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ABSTRACT

The existing literature on skill-biased technical change has not considered how the technological endowment itself plays a role in the returns to skill. This paper constructs a simple model of skill biased technical change which highlights the role that resource endowments play in the returns to education. The model predicts variation in returns to education with skill biased technological change if there is significant heterogeneity in resource endowments before the technological change. Using a variety of historical sources, we document the heterogeneous technology levels by region in the American past. We then estimate the returns to education of high school teachers in the early twentieth century using a new data source. a report from the U.S. Commissioner of Education in 1909. Overall, we find significant regional variation in the returns to education that match differences in resource endowments, with large (within-occupation) returns for the Midwest and Southwest (7%), but much lower returns in the South (3%) and West (0.5%). We also show that our results are generalizable to returns to education in the United States and that returns to education for teachers tracked quite closely with the overall returns to education from 1940 onward.

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1 Introduction

Research on skill biased technical change (SBTC) has given rise to a new literature linking education, technology, and economic growth. The consensus now is that high rates of return to education at the beginning of the century signaled the end of the period of early industrialization where raw materials and unskilled labor substituted easily for skilled labor (Goldin and Katz 1998). With the use of new large-scale processing technologies and the increasing electrification of the industrial workplace, the returns to education increased dramatically in the early years of the last century. Goldin and Katz (1999, 2000) used the Iowa state Census of 1915 to sketch out the returns to education in the early twentieth century, and a new view of U-shaped returns to education over the twentieth century has emerged. Returns declined with the advent of the high school movement in the 1920s and 1930s (Goldin and Katz 1995), perhaps intensified by the wage controls used in the second World War (Goldin and Margo 1992), and rose again in the second half of the century.

At the same time, there is a growing body of contemporary evidence that factor endowments play a role in the returns to skill. Comin, Hobijn, and Rovito (2007) have shown that technological lags between countries are large and they are correlated across technologies, consistent with the idea that regions are at the forefront or backwater of technological change broadly and not only in selected areas. Autor, Levy and Murname (2003) show that adoption of PCs increased the skill demands for the same occupations over time, leading to increasing returns to education. Abowd, et al. (2007) have shown that firms that use the most sophisticated technology employ more skilled workers, and this also suggest that the geographic location of firms will not be uniform but itself may be a function of the level of skill in the local labor market. Beaudry, Doms, and Lewis (2006) show that cities with larger supplies of skilled labor adopted PCs more quickly than others, and that this caused the increase in returns to skill to be greatest for cities that adopted PC more aggressively. Overall, there is now strong evidence that technological differences and differences in factor endowments such as capital and skilled labor play a large role in how SBTC effects the labor market and technology adoption (Caselli and Coleman 2006). The open question is how (or if) these endowments played a role in previous waves of SBTC, such as the United States at the turn of the last century.

When one takes regional heterogeneity of factor endowments into account there are very good reasons to believe that the Northeast and Midwest had U-shaped returns to education but that other regions of the country had steadily increasing returns to education over the twentieth century. First, available large-scale processing technologies that led to the rise in the returns to education did not diffuse evenly across the United States. The industrial states of the Northeast and Midwest had larger concentrations of such industries than the South and West. The South and West employed older-technology industries for the most part (including traditional agriculture), and it is therefore unlikely that the returns to education in those regions would be large in the early twentieth century. Similarly, the increasing technological sophistication of agriculture, which led states like Iowa to invest heavily in education, was largely a phenomena of the Midwest and Northeast. The South was still able to exploit its large supply of unskilled labor, and the West had a relative abundance of raw materials but a scarcity of labor. In general, potential correlates and precursors of high rates of return to education were not evenly distributed across the U.S. at the start of the last century.

Not only would changes in demand for skill have varied across regions, but the relative supply of skilled workers was also variable across regions. Investment in education and infrastructure more generally varied considerably, and the high school movement that came later diffused unevenly as well. In the South and Southwest in 1910, high school graduation rates were only four percent, while they were triple that in the Midwest and Pacific Coast, and still higher in New England (Goldin 1999). Finally, the transportation and information technologies at the beginning of the twentieth century were not uniform, and as such the first half of the twentieth century saw a significant integration of regional and local labor markets into a national market, spurred not only by wage controls, but also by the national minimum wage, which spurred capital investment in Southern agriculture (Wright 1987, Mitchener and McLean 1999, 2003).

In light of the historical fact of regional heterogeneity and the contemporary evidence about the role of factor endowments in SBTC, this paper asks the following question: To what extent did differences in factor endowments effect the return to skill during the first era of skill biased technical change? Indeed, it may well be true that existing factor endowments played a large role in the adoption of new technology, and as such SBTC would have been a function of pre-existing conditions. Even more, any discussion of the technology-skill complementarity in American history should take into account the regional differences in the American economy in the early twentieth century. Doing so highlights the importance of the educational and capital endowments in the early stages of SBTC, and provides a strong link between the SBTC literature and contemporary studies of local and regional labor markets. This is especially important for policies in both large cities and for developing countries since differences in factor endowments may require different short-term responses to skill-biased technological change. We formally develop the idea of capital-complementing skill-biased technical change in a simple two-sector model and show that the initial level of capital is an important piece of the returns to education relationship. The model shows that capital-rich markets should experience the largest increase in returns to education and complementing this, skill-rich markets will have the largest increases in the returns to capital.

In describing the origins of SBTC, the rates of return to education in the early twentieth century reported by Goldin and Katz has been limited to a single state, which may have been a relative outlier for that time. What was lacking was a data source that would allow us to estimate the returns to education by region, to see if significant differences existed and to measure the magnitude of those differences. In this paper we use a new data source, a report from the U.S. Commissioner of Education in 1909, to estimate the returns to education of high school teachers in the early twentieth century. Our data list not only the education and earnings of the teachers individually for a number of different states, but also includes actual years of experience in the teaching profession, allowing us to estimate the returns to schooling while controlling for experience directly.[1] More importantly, the data was gathered in a systematic fashion, allowing us to estimate the returns to education by region without the additional complication of differences in data quality and reliability. These returns are for a single occupation – the absolute levels may understate returns generally, since one of the important gains of schooling comes from enabling workers to choose higher paid occupations. Nonetheless, secondary teachers returns are of interest since they likely reflect the rising demand for high school education relative to the current stock of high school educated workers (the pool of potential teachers). That is, rising demand for high school education creates a derived demand for educated teachers. Overall, we find significant regional variation in the returns to education, with large returns congruent to Goldin and Katz's estimates for the Midwest (7%), but substantially lower returns in the South (3%) and West (0.5%).

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[1] Note that the requirements to teach at the secondary level varied greatly in the past, and the professionalization of the teaching profession, in terms of certification and degree requirements, did not begin until after the high school movement. For example, from 1909 to 1919 only eleven states began requiring a high school diploma for the lowest level of teacher certification; Washington, Oregon, Idaho, Montana, Illinois, Indiana, New Jersey, Utah, Vermont, New Hampshire, and Maine (Law and Marks 2007).

In considering the generalizability of our main finding, we uncover several facts which strengthen our conclusion. The geographical patterns we find hold for male teachers and for less experienced teachers, for whom outside options may be more relevant and may therefore be more closely connected to the wider labor market. We further find that teachers' returns to education are indicative of overall returns to education. We use IPUMS returns to show that the returns to education for teachers track quite closely with the overall returns to education from 1940 onward. We also show that the returns to education for the states in our historical data track well with national returns over this later period.

The paper proceeds as follows. The next section reviews the facts about regional economic heterogeneity at the beginning of the twentieth century and presents our two sector model which highlights variation in returns to education at the start of skill biased technical change. The third section presents the empirical results, which are based on the 1909 Commissioner of Education Report. They show that there was significant regional variation in the returns to education in the early twentieth century. The fourth section addresses the robustness and extensions of the empirical results. The final section concludes.

2 Skill, Technology, and the Returns to Education

The existing explanation for the trend in returns to education has not acknowledged, for the most part, the substantial variation in the preconditions for the rise in the returns to education. There are two ways in which the existing theory should be modified to fit the regional histories of the United States. First, the differences in the resource and capital endowments in different regions of the country must be accounted for. Second, the preconditions for increasing returns to education, as required by the theory, must be reconciled with the historical record. Below, we sketch out these two issues, presenting evidence of significant variation in education and other factor endowments by region and augmenting the theory of skill biased technical change to yield predictions of the returns to education for different regions of the United States at the beginning of the twentieth century.

2.1 The Historical Record

The differences in the factor endowments in different regions of the U.S. in the early twentieth century is well known. Capital development in South, from the end of the Civil War to at least World War I, was rather inefficient (Davis 1965, Sylla 1969, Wright 1987, Ransom and Sutch 2001), and financial institutions in the South were not structured in the same way as those in the Northeast and Midwest, with Southern banks much smaller than the national average and with higher interest rates in the South. This is important to the extent that capital markets in the U.S. were segmented in the early twentieth century. The South did not have as many capital intensive industries as the Northeast and Midwest at the beginning of the twentieth century, and North (1961) has argued that the South did not re-invest the gains made from its productive agricultural sector. Similarly, the South, with its sharecropping system and Jim Crow legislation, had a large supply of unskilled labor of both races (Ransom and Sutch 2001, Collins 1997). Furthermore, black unskilled labor was locked in the South by the large flows of immigrants from Europe and racial discrimination in non-farm employment in the U.S. in general (Collins 1997). The West, with its relatively sparse population, had an abundant resource endowment that was only beginning to be exploited in the early twentieth century (Nelson and Wright 1992). In general, this implies that the trade offs where raw materials and unskilled labor substituted for skilled labor would have been more prevalent in the South and West since they had an abundance of the former.

