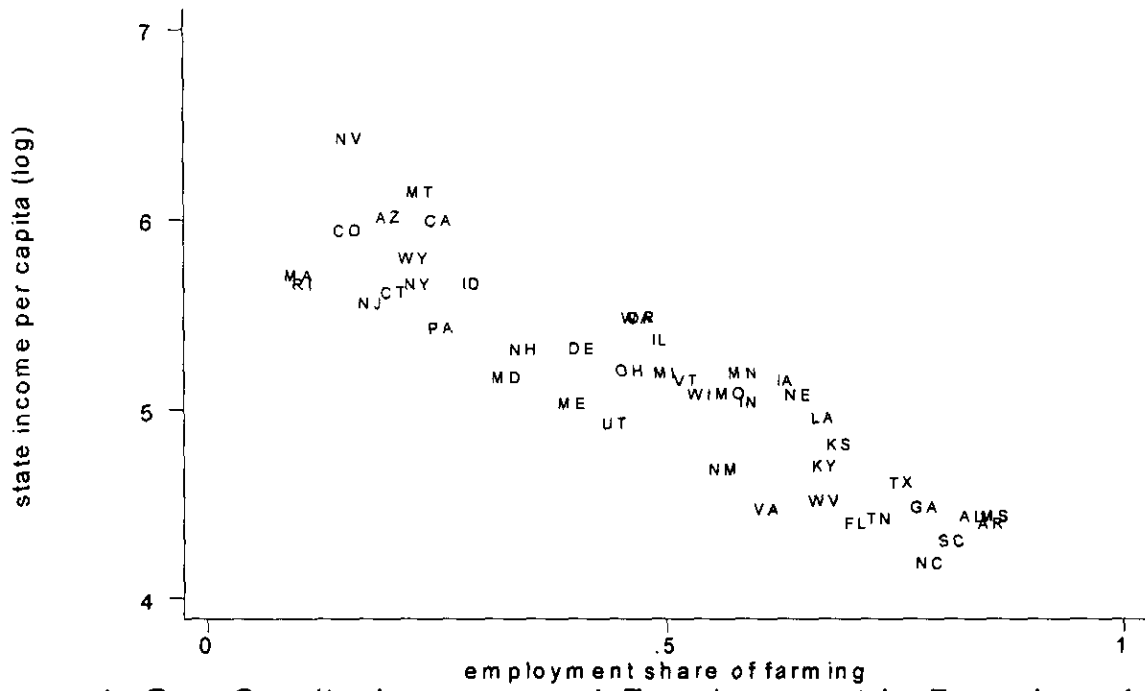


Figure 1: Per-Capita Income and Employment in Farming: 1880

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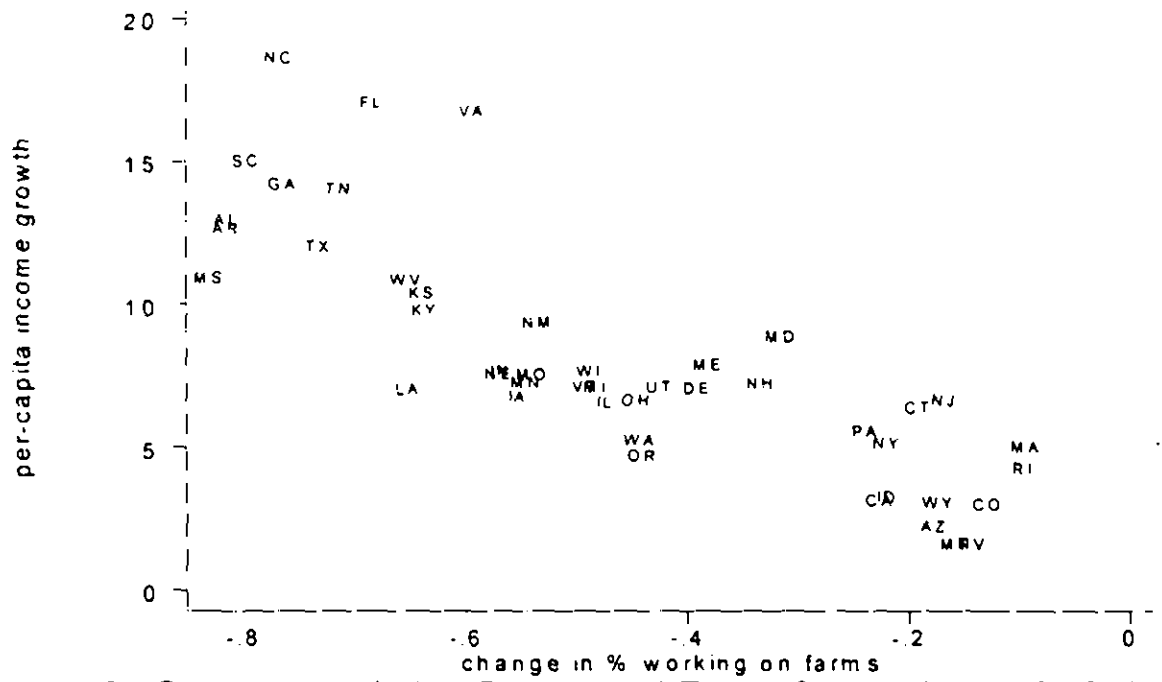