The historical record also tells us that the processes that led to the increasing returns to education were less prevalent in the South and West. Given the South's low levels of capital intensity and warm climate, there were relatively few of the new large-scale processing technologies highlighted by Goldin and Katz (1998) in the South and West at the end of the nineteenth century. As Wright (1987) has shown, the South was simply not in a position to industrialize (beyond the harvesting of raw materials) in any large extent before the first World War. A possible exception would be textiles, an older industry that had permeated the South before the early twentieth century, which was bolstered by cheap Southern (low-skilled) labor, and would later exceed its northern competition (Carlson 1981, Wright 1981). Similarly, the South's agriculture, with its dependence on labor-intensive work, was not as sophisticated as the agriculture of the Northeast and Midwest, nor the cattle ranching seen in the West. Indeed, Goldin and Sokoloff (1984) have argued that industrialization first appeared in the Northeast and Midwest because of the crops grown there, which led to agricultural technology that made women relatively less productive than men in agriculture. In terms of the educational structures necessary to see large returns to education develop, Goldin and Katz (1998) have shown that large investments in education took place most successfully in homogeneous populations. As such, racial diversity in the South would have caused lower investments in schooling, and it is certainly true that low investments in education left large portions of the southern workforce relatively unskilled at the turn of the last century (Margo 1990).[2]

There is also research that details the extent to which the labor market in the United States was fragmented in the late nineteenth and early twentieth centuries. Rosenbloom (1990, 1996) has shown that the labor market in the early years of the twentieth century was fragmented, and North-South differentials in wages suggest that a national labor market did not exist before the first World War. While it is not true that every locality had its own independent labor market, it is true that the South and North had different labor markets that were not fully integrated to any large degree until after the first World War. Wright (1987) contends that the Southern labor market was not integrated until the New Deal forced the South to invest in capital for the agricultural sector, and that the South was finally brought into the rest of the national labor market by the end of the second World War.

2.2 Measuring the Historical Factor Endowments

The literature suggest that there are educational and technological factors related to the returns to education in the early twentieth century.[3] Skill-biased technologies were associated with capital intensity. If a region had a relatively high educational levels and small amounts of capital, we would expect relatively low returns to education. If a region had low educational levels and relatively large amounts of capital, we would expect for the returns to education to be high.[4] But how can we measure the factor endowment, and was there heterogeneity in the factor endowment by region in the late nineteenth and early twentieth century? To answer these questions we first look at estimates of labor productivity and then assemble evidence from the *Historical Statistics of the*

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[2] Bleakley (2007) notes that the eradication of hookworm in the South, begun in 1910, raised the lifetime return to education in the region.

[3] Intuitively, one could think of eductaional factors as supply and technological factors as demand.

[4] A priori, we cannot form firm hypotheses about the returns to education in regions that had large levels of both education and capital or small levels of both education and technology.

United States, historical *Statistical Abstracts of the United States*, and the *Census of Manufactures* to measure differences in factor endowments by region from the late nineteenth to early twentieth century. Educational factors include the general education level of the population in a particular region, investments in education, and school enrollment rates as they would be evidence that a particular region would have the skill in the workforce to readily adopt to new technologies. We also measure proxies for the importance of new skill-intensive technologies, including the capital stock, both in manufacturing and agriculture, the use of various sources of power, the share of the labor force employed in manufacturing, and evidence of technology adoption more generally.

Beginning with estimates of labor productivity, Table 1 shows estimates of price adjusted income per worker by region and for individual states from 1880 to 1920.[5] The regional heterogeneity in labor productivity was large, with the West far ahead of the rest of the nation while the South lagged behind. In the bottom panel of Table 1 we show estimates of labor productivity for the states in our historical data and their geographic neighbors. The results show that estimates for individual states are fairly representative for their region; they are close to the estimates for their neighbors and the growth over the 1880 to 1920 period for individual states varies at the regional level.

While these labor productivity estimates establish regional heterogeneity in labor productivity, and support the assertion that regional labor markets were substantially segmented, they do not tell us about regional heterogeneity in factor endowments themselves. For example, states with a significant percentage of the labor force in mining have a higher level of labor productivity. Mitchener and McLean (2003) note that this is likely due to both the large natural resource endowment in the West and its relative labor scarcity. A priori, returns to education in the West may have been particularly low due to the high wages commanded by unskilled workers, or they could be high because of the technology used to extract these resources. Similarly, these trends in labor productivity tell us little about how labor productivity (price-adjusted income per worker) varied with changes in the educational, capital and resource endowments. Since these estimates of labor productivity are themselves a function of the factor endowments, we must turn to more direct measures to gauge the extent of heterogeneity in educational and non-labor endowments in the

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[5] Following Mitchener and McLean (1999, 2003) we take price adjusted income per worker as the measure of labor productivity.

American past.

Tables 2 and 3 summarize these educational and non-labor factors. Table 2 lists measures associated with both the level and growth of education, listing the literacy rate, school expenditures, and school enrollment for the high school aged population in the early twentieth century. California, Illinois, Iowa, Ohio, and Wisconsin all have high literacy rates, each above 95% by 1910 and all but California above 95% in 1900, suggesting a large endowment of relatively skilled workers. Both Georgia and Texas have relatively low literacy rates, suggesting a smaller endowment of skilled workers. The second panel shows school expenditures, both per capita and per capita of the school aged population. Although all states saw significant growth in school expenditures per capita from 1900 to 1920, Georgia was spending less than one quarter of what the Midwestern states were, and Texas only slightly more than half. California, by contrast, was spending more than 150% of what the Midwestern states were. The last panel of Table 2 shows school attendance rates for high school age students. In 1910, Georgia is the only state in which less than three quarters of 14 or 15 year olds are not attending school. Texas' attendance rates were approaching the rates for the Midwestern states and show a particularly high attendance rate for 16 to 17 year olds. By 1930, California has the highest attendance figures for 1910 to 1930 for 14 and 15 year olds, and very high rates for 16 to 20 year olds.

Table 3A presents some growth in factors associated with the spread of skill-intensive production methods. The manufacturing share of the labor force in Illinois, Ohio, and Wisconsin grows by an average of 95% from 1900 to 1910. In Iowa the manufacturing share of the labor force grows by 124% between 1900 and 1910, and in Texas the percentage employed in manufacturing nearly doubles between 1900 and 1910, increasing by 99%. Similarly, the value of machinery per the agricultural workforce increases substantially between 1900 and 1910 in Texas. The growth of Georgia's labor force in manufacturing was relatively modest (only 68%), suggesting a relatively less influential spread of skill-intensive technologies in Georgia, and the manufacturing sector grows the least in California between 1900 and 1910 (only 64%). Table 3A also shows that the growth in agricultural factors associated with high-skill production such as machinery value and livestock value grow relatively modestly from 1900 to 1910 for all states. There were differences in capital deepening, however, the level of capital per establishment in 1905 was much greater than in 1900 for all states, partly driven by a decrease in the number of establishments, but an outlier in this factor is Texas, which sees a significant increase in the amount of capital per establishment.

As we noted earlier, the story of skill biased technical change supposes a displacement of the old technology for the new, skill complementing technology, and Table 3B presents evidence of the prevalence of capital-intensive technologies by state in the beginning of the twentieth century. There was marked variation in the importance of these technologies by region in the early 20th century. The number of technological firms and the value added by manufacturing varied considerably. There were many more technological firms in the Midwestern states than in the South or the West. California and Texas, states with significant natural resource endowments, have relatively low levels of value added in manufacturing. This carries over into more direct measures of technology, such as the number of internal combustion engines and electric motors, which were much more prominent in the Midwest than in the South or West. California and Texas do increase the number of electric motors by the beginning of the twentieth century, but Georgia still lags well behind the other states in the use of this new technology.

These differences carried over into the early twentieth century. Table 3C presents evidence from the first three decades of the twentieth century. Internal combustion horsepower shows the marked variation in how intensively these technologies were used. Both Georgia and Texas have less than 1,000 internal combustion horsepower in 1900, although they do increase horsepower significantly by 1910. Further inferences can be drawn from the number of internal combustion engines and electric motors per establishment in 1919 and the amount of horsepower from both sources in 1929. While Texas leads in internal combustion power in 1929 and has relatively high amounts of electric power, California, and Georgia lag behind the other states both in the number of electric motors and in horsepower generated by them. Even with the gains made by California, Georgia, and Texas, they continue to lag behind the Midwestern states in the number of electric motors per establishment in 1919, and in the amount of electric horsepower per establishment in 1929.

All told, the evidence in Tables 1 and 2 show that there were marked differences in the factors related to the returns to education in the early twentieth century. Although we argue that these differences can allow us to crudely group states by their factor endowments and use of technologies, it is important to note that this evidence is suggestive. We do not argue here that every measure should agree with our general assertions about the regional differences in the supply and demand for skill, and we would be surprised if they did. For example, Lamoreaux and Sokoloff (2000) show that during the late nineteenth century there began to be a divide geographic divide between the centers of invention and the centers of production in some respects. All of the evidence presented here, however, is more consistent with the proposition of regional heterogeneity than homogeneity, and agrees with our general point about significant regional variation in the educational and technological endowments.

These regional differences do not fit well into a monolithic model of skill-biased technical change and U-shaped returns to education over the twentieth century. The Midwestern states appear to have large endowments of capital and education, and prominent use of capital-intensive, frontier technologies, while Georgia has a relatively little capital for frontier technologies and low levels of education. California and Texas, however, are more difficult to classify. Relative to each other, California has a larger educational endowment than Texas (and every other state, for that matter), but technologically the two states are roughly similar and are close to one another on most ordinal ranking of the technology indicators in Table 3. While some regions fall easily into a set that would yield predictions about the returns to education, direct estimates of the returns to education are necessary for regions with indeterminate predictions for the returns to education based on their endowments.[6]

Overall, there is striking heterogeneity in the factors and proxies related to the return to education. A movement towards new capital and skill-intensive processing technologies would not have the same effect on the relatively unindustrialized South as it would on the Midwest. Similarly, one would predict that, given differences in their educational endowments, skill-biased technological change would have a different impact in California as opposed to Texas.[7] Given these regional differences in factor endowments at the beginning of the twentieth century, we would expect skill biased technical change to produce regional differences in returns to education in the early twentieth century. Below, we present a simple model that captures features of the technology-skill story in a two-sector model, to highlight the importance of factor endowments in explaining returns to education with SBTC.

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[6] We also note that, generally, supply of skill is slow to adjust to technology-based demand for skill. As such, levels of skill at a point in time will be exogenous, and returns in the short run would reflect primarily technological factors while long run returns would reflect the endogenous nature of the supply and demand for skill.

[7] Although we can form predictions about the returns to education in California versus Texas, it is more difficult to predict what the returns would be relative to returns in the Midwest or South.

2.3 A Model of Skill Biased Technical Change with Heterogeneous Endowments

Assume initially that there are two sectors of production, a land-dependent sector, t (for traditional agriculture) and a capital-dependent sector o (for old capital-dependent sector).[8] The two sectors use skilled and unskilled labor together with either capital K or land T to produce output:

$$\begin{aligned} Y_i &= K_o^{\alpha} H_o^{\beta} L_o^{1-\alpha-\beta} \\ Y_t &= T^{\alpha} H_t^{\beta} L_t^{1-\alpha-\beta} \\ H_t + H_o &= H \\ L_t + L_o &= L \\ K_o &= K \end{aligned}$$

We model each region as a small open economy that takes the relative price of output in each sector as given, but has its own factor markets. We normalize this relative price of output to one. High- and low-skilled labor are mobile across sectors, and so in equilibrium they each get paid their marginal product and these wages are equalized across sectors. Solving the equilibrium labor allocation and wages is straightforward: in equilibrium, the fraction of high-skilled workers employed in the capital-dependent sector is increasing in the capital/land ratio, and equal to the fraction of low-skilled workers employed:

$$\begin{aligned} \frac{K}{K+T} &= \frac{\tilde{H}_o}{H} = \frac{\tilde{L}_o}{L} \\ \frac{\tilde{w}_H}{\tilde{w}_L} &= \frac{\beta}{1-\alpha-\beta}\left(\frac{H}{L}\right)^{-1} \end{aligned}$$

The expressions show that the fraction of workers employed in industry is increasing in the capital/land ratio, and the relative wage of high-skilled workers is decreasing in their relative abundance. (The tildas signify the initial equilibrium.) Assumption (A1) assures that high-skilled workers are scarce enough to earn a premium over low-skilled workers:

$$\frac{H}{L} < \frac{\beta}{1-\alpha-\beta} \tag{A1}$$

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[8] Here t could represent any sector that is natural resource intensive, but not capital intensive. T would then represent all natural resources.

Now consider the introduction of a new capital-dependent sector (n):

$$Y_i = AK_n^{\alpha} H_n^{\gamma} L_n^{1-\alpha-\gamma}$$

Since capital is now mobile across the two capital-dependent sectors, the capital constraint becomes:

$$K_o + K_n = K$$

The new capital intensive sector differs from the old sector in that it is more skilled labor-intensive. Mathematically, this assumption is expressed:

$$\gamma > \beta \tag{A2}$$

This assumption captures the skill-biased nature of the new technology.

We show that if the new capital-intensive technology is a large enough improvement over the old technology, the new equilibrium has the following characteristics.

Proposition 1 *Given (A1)-(A2), if the productivity of the new technology is sufficiently large, the new capital-intensive sector displaces the old capital-intensive sector, and the new capital-intensive technology sector employs a higher fraction of high-skilled workers than low-skilled workers. That is,*

$$\begin{aligned} \exists A^* \ s.t. \ for \ A &> A^* \\ K_n &= K \\ \frac{H_n}{H} &> \frac{L_n}{L} \end{aligned}$$

Proposition 2 *Given (A1)-(A2), given the same level of productivity, the number of high-skilled employed in the new capital-intensive technology exceeds the number of high skilled previously employed in the old capital-intensive technology. The relative wage of high-skilled workers also exceeds* *the previous relative wage. That is,*

$$\begin{aligned} \textit{for } A &> A^* \\ H_n &> \tilde{H}_o \\ \frac{w_H}{w_L} &> \frac{\tilde{w}_H}{\tilde{w}_L} \end{aligned}$$

Furthermore, if the productivity is even larger, the number of low-skilled workers in the new capital-intensive technology exceeds the number employed in the old capital-intensive technology. In particular,

$$\begin{aligned} \exists \hat{A} &> A^* \textit{ s.t. for } A > \hat{A} \\ L_n &> \tilde{L}_o \end{aligned}$$

Proposition 3 *Given (A1)-(A2), the higher the capital/land ratio, the higher the fraction of high-skilled* and *low-skilled workers employed in the new capital-intensive technology and the higher the relative wage of high-skilled workers. That is,*

$$\begin{aligned} \textit{for } A &> A^* \\ \frac{dH_n}{d(K/T)} &> 0 \\ \frac{dL_n}{d(K/T)} &> 0 \\ \frac{d(w_H/w_L)}{d(K/T)} &> 0 \end{aligned}$$

Proposition 4 *Given (A1)-(A2), the introduction of the new technology raises the return to capital relative to land. Furthermore, the higher the high-skilled/low-skilled labor ratio, the larger is this increase in the relative rental rate of capital.*

$$\begin{aligned} \textit{for } A &> A^* \\ \frac{R_K}{R_T} &> \frac{\tilde{R}_K}{\tilde{R}_T} \\ \frac{d(R_K/R_T)}{d(H/L)} &> 0 \end{aligned}$$

Proof. See appendix. ■

Together Propositions 1 and 2 show that the model replicates the story of Goldin and Katz (1998). That is, the new capital-dependent sector expands, increasing the relative demand for skilled workers and also their relative wage. If the new technology is a dramatic enough advance it furthers industrialization– displacing the old technology and even employing more unskilled workers than the old technology.[9] This is the standard skill-biased technical change story.

Proposition 3 has strong implications that predict higher returns and more labor employed in the new technology in areas with high relative endowments of capital. Thus, there will be variation in the returns to education that go hand-in-hand with the nature and extent of industrialization before the technological change. The result is entirely intuitive– the region that is technologically backward sees little increase in the returns to education because the technological change is skill intensive, but the backwards region has little of either the old or new capital-intensive technologies. In order for batch processing and electrification to induce high returns to education, there had to be industries that could implement and successfully take advantage of the new technologies. In other words, displacement of old technology will not result in increased returns to education if there is not a significant amount of old technology to be replaced. Proposition 3 highlights the role that the technological endowment has with the return to education. If a region did not have the infrastructure or extensive industry before the diffusion of skill intensive technologies, it would not lead to large returns to education in that region. Proposition 3 therefore provides us with the central test of the theory in the next section.

Finally, Proposition 4 shows how the new technologies increased the incentives to invest in physical capital, especially in areas with high levels of human capital. The new technology increases the return to capital, and the increases will be larger the larger the educational endowment. The model therefore offers an explanation for increased levels of industrialization experienced in the first half of the century, but faster industrialization in the Northeast, Midwest and West (where schooling levels were high) than in the South, where they were lower.

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[9] Given the static nature of the problem, Proposition 1 implies extreme displacement. In the real world, the changeover of capital from the old to new technology is clearly a slower process.

2.4 Derived Demand and Teachers' Relative Wages

Ideally, we would like to test these implications directly using economy wide wage data. Unfortunately, such data is not readily available. We show that reasonable assumptions translate the relative wages of workers overall into relative wages of high- and low-skilled teachers through the derived demand for education and ultimately teachers. We model a schooling sector, and allow students to decide whether to become high- or low-skilled. Let h and l denote the number who become high- and low-skilled, respectively, which are produced using high- and low-skilled workers:

$$\begin{aligned} h &= F_h(H_h, L_h) \\ l &= F_l(H_l, L_l) \\ H_h + H_l &= H_s \\ L_h + L_l &= L_s \end{aligned}$$

The following proposition delineates three assumptions for the above predictions regarding relative wages in the economy overall to also hold for relative wages in the schooling sector.

Proposition 5 *Assume:*
(i) the relative supply of high-skilled teachers is increasing in the relative supply of high-skilled workers in the overall labor force, i.e., $\frac{\partial(H_s/L_s)}{\partial(H/L)} > 0$*; (ii) the relative student demand for high- vs. low-skilled educations is increasing in the relative wage to high-skilled workers, i.e.,* $\frac{\partial(h/l)}{\partial(w_h/w_l)} > 0$*; (iii) the production of high-skilled education is more intensive in high-skilled teachers than the low-skilled education, i.e.,* $H_h/L_h > H_l/L_l$*. Then the relative wage of high-skilled teachers increases, and increases more the higher the capital to land ratio:*

$$\begin{aligned} \frac{w_h}{w_l} &> \frac{\tilde{w}_h}{\tilde{w}l} \\ \frac{d\,(w_h/w_l)}{d\,(K/T)} &> 0 \end{aligned}$$

Proof. See appendix. ■

Given the assumptions in Proposition 5, the predictions for relative wage overall in Propositions 2 and 3 also hold for the relative wage of teachers. Intuitively, increasing returns to skill (which are a function of the factor endowments) lead to increasing demand for education. Since the type of education demanded is intensive in high-skilled individuals, the returns to education for teachers of high level skills will mirror the returns to skill more generally. We turn now to the data on teacher's earnings.