Figure 2: Growth and the Structural Transformation: 1880-1990

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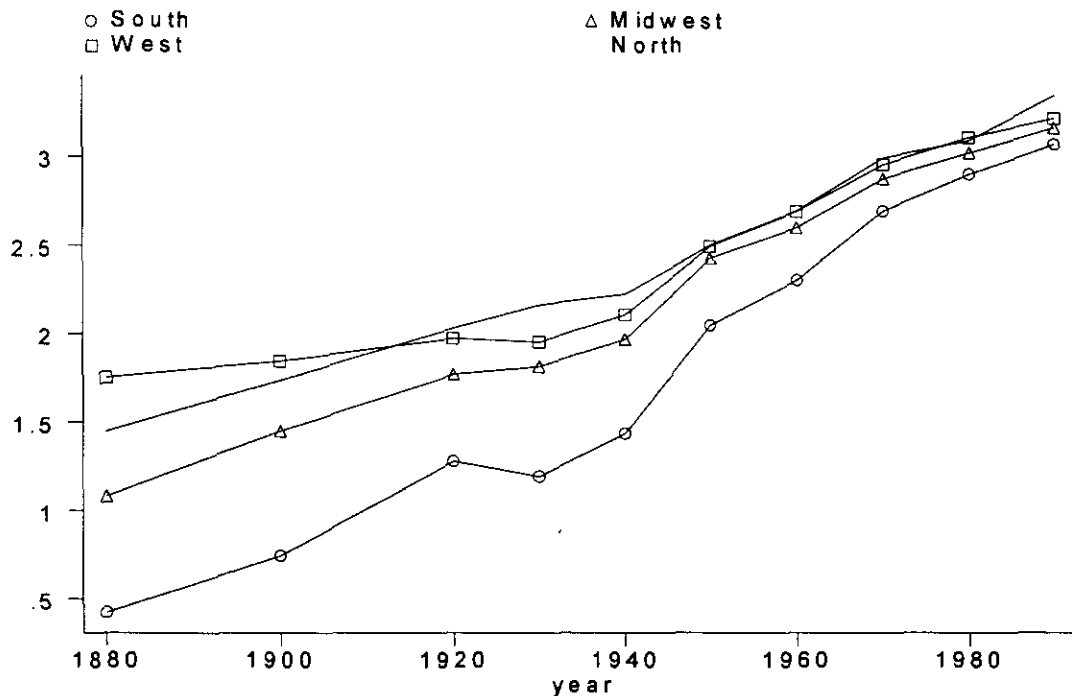


Figure 3: Real Personal Income of US Regions (log)

STATA

Figure 4: Non-Agricultural/Agricultural Wage Differential and Agricultural Employment