3 The Returns to Education in the Early 20th Century

3.1 Data

We estimate the returns to education with a new and unique data source, a 1909 report from the U.S. Commissioner of Education which allows us to estimate the returns to education of secondary teachers in the early twentieth century by region. The data come from a report prepared for then U.S. Commissioner of Education Elmer Ellsworth Brown on the labor force of teachers. The report, entitled *"The Teaching Staff of Secondary Schools in the United States"* by Edward L. Thorndike was the first report in a five-year, five-report plan to collect data on secondary education (the other four focused on the student body, curriculum, finances, and special education, respectively). Thorndike spent a large part of his professional life researching features of secondary education, many of which have implications for the issues analyzed here.

As noted elsewhere (Goldin and Katz 1995) the rise of the high school movement in the United States was changing the relationship between schooling and wages in the early twentieth century. Thorndike (1922) notes that the number of students enrolled in high school in 1918 was more than six times greater than the number enrolled in 1890. Similarly, while only ten percent of teenagers continued on to high school in 1890, more than thirty percent did by 1920. These changes in high school enrollment changed the high school curriculum and the requirements one had to meet to become a teacher.[10] Thorndike and Robinson (1923) show that the homogenized training of high school students that was the norm in the late nineteenth century had given way to a curriculum that emphasized science and mathematics at the expense of English literature and Latin. In addition to a different focus, the high school curriculum was now highly specialized, the expansion of the curriculum meant that students were rarely taking identical courses of study, a common feature in

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[10] Only beginning in 1909, after our survey, did any states begin to require a high school diploma for the lowest level of teacher certification.

modern high school education. Thorndike and Symonds (1922) saw these changes as altering the returns to skill for high school graduates, but that demand for high school education would remain strong.

> It seems unlikely that the enviable status shown for graduates in 1892 to 1901 in respect to occupations can be fully maintained now and in the future. To maintain it would require that the favored occupations be practically closed to all but high school graduates. This may perhaps be taking place. The supply of high school graduates is increasing so fast that any profession or reputable semi-profession may demand such. Even if it is not fully maintained—indeed, even if there is a considerable movement downward—the high school graduates will still have noteably high occupation status; the correlation between amount of education and dignity of occupation will still be close. (Thorndike and Symonds, p. 451)

These changes in the function and curriculum of high schools had implications for teachers, and they mirrored the changes in the larger labor market. Teachers themselves were now more specialized than before. Thorndike (1923) found that in a survey of teachers own interest in academic subjects that teachers themselves preferred courses with "modern" content such as science and mathematics to literature. He also noted that there were significant age differences in these academic interests. Older teachers, who themselves had been trained in "traditional" high schools, were more interested in Latin and English literature, while young teachers expressed strong interest in physical and biological sciences. As students in high schools sought out these "modern" subjects more than "traditional" ones, the returns to education for teachers will reflect both derived demand for skill and the same market forces that were operating in the labor market more generally.

The report we use was designed to uncover the relationship between experience, education, and wages among high school teachers. It presents tabulated data on the (i) income, (ii) experience, (iii) education, and (iv) gender of U.S. secondary school teachers in 1908, which was collected from a survey corresponding to the 1906-1907 academic year. The data were collected via survey for approximately five thousand teachers, chosen to be a representative sample of the nation's secondary teaching workforce at the time and to be directly comparable across regions. While there are several sources of data that list the education and experience of teachers in specific localities and school districts, Thorndike's goal of a nationally representative picture of the relationship makes his data unique – and it is the only source we know of that allows us to address the issue of geographic heterogeneity in returns to education at this time. Indeed, Thorndike took great care to consider and eliminate the regional and idiosyncratic biases in the data, and the report which accompanies the data used here details many of the potential sources of error that he attempted to eliminate with his survey. The Thorndike report's systematic and consistent measures of education, experience, and wages across space allows us to estimate geographic variation in the returns to education before the 1940 Census.

The data were collected using a two-part survey sent by the Office of Education to administrators for a sample of secondary schools. The first survey collected the salaries, years of secondary and post-secondary education, and actual years of experience of all teachers in the schools surveyed. The fact that years of experience are directly reported is a major strength of the data, since imputed "potential years of experience" (i.e., the traditional $age - years\ of\ schooling - 6$) can diverge strongly from actual experience. This is particularly true for women, who are not as closely tied to the labor force and who constituted a significant share of secondary school teachers at the time.[11] The second survey was a follow up survey sent with the intent of measuring any biases or measurement error in years of education (e.g., adding in primary schooling) and experience (e.g., reporting years of service at the particular school surveyed). Thorndike spent a great deal of effort discussing potential sources of measurement error and trying to quantify or minimize them. The second survey showed that the larger initial survey did not suffer from any aggregate biases. The data we use comes from the first survey.

In general, the data appear to be of extremely high quality. For example, Thorndike mentions that income may vary somewhat due to varying lengths of the school year, such that low salaries in the South are partially explained by shorter school years. The data would nonetheless reflect the actual income received. Thorndike also mentioned that private schools who underpay may feel pressure to overestimate their incomes. For years of education, the distinction between secondary and post-secondary education was not always clear, but this will not affect our results since we look only at the sum of these two. For experience, Thorndike mentioned a tendency to report roughly and to include the current year of service.

Unfortunately, we do not have the original survey returns, only the processed data from the report. We focus on two sets of tables (Tables 7-10 in the original Thorndike Report) for our

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[11] On the other hand, this does introduce a discrepancy between our estimates and estimates based on the more common potential experience.

purposes. The first is individual public school teacher data tabulated separately for California, Georgia, and Texas, and tabulated together for Illinois, Ohio and Wisconsin.[12] These states cover the West Coast (California), Southwest (Texas), Southeast (Georgia), and Midwest (Illinois, Ohio and Wisconsin). These tables allowed creation of a dataset of teachers including their state, gender, income, experience, and education levels. The second set of tables gives separate details on Illinois, Ohio and Wisconsin teachers, but only provides the median income level for each experience-education-gender cell. This allows creation of a dataset of median incomes by gender, experience, education and state for all six states separately.[13] We combine this data with IPUMS data on the industrial composition of the workforce in 1910, 1920 and 1930, and later information on teachers and workers earnings in Census records from 1940 on.

3.2 Summary Analysis

Table 4 presents summary statistics for the individual data by state and gender. Several interesting observations can be gleaned from these. First, secondary teachers averaged 12.6 to 13.8 years of education, having completed not much beyond high school education themselves. These low levels of education are of particular interest because they indicate that increased demand for more, and more modern schooling might have immediate effects on the derived demand for teachers education. Men and women had similar levels of education with women having slightly more education on average in the Midwestern states, and men having a slight advantage in the other states. Education levels are also fairly similar across states, with the exception of California, whose secondary teachers had an additional year of education on average.

Second, average salary levels vary greatly, both between men and women and across states. For example, men in California earn about three times what women in Georgia earn. Salaries in California are substantially higher (roughly \$300/year or 35% higher) than in Georgia and the Midwest states, while those in Texas are significantly lower (about \$100/year or 12%). Again, these wage patterns are in line with the patterns in output per worker, indicating that schooling wages reflected broader labor market conditions. As expected, women earn lower salaries in all

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[12] Thorndike explained that the data were calculated together because the data were similar.

[13] All data from the tables was entered twice, in separate files, to assure accurtate data entry. The use of tabulated data does introduce additional sources of measurement error in the data as both income and experience are grouped into small ranges. Neither of these should substantially change our estimates of the returns to education, and indeed replicating the corresponding groupings in the U.S. census data does not alter the results substantially.

states with the largest difference in Georgia and the smallest differences in the Midwestern states. Beyond gender discrimination, a possible reason for this male wage premium is that a significant number of male secondary teachers performed a dual role of teacher and administrator. Thorndike notes this fact in his report, although we cannot distinguish in the data which teachers were also administrators.

Third, teachers average between 8.2 and 9.6 years of experience, with male teachers having on average 2.0 to 3.6 more years of experience. The additional years of experience may also be related to the previously-mentioned dual teacher-administrator role that males often play. Thus, experience levels were not particularly high, and there were likely many teachers with limited occupation specific on-the-job training, who may have entertained options in the broader labor market. Finally, it should be noted that secondary teaching is a mixed-gender occupation. For the sample overall about half (fifty five percent) of the teachers are men. In the Southern states of Georgia and Texas, this is closer to 2/3 of teachers, while in California women constitute 2/3 of secondary school teachers in the data. Again, male teachers likely had more options for work outside of teaching.

3.3 Regional Variation in the Returns to Education

We estimate the returns to education using a standard Mincerian regression

$$\log(w) = \alpha + \beta_1 s + \beta_2 x + \beta_3 x^2 + \beta_4 g + \varepsilon$$

where w is the wage of a person with s years of schooling, x years of experience, and gender g. Table 5 presents the regression results for each of the states. The estimates show considerable geographic variation in the Mincerian return to schooling.[14] The three Midwestern states and Texas had high returns, 7.0 and 7.1 percent, respectively. Recall that the Midwestern states had high levels of industry, and so likely rapidly rising demand for skill, while Texas had a small educational endowment relative to its technological endowment. In contrast, the returns are much lower in Georgia and especially California. The return in Georgia is just 3.3 percent which is significantly

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[14] We formally tested for differences in the regional returns to education in a pooled regression (unreported), in which we rejected the hypothesis of equal returns between the Midwest and South. As the purpose of this study is to document the extent of the variation and to estimate the returns by region, we present the separate regressions throughout.

different from the returns in Texas and the Midwest states, despite the smaller sample size in Georgia and the consequently larger standard error. This suggest that the low supply of educated labor and low demand for skill in Georgia combined to yield low returns to education. The return in California is a miniscule 0.5 percent and not statistically significant. Recall that California teachers averaged 1.2 more years of education than teachers in the other states, and that California had a large educational endowment relative to its technological endowment.

As described in the previous section, the individual data for Illinois, Ohio and Wisconsin is pooled together. We do, however, have data on median incomes (by sex, education, and experience) separately for each of these three states. Regressions can therefore be run separately using median-level data for these three as a way to disaggregate the returns to education estimates. A key question in interpreting this data is the extent to which estimates from median-level regressions are comparable to individual-level regression results. To answer this question, we construct comparable median-level data for the states that have individual data and compare regression results. If the estimates for the returns to education are similar in the median and individual regressions, then we would surmise that median regressions for the individual Midwestern states will give us reliable estimates of the returns to education for each Midwestern state. Table 6 shows that median regressions do in fact express much of the same information about returns to schooling that individual-regressions do and the qualitative interpretations remain the same. Focusing on the schooling coefficients, Mincerian returns are low in California and Georgia, and relatively high elsewhere.[15] We conclude that the qualitative patterns in the median-level estimates are strongly indicative of patterns in the individual-level estimates. As such, we believe that estimates for the return to education for each Midwestern sate will not be biased by the median representation of the data.

The median level estimates are presented separately for Illinois, Ohio and Wisconsin in Table 7. The main lesson from Table 7 are that wage returns to schooling found in the Midwest using the individual-level data do not appear to be at the same high level across all three states. Mincerian returns are high in Illinois and Ohio, but much lower in Wisconsin. These lower Mincerian returns

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[15] Focusing on the constant term results, we see that constant terms are somewhat higher in the median regressions. The difference in levels is not surprising since the individual- and median-level regressions weight individuals differently; the median regressions give each experience-education cell equal weight, while the individual data use the weights in the sample population. The patterns by sex across states also match up well. The one exception is that returns are typically lower for women in the median-level estimates and slightly higher for men.

are accompanied by higher wage levels in Wisconsin, as evidence by the significantly larger intercept. Thus, even amongst similar states in the same geographic region, there appear to be important differences in the returns to schooling.

Overall, there is substantial variation in the returns to education for these secondary teachers in 1909. The variation is consistent with the theory described in the previous section. As predicted, the returns to education vary with the factor endowments. The Midwest, with its large endowment of education, but also large and growing levels of capital and capital-intensive, skill-complementary technologies, had high returns to education. The South, with its small factor endowments, had low returns to education. California and Texas had similar levels of capital and capital-intensive technologies, but California had a much larger educational endowment. Consistent with a relative oversupply of skill, the relatively large educational endowment in California yields low returns to education, and the small educational endowment yields higher returns in Texas.[16] If these returns to education are indicative of general returns to education for these regions the theory of U-shaped returns to education over the twentieth century would have to be augmented to reflect this regional heterogeneity. In the next section we consider the generalizability and robustness of the results presented in this section.

4 Extensions and Implications

4.1 Robustness

It is important to establish, first, that the returns reported above reflect the return to education across region and not another measure that varies by region such as teacher salary. While Goldin and Katz (2003) have ruled out compulsory schooling and child labor laws as sources of such differences, we must address the question of whether the returns to education for teachers reflect broader market conditions and not only the market for teachers. If the returns simply reflected salary differences by region for teachers, we would not predict the very low returns in California given the substantially higher salaries in that state. Similarly, the high returns in Texas would not be consistent with the low salaries in that state and the similar years of schooling in Texas and in

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[16] Given the estimates of income per worker in the previous section, low returns in California could also partly be due to labor scarcity, which would raise the wages of the unskilled relative to the skilled.

the Midwestern states. We believe that the extent to which the returns to education vary across regions in ways that are not predicted by the summary statistics in Table 4 establishes that the returns reported here are indeed estimates of the return to education and not simply teacher salary variation across states.

We have argued that the geographic variation uncovered in teacher's returns to schooling is indicative of variation in returns in the overall labor force. We use two checks to test the robustness of this assumption. First, we estimate the returns for men only. We divide the sample by gender for two reasons. First, women teachers may have had fewer outside options in the broader labor market. Competition for their services may not have been strong enough for teacher's returns to reflect returns overall. Men would have been more integrated into the market, however, and would have had fewer restrictions placed on their supply of labor. Secondly, Carter and Savoca (1991) have suggested that different levels of education and wages by gender were due to the fact that women were expected to be less attached to the labor market than males, making it unwise to invest heavily in education and lowering the wages that they received in the labor market. Although this point is related to the first, it also suggest that the education of women in teaching occupations would be different from those of men, which was shown earlier. To the extent that variation in schooling identifies the returns to education in a Mincerian regression, separating the sample by gender would tell us if the total returns were biased.

Second, we estimate the returns for teachers with few years of experience. We focus on teachers with little experience because these teachers would presumably have invested less in teacher-specific human capital, and so would hold relatively more general human capital for potential use in the broader labor market. As we noted earlier, younger teachers were more likely to be skilled in science and mathematics, and thus were different in training and orientation than older teachers. The general idea is that the returns to education for teachers with more experience in teaching may not reflect labor market conditions as much as they would reflect occupation or firm-specific investments or skills. We also posit that teachers with less experience also have more and varied outside options. We take "little experience" to be five years or less in the teaching profession. Considering that teachers in the sample averaged more than eight years of experience, this cut-off certainly captures the less experienced teachers while at the same time being a large enough sample to yield robust estimates of the returns to education for the group of teachers with the least attachment to the profession.

Table 8 shows that the pattern in overall returns shows up in men's returns as well (despite the fact that women were an important fraction of teachers) and in returns for the young. The returns in California and Georgia are low, while those in the Midwest and Texas were high. These results further support the contention that our estimates of the return to education do not simply reflect regional salary differentials. The returns for men in Georgia would be higher than those in Table 8 if their high salaries and the same average schooling, as reported in Table 4, were used to predict the return to education. Overall, the results of Table 8 give us further confidence that the geographic variation in teachers' returns to schooling reflect geographic variation in schooling returns of the workforce overall.

4.2 Generalizability and Secular Implications

Applying the evidence for secondary teachers to our story of relative endowments in the overall economy raises the question of whether these estimated returns to education are informative about the returns to education in the labor force overall. Specifically, does variation in teachers' returns to education track with the variation in returns to education of the overall labor force? What can these data tell us about the overall returns to schooling in 1909 relative to 1940? To answer these questions we must look at comparisons of teachers with workers more generally in the U.S. We use IPUMS census data to confirm the relationship between teacher's returns and overall returns over time, and then compare our 1909 results with later results. One caveat is that the census occupational code for teachers includes all teachers (except for professors/instructors and music, dance or art teachers), and not just secondary teachers. To the extent that education selects people into higher paying secondary school teaching, the IPUMS data will overstate the return to schooling *within* secondary education and thus exceed our estimates.

Figure 1 answers the question about secular variation, showing that the relationship between teachers' returns and overall returns is strong over time. The four different series represent teachers' returns for the states we examine, teachers' returns for all states, overall returns for the states we examine, and overall returns for the nation as a whole. Again the number of teachers in the sample states is relatively few (especially in the 1950 census), so we present robust regression results.[17] All

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[17] Robust regressions incorporate a recursive algorithm for reweighting observations that downweights outliers that

four series move substantially together with a mid-century decline followed by rising returns. Indeed, the results for all workers across the nation and all workers in the sample states are nearly identical. While the estimates of teachers' returns in the sample states have perhaps the weakest relationship with overall returns across the nation, the relationship is still quite strong. The correlation between the two series is 0.81 and a regression of overall returns on teachers' returns in the sample states explains 66 percent of the variation in overall returns. We therefore again conclude that comparing teachers' returns over time can give us a strong indication of patterns in overall returns over time.

Table 9 does precisely this, comparing the 1909 return to several benchmarks from the 1940 census. The 1909 return is based on a weighted regression of the individual data in 1909. Since the sample sizes varied greatly over region and were not entirely representative, the weights were chosen to make the sample representative of the sample of teachers in 1940. This required weighting the California sample by a factor of 1.92, the Georgia sample by a factor of 1.94, and the Texas sample by a factor of 1.74, and weighting the Midwest sample by a factor of 0.59. The resulting estimate for the return to education was 8.3 percent in 1909. At first glance, the returns seem quite high for a within-occupation return to schooling. Comparing with 1940, however, the return is not overly high. Indeed it is slightly less than the Mincerian return of 9.1 percent estimated for teachers in these same states in 1940 though not significantly different. The returns for all workers in these states were somewhat higher at 9.6 percent per year in 1940, while those for the nation overall were slightly lower at 8.9 percent.

Using 1940 as a benchmark, we would surmise that since the return to schooling for teachers in the sample states was representative of the returns to workers for the nation overall, that the same is true for 1909. In this case, returns in 1909 would be relatively high (since 1940 preceded the Great Compression and was a year of relatively high returns to schooling), but lower than the most comparable evidence, the returns in Iowa in 1914. Recall the caveat that the returns from 1940 are for all teachers, not just secondary teachers. The 1940 teachers' regressions include both primary and secondary teachers, while the 1909 estimates are based on only secondary teachers. Secondary teachers tend to be more educated and substantially better paid. To the extent that schooling enables teachers to sort into higher paying secondary education jobs, the 1940 estimates

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have too strong an influence on regression results. Robust regressions produced substantially lower estimates than OLS in 1950 (0.075 vs. 0.096), but otherwise similar results. Robust regression also has little effect on the 1909 sample estimates.

would be biased upward as an estimate of the return to education of secondary teachers.

5 Conclusion

We have presented evidence that differential factor endowments and prevalence of technologies are important parts of the story of how skill biased technical change the returns to education. In our model of skill biased technical change, we showed how returns to education vary with factor endowments. We have argued that the shape of these changes over time will be related to factor endowments before the skill-biased technical change. Our model predicted that regions with greater degrees of capital intensity would experience higher returns to education than those with less capital intensive endowments. With skill biased technical change, we should expect U-shaped returns in regions with large capital endowments, but steadily increasing returns in regions with relatively small capital endowments.

We have shown, using historical evidence on the returns to education for secondary teachers in the U.S., that the returns to education showed marked geographic variation. Our data on the returns to skill for secondary teachers in the very earliest part of the twentieth century is consistent with our theoretical predictions. Teachers in the Midwest had greater returns to education than those in the South. Furthermore, we found that this result is robust – the returns to teachers tracks with the returns to skill more generally, and our result was robust to considering only men and younger teachers. In sum, we find strong evidence that returns to education were large in 1909 in the Midwest, consistent with Goldin and Katz, but that they may have varied considerably across states. As such, the study of U-shaped returns to education should be modified to reflect the fact that returns for some regions would rise continuously throughout the twentieth century.

The variation in returns to education has important implications for the study of the returns to skill more generally, and for education and immigration policies in many developing nations in particular. Rather than states or regions of one nation, our model easily generalizes up to different nations or down to individual cities with sufficiently segmented factor markets, where locations with large capital endowments will see large returns to education, while those with relatively small capital endowments will see small returns initially. For example, Uwaifo (2006) notes considerable debate over the size and shape of returns to education in Sub-Saharan Africa, with most anecdotal evidence pointing to low returns. Her estimates of the return to education in Nigeria in the 1990s (3.6%) are similar to the returns we found in Georgia in 1909. Our results suggest that while skill biased technological change will eventually lead to universal large returns to skill in the long run as markets integrate and capital intensity diffuses, in the short run locations with relatively small capital endowments may see negligible returns to education. This has important implications for immigration, emigration, and urban policies in locations with small factor endowments – to create incentives for the high-skilled workforce to remain when the returns to education are low at home, but large in other parts of the world.

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6 Appendix

6.1 Proof of Proposition 1:

A) Proving $K_n = K$

Since the land-intensive technology and the old capital-intensive technologies have the same factor shares, it can be readily shown that they will always employ the same ratio of inputs. It is also trivial to show that K_n, H_n and L_n are increasing in A. Thus, A^* can be derived as the level that equates the marginal return to capital in the new capital-intensive technology when all capital is employed in that sector (i.e., $K_n = K$) to the marginal return to land in the land-intensive sector (which equals the potential marginal return to capital in the old capital-intensive sector):

$$\begin{aligned} R_{K,n}(A^*) &= R_{K,o}(A^*) \\ A^* \alpha K^{\alpha-1} \left(f_H H\right)^{\gamma} \left(f_L L\right)^{1-\alpha-\gamma} &= \alpha T^{\alpha-1} \left(\left(1-f_H\right) H\right)^{\beta} \left(\left(1-f_L\right) L\right)^{1-\alpha-\beta} \end{aligned}$$

Solving for

$$A^* = \frac{(1-\alpha-\beta)^{1-\alpha-\beta} \beta^{\beta}}{(1-\alpha-\gamma)^{1-\alpha-\gamma} \gamma^{\gamma}} \left(\frac{H}{L}\right)^{\beta-\gamma} \left[\frac{(1-\alpha)(T+K)}{(\beta T+\gamma K)} - 1\right]^{\beta-\gamma}$$

For all levels higher than A^*, $R_{K,n}(A^*) = \tilde{R}_{K,o}(A^*)$ and so $K_n = K$.

B. Proving $\frac{H_n}{H} > \frac{L_n}{L}$

We prove by contradiction. Defining $f_H \equiv \frac{H_n}{H}$ and $f_L \equiv \frac{L_n}{L}$ we assume $\frac{H_n}{H} \leq \frac{L_n}{L}$, which is $f_H < f_L$.Optimality again requires

$$\begin{aligned} w_H &= \gamma A \left(\frac{K}{f_L L}\right)^{\alpha} \left(\frac{f_H H}{f_L L}\right)^{\gamma-1} \\ &= \beta \left[\frac{T}{(1-f_L) L}\right]^{\alpha} \left[\frac{(1-f_H) H}{(1-f_L) L}\right]^{\beta-1} \qquad (1) \\ w_L &= (1-\alpha-\gamma) A \left(\frac{K}{f_L L}\right)^{\alpha} \left(\frac{f_H H}{f_L L}\right)^{\gamma} \\ &= (1-\alpha-\beta) \left[\frac{T}{(1-f_L) L}\right]^{\alpha} \left[\frac{(1-f_H) H}{(1-f_L) L}\right]^{\beta} \qquad (2) \end{aligned}$$

Dividing the two equations by each other yields:

$$\begin{aligned} \frac{\gamma}{(1-\alpha-\gamma)} \frac{(1-f_H)}{(1-f_L)} &= \left(\frac{f_H}{f_L}\right) \frac{\beta}{(1-\alpha-\beta)} \\ \frac{\gamma}{(1-\alpha-\gamma)} &\leq \frac{\beta}{(1-\alpha-\beta)} \\ \gamma &\leq \beta \end{aligned}$$

But $\gamma > \beta$, by assumption.

6.2 Proof of Proposition 2

A) Proof of $H_n > H_o$

Again, one can trivially show that H_n is increasing in A, so it suffices to show that at $A = A^*$, $H_n > H_o$. We prove equivalently that $f_H > \tilde{f}_H$. Consider the first order conditions above. Dividing the top by the bottom yields and expression for which we define an implicit function:

$$g_1(f_H, f_L) = \begin{bmatrix} \frac{\gamma}{(1-\alpha-\gamma)}\frac{(1-f_H)}{f_H} - \\ \frac{(1-f_L)}{f_L}\frac{\beta}{(1-\alpha-\beta)} \end{bmatrix} = 0$$

It is trivial to show that $\partial g_1/\partial f_H < 0$ and $\partial g_1/\partial f_L < 0$. Since $f_L < f_H$, it suffices to show that $g_1(\tilde{f}_H,\tilde{f}_L) > 0$. Substituting in $\tilde{f}_H = \tilde{f}_L = K/(T + K)$ yields

$$g_1(\tilde{f}_H, \tilde{f}_L) = \frac{T}{K}\left(\frac{\beta}{(1-\alpha-\beta)} - \frac{\gamma}{(1-\alpha-\gamma)}\right) < 0$$

since $\gamma > \beta$.

B) Proof of $\frac{w_H}{w_L} > \frac{\tilde{w}_H}{\tilde{w}_L}$

We prove by contradiction assume:

$$\begin{aligned} \frac{w_H}{w_L} &< \frac{\tilde{w}_H}{\tilde{w}_L} \\ \frac{\beta}{(1-\alpha-\beta)}\left(\frac{(1-f_H)\,H}{(1-f_L)\,L}\right)^{-1} &< \frac{\beta}{(1-\alpha-\beta)}\left(\frac{\tilde{f}_H H}{\tilde{f}_L L}\right)^{-1} \\ \left(\frac{1-f_H}{1-f_L}\right)^{-1} &< 1 \\ f_H &< f_L \end{aligned}$$

which contradicts Proposition $\not{1}$.

C) Proof of $L_n > \tilde{L}_o$ for $\forall A$ for $\hat{A} > A^*$

It is trivial to show that both H_n and L_n are increasing in A. We show that $H_n + L_n < \tilde{H}_o + \tilde{L}_o$ for $A = A^*$ and then derive $\hat{A}$.

Assume $A = A^*$ and $L_n > \tilde{L}_o$. By construction at A^*, the marginal product of capital and land are equated, as are the marginal product of low skilled workers:

$$\begin{aligned} \alpha A^* K^{\alpha-1}\left(f_H H\right)^{\gamma}\left(f_L L\right)^{1-\alpha-\gamma} &= \\ \alpha T^{\alpha-1}\left(\left(1-f_H\right)H\right)^{\beta}\left(\left(1-f_L\right)L\right)^{1-\alpha-\beta} & \end{aligned}$$

$$\begin{aligned} \left(1-\alpha-\gamma\right)A^* K^{\alpha-1}\left(f_H H\right)^{\gamma}\left(f_L L\right)^{-\alpha-\gamma} &= \\ \left(1-\alpha-\gamma\right)T^{\alpha-1}\left(\left(1-f_H\right)H\right)^{\beta}\left(\left(1-f_L\right)L\right)^{-\alpha-\beta} & \end{aligned}$$

Dividing these two expressions by each other yields:

$$\begin{aligned} \frac{1}{(1-\alpha-\gamma)}\left[\frac{f_L L}{K}\right] &= \frac{1}{(1-\alpha-\beta)}\left[\frac{(1-f_L)\,L}{T}\right] \\ \frac{T}{(1-\alpha-\gamma)}\left(1-f_L\right) &= \frac{K}{(1-\alpha-\beta)}f_L \\ \frac{(1-\alpha-\gamma)\,K}{(1-\alpha-\gamma)\,K + (1-\alpha-\beta)\,T} &= f_L \end{aligned}$$

The expressions can be solved for f_L and $f_{H:}$. Now we start with the assumption:

$$\begin{aligned}\frac{(1-\alpha-\gamma)\,K}{(1-\alpha-\gamma)\,K+(1-\alpha-\beta)\,T} &> \frac{K}{T+K}\\ \gamma &< \beta\end{aligned}$$

which contradicts (A2)

We now derive $\hat{A}$ by assuming:

$$\hat{f}_L = \tilde{f}_L = \frac{K}{T+K} \tag{3}$$

and solving for the implied $\hat{A}$. The first order conditions for high and low skilled labor again yield the following expression:

$$\begin{aligned}\left(\frac{1-\alpha-\gamma}{\gamma}\right)\frac{\left(1-\hat{f}_L\right)}{\hat{f}_L} &= \left(\frac{1-\alpha-\beta}{\beta}\right)\frac{\left(1-\hat{f}_H\right)}{\hat{f}_H}\\ \left(\frac{1-\alpha-\gamma}{\gamma}\right)\frac{T}{K}\hat{f}_H &= \left(\frac{1-\alpha-\beta}{\beta}\right)(1-f_H)\\ \hat{f}_H &= \frac{\gamma\,(1-\alpha-\beta)\,K}{[\gamma\,(1-\alpha-\beta)\,K+\beta\,(1-\alpha-\gamma)\,T]}\end{aligned}$$

Substituting $\hat{f}_L$ and $\hat{f}_H$ into the first order condition on high-skilled labor, we solve for $\hat{A}$:

$$\hat{A} = \frac{\beta}{\gamma}\left[\frac{\beta\,(1-\alpha-\gamma)\,(T+K)}{[\gamma\,(1-\alpha-\beta)\,K+\beta\,(1-\alpha-\gamma)\,T]}\,\frac{H}{L}\right]^{\beta-\gamma}$$

6.3 Proof of Proposition 3

The relative wage equals the ratio of the marginal products in agriculture, which can be simplified to:

$$\begin{aligned}w_H/w_L &= \frac{\beta}{1-\alpha-\beta}\left(\frac{L_a}{L_a}/\frac{L}{H}\right)\\ \frac{d\log\left(w_H/w_L\right)}{d\log\left(K/T\right)} &= \frac{d\log(1-f_L)}{d\log\left(K/T\right)}-\frac{d\log(1-f_H)}{d\log\left(K/T\right)}\end{aligned}$$

so we proceed by showing that $\frac{d\log(1-f_H)}{d\log(K/T)} < \frac{d\log(1-f_L)}{d\log(K/T)} < 0$, which implies $\frac{dH_n}{d(K/T)} > 0$ and $\frac{dL_n}{d(K/T)} > 0$, and, by the above equation, $\frac{d(w_H/w_L)}{d(K/T)} > 0$. To simplify presentation, we change notation to work directly with the fractions of labor in agriculture, ${}^{a}f_L \equiv 1-f_L$ and ${}^{a}f_H \equiv 1-f_H$, and use the implicit function defined by the log of the first-order conditions for comparative statics

$$
\begin{aligned}
\log\left(\frac{\gamma}{\beta}\right) + \log A + (\alpha+\beta-1)\log {}^a f_L + & \\
(1-\alpha-\gamma)\log\left(1 - {}^a f_L\right) + (1-\beta)\log {}^a f_H + & \\
(\gamma-1)\log\left(1 - {}^a f_H\right) + \alpha\log\left(\frac{K}{T}\right) + (\gamma-\beta)\log\left(\frac{H}{L}\right) &= 0 \\
\log\left(\frac{1-\alpha-\gamma}{1-\alpha-\beta}\right) + \log A + (\alpha+\beta)\log {}^a f_L + & \\
(-\alpha-\gamma)\log\left(1 - {}^a f_L\right) - \beta\log {}^a f_H + & \\
\gamma\log\left(1 - {}^a f_H\right) + \alpha\log\left(\frac{K}{T}\right) + (\gamma-\beta)\log\left(\frac{H}{L}\right) &= 0
\end{aligned}
$$

Now solving the first order conditions for the change $d\log {}^a f_H$ and $d\log {}^a f_L$ as $\log(K/T)$ yields the following system of equations:

$$
\begin{matrix}
\left[\begin{matrix} (1-\beta)+ \\ (1-\gamma)\left(\frac{{}^a f_H}{1-{}^a f_H}\right) \end{matrix}\right] & \left[\begin{matrix} (\alpha+\beta-1)- \\ (1-\alpha-\gamma)\left(\frac{{}^a f_L}{1-{}^a f_L}\right) \end{matrix}\right] \\
\left[\begin{matrix} -\beta- \\ \gamma\left(\frac{{}^a f_H}{1-{}^a f_H}\right) \end{matrix}\right] & \left[\begin{matrix} (\alpha+\beta)+ \\ (\alpha+\gamma)\left(\frac{{}^a f_L}{1-{}^a f_L}\right) \end{matrix}\right]
\end{matrix}
\begin{matrix} \frac{d\log {}^a f_H}{d\log(K/T)} \\ \frac{d\log {}^a f_L}{d\log(K/T)} \end{matrix}
=
\begin{matrix} -\alpha \\ -\alpha \end{matrix}
$$

Defining the 2 by 2 matrix as M. Given ${}^a f_L >{}^a f_H$ (which follows immediately from Proposition 1), we show after algebraic simplification that that the determinant of M is positive:

$$
\begin{aligned}
|M| &= \alpha + \alpha\left(\frac{{}^a f_H}{1 - {}^a f_H} + \frac{{}^a f_L}{1 - {}^a f_L}\right) + \\
&\quad \alpha\left(\frac{{}^a f_H}{1 - {}^a f_H}\right)\left(\frac{{}^a f_L}{1 - {}^a f_L}\right) + \\
&\quad \alpha(\gamma-\beta)\left(\frac{{}^a f_L}{1 - {}^a f_L} - \frac{{}^a f_H}{1 - {}^a f_H}\right) > 0
\end{aligned}
$$

Applying Cramer's rule, we show that the resulting solutions are therefore negative:

$$
\begin{aligned}
\frac{d\log {}^a f_H}{d\log(K/T)} &= \frac{-\alpha\left[1 + \left(\frac{{}^a f_L}{1-{}^a f_L}\right)\right]}{|M|} < 0 \\
\frac{d\log {}^a f_L}{d\log(K/T)} &= \frac{-\alpha\left[1 + \left(\frac{{}^a f_H}{1-{}^a f_H}\right)\right]}{|M|} < 0
\end{aligned}
$$

and the difference between the first exceeds the second:

$$
\begin{aligned}
\frac{d\log^{a} f_L}{d\log\left(K/T\right)}-\frac{d\log^{a} f_H}{d\log\left(K/T\right)} &= \frac{\alpha\left(\frac{^{a}f_L}{1-^{a}f_L}-\frac{^{a}f_H}{1-^{a}f_H}\right)}{\left[\begin{array}{c}\alpha+\alpha\left(\frac{^{a}f_L}{1-^{a}f_L}+\frac{^{a}f_H}{1-^{a}f_H}\right)\\ +\alpha\left(\frac{^{a}f_L}{1-^{a}f_L}\right)\left(\frac{^{a}f_H}{1-^{a}f_H}\right)+\\ \alpha((\gamma-\beta)\left(\frac{^{a}f_L}{1-^{a}f_L}-\frac{^{a}f_H}{1-^{a}f_H}\right)\end{array}\right]} \\
&> 0
\end{aligned}
$$

6.4 Proof of Proposition 4

The fact that $\frac{R_K}{R_T} > \frac{\tilde{R}_K}{\tilde{R}_T}$ follows directly from Proposition 1. We know that $\frac{\tilde{R}_K}{\tilde{R}_T} = 1$, and from the proof in Proposition 1, we show that $R_K > R_T$. We show now that the relative return to capital and labor is increasing in H/L:

$$
\begin{aligned}
\frac{R_K}{R_T} &= \frac{\alpha A K^{\alpha-1}\left(f_H H\right)^{\gamma}\left(f_L L\right)^{1-\alpha-\gamma}}{\alpha T^{\alpha-1}\left(\left(1-f_H\right)H\right)^{\beta}\left(\left(1-f_L\right)L\right)^{1-\alpha-\beta}} \\
&= A\left(\frac{K}{T}\right)^{\alpha-1}\left(\frac{f_H}{f_L}\right)^{\gamma}\left(\frac{1-f_L}{1-f_H}\right)^{\beta}\left(\frac{H}{L}\right)^{\gamma-\beta}
\end{aligned}
$$

$$
\frac{1-\alpha-\gamma}{\gamma}\left(\frac{f_H}{f_L}\right)=\frac{1-\alpha-\beta}{\beta}\left(\frac{1-f_H}{1-f_L}\right)
$$

$$
\begin{aligned}
\frac{R_K}{R_T} &= A\frac{\beta\left(1-\alpha-\gamma\right)}{\gamma\left(1-\alpha-\beta\right)}\left(\frac{K}{T}\right)^{\alpha-1}\left(\frac{f_H H}{f_L L}\right)^{\gamma-\beta} \\
\frac{d\left(R_K/R_T\right)}{d\left(K/L\right)} &= C\left(\frac{K}{T}\right)^{\alpha-1}\left(\frac{H_n}{L_n}\right)^{\gamma-\beta-1}\frac{d\left(H_n/L_n\right)}{d\left(K/L\right)} > 0
\end{aligned}
$$

where

$$
C = A\left(\gamma-\beta\right)\frac{\beta\left(1-\alpha-\gamma\right)}{\gamma\left(1-\alpha-\beta\right)}
$$

6.5 Proof of Proposition 5

Given condition (iii), the effect of (h/l) on w_h/w_l follows from the Stolper-Samuelson Theorem. Condition 1 connects the effects on $w_{h,s}/w_{l,s}$ to w_H/w_L. Similarly, given condition (iii), the effect of H_s/L_s on w_h/w_l follows from the Rybcynski Theorem, while Condition (ii) connects these effects on $w_{h,s}/w_{l,s}$ to w_H/w_L.

Table 1
Summary of Productivity Estimates by Region and State, 1880-1920

	Nominal Personal Inomce per Capita Relative to the US Average			Price Adjusted Income per Worker Relative to US Average		
Region	1880	1900	1920	1880	1900	1920
West	190	153	124	131	126	117
Midwest	97	103	101	110	114	102
South	54	54	64	56	56	67
Northeast	114	139	132	133	128	125

	Price Adjusted Income per Worker				Percent Cotton	Growth Rate of
				Percent of	Mechanically	Income / Worker
State	1880	1900	1920	Labor in Mining	Harvested	1880 - 1920
California	777.1	754.9	2223.0	13.1	87.0	1.14%
Georgia	213.5	206.8	857.2	0.1	14.0	1.51%
Illinois	669.6	729.2	2042.1	1.7	0.0	1.21%
Iowa	565.0	625.4	1585.7	0.9	0.0	1.12%
Ohio	593.4	624.8	1842.0	0.8	0.0	1.23%
Texas	289.0	389.6	1371.3	0.0	58.0	1.69%
Wisconsin	508.1	523.7	1537.4	0.4	0.0	1.20%
Alabama	214.1	212.5	796.9	0.3	8.0	1.43%
Arizona	650.1	689.8	1747.5	30.0	73.0	1.07%
Colorado	638.6	733.5	1817.6	32.2	0.0	1.14%
Indiana	498.4	545.5	1610.2	0.9	0.0	1.27%
Maine	413.1	464.5	1558.5	0.6	0.0	1.44%
Massachusetts	693.1	677.6	1891.2	0.2	0.0	1.09%
Michigan	536.2	528.0	1641.0	1.6	0.0	1.21%
Minnesota	590.2	619.9	1522.0	0.0	0.0	1.03%
Montana	647.9	738.7	1643.2	27.8	0.0	1.01%
Nevada	1034.6	776.8	1976.0	28.6	0.0	0.70%
New York	750.7	778.5	2438.5	0.3	0.0	1.28%
New Mexico	275.8	408.7	1370.5	6.6	64.0	1.74%
Oregon	550.5	570.0	1920.4	7.1	0.0	1.36%
Pennsylvania	644.2	635.2	1935.8	7.3	0.0	1.19%
South Carolina	190.6	176.4	805.7	0.1	6.0	1.57%
South Dakota	433.9	559.8	1596.5	14.0	0.0	1.41%
Tennessee	285.9	284.3	1000.1	0.4	19.0	1.36%
Washington	508.1	523.7	1537.4	4.0	0.0	1.20%
Utah	431.8	558.9	1629.5	9.5	0.0	1.44%
Wyoming	638.3	574.7	2093.6	4.5	0.0	1.29%

Sources:
Regional Estimates (Top Panel) come from Mitchener and McLean (1999) Table 1 (p. 1019)
State Estimates (Bottom Panel) come from Mitchener and McLean (2003) Appendix Table 1
The relative income estimates are population weighted and take the US average as 100 (e.g. a region estimate of 50 implies that region had income per worker that was 50% of the US average).
For the methodology used to estimate Personal Income per Capita and Price Adjusted Income per Worker see Mitchener and McLean (1999). For the methodology used to estimate the percent of the labor force in mining and the percent of cotton mechanicaly harvested see the appendix of Mitchener and McLean (2003).

Table 2

Summary of Educational Endowment Factors for the Returns to Education, 1900-1930

State	1900 Literacy Rate	1910 Literacy Rate
California	94.47	95.48
Georgia	66.94	76.74
Illinois	95.9	95.73
Iowa	97.59	97.98
Ohio	95.84	96.46
Texas	83.95	87.77
Wisconsin	95.12	96.34

Literacy Rate Calculated for those above the age of 10 based on IPUMS 1900 and 1910 5% samples.

Public Elementary and Secondary School Expenditures 1900-1930

State	Total Expenditures (thousands of Dollars)				Per capita of state population (in Dollars)				Per capita of population 5-17, (in Dollars)			
	1900	*1910*	*1920*	*1930*	*1900*	*1910*	*1920*	*1930*	*1900*	*1910*	*1920*	*1930*
California	6,909	18,211	48,980	146,943	4.65	7.66	14.29	25.88	19.61	39.40	72.12	128.99
Georgia	1,980	4,420	9,076	18,677	0.89	1.70	3.13	6.42	2.52	5.30	9.72	20.87
Illinois	17,757	34,036	69,358	154,142	8.08	6.04	10.69	20.20	13.03	24.53	44.32	87.07
Iowa	8,496	12,767	37,334	50,737	3.81	5.76	15.53	20.53	12.04	21.85	62.44	82.53
Ohio	13,335	25,500	67,427	145,910	3.21	5.35	11.71	21.95	11.30	22.63	50.63	91.22
Texas	4,465	11,777	33,606	78,150	1.46	3.02	7.21	13.42	4.18	9.65	23.81	48.01
Wisconsin	5,493	10,789	27,255	54,088	2.65	4.64	10.36	18.40	8.88	16.84	39.93	72.71

Sources: 1900: Statistical Abstract of the United States, 1925, 1910-1930: Statistical Abstract of the United States, 1935

School Attendance as Percentage of Eligible Population 14-20 Years of Age 1910-1930

State	14 to 15 Year Olds			16 to 17 Year Olds			18 to 20 Year Olds		
	1910	*1920*	*1930*	*1910*	*1920*	*1930*	*1910*	*1920*	*1930*
California	83.6	89.1	97.2	50.1	54.7	82.1	17.3	21.9	32.7
Georgia	59.3	67.7	73.7	37.3	39.7	43.6	12.1	11.7	14.3
Illinois	75.4	79.0	92.4	36.8	37.1	57.1	11.7	12.3	19.9
Iowa	81.8	85.8	89.8	50.5	51.4	63.9	17.9	19.4	25.1
Ohio	79.0	87.8	96.6	42.4	44.4	67.7	14.1	14.4	22.8
Texas	76.7	79.1	84.6	51.0	48.8	57.2	15.2	14.2	19.8
Wisconsin	75.4	77.8	86.3	36.2	42.2	63.4	13.1	14.6	21.5

Sources: 1910-1920:Abstract of the 14th Census of the United States, 1930: Abstract of the 15th Census of the United States

Table 3A
Summary of Technological Endowment Factors for the Returns to Education, 1900-1910

1900

State	Percent of Labor Force in Manufacturing	Value of Livestock Per Capita	Value of Machinery per Capita	Value of Livestock per Ag Workforce	Value of Machinery Per Ag Workforce	Capital per Establishment 1900/ Capital per Establishment 1905
California	14.73	45.3	14.4	306.0	96.9	2.5
Georgia	7.62	15.9	4.4	53.2	14.8	3.5
Illinois	20.49	40.2	9.3	279.1	64.8	3.2
Iowa	7.87	124.9	26.0	482.5	100.3	3.4
Ohio	25.28	30.3	8.7	190.1	54.9	3.3
Texas	4.86	78.9	9.9	251.6	31.5	5.0
Wisconsin	19.42	46.6	14.1	237.8	72.2	2.4

1910

State	Percent of Labor Force in Manufacturing	Value of Livestock Per Capita	Value of Machinery per Capita	Value of Livestock per Ag Workforce	Value of Machinery Per Ag Workforce
California	24.13	53.6	15.4	367.8	105.3
Georgia	12.79	31.0	8.0	99.2	25.7
Illinois	39.05	54.8	14.0	449.4	114.6
Iowa	17.69	176.6	42.9	751.9	182.7
Ohio	47.05	41.4	10.7	300.9	78.1
Texas	9.69	81.8	14.6	269.6	48.1
Wisconsin	39.61	67.9	22.7	357.3	119.4

Sources:
Value of Machinery and Value of Livestock: 1916 Statistical Abstract of the United States
Percent of the Labor force in Manufacturing: Percent of labor force in Broad, Large and Speical Manufacturing and Electrification Industries as given by the 1924 Statistical Abstract of the United States.
Population Size, and Agricultural Workforce Size: 1924 Statistical Abstract of the United States
Capital per Establishment in 1900: 1905 Statistical Abstract of the United States
Capital per Establishment in 1905: 1910 Statistical Abstract of the United States

Table 3B
Summary of Technological Endowment Factors for the Returns to Education, 1890 - 1910

State	Number of Tech. Industry Firms, 1890	Value Added per Man. Establishment, 1904	Internal Combustion Engines, 1904	Electric Motors 1899	Horsepower per Establishment, 1899
California	1,540	20.67	--	281	25.41
Georgia	1,673	49.20	118	45	45.27
Illinois	5,459	53.01	1,447	1,839	38.91
Iowa	2,613	30.35	922	211	22.09
Ohio	7,997	46.12	2,004	1,721	56.51
Texas	2,503	25.68	403	54	37.39
Wisconsin	4,512	45.21	1,037	551	46.47

State	Number of Tech Industry Firms, 1900	Value Added per Man. Establishment, 1909	Internal Combustion Engines, 1909	Electric Motors 1909	Horsepower per Establishment, 1904
California	2,184	22.78	765	1,591	30.76
Georgia	3,301	48.20	418	829	68.47
Illinois	8,209	58.93	1,755	17,432	49.70
Iowa	3,821	38.25	1,336	1,448	24.67
Ohio	9,557	64.78	3,354	21,279	81.03
Texas	5,793	29.88	802	1,011	52.13
Wisconsin	4,512	57.97	1,578	7,501	51.44

Sources:
12th, 13th, and 14th Census of Manufactures, General Report and Analytical Tables (various Tables).
Technical Industry firms are defined as the following: Aluminum Manufactures, Automobile bodies and parts, Automobile repairing, Automobiles, brick, tile, and fire-clay products, bronze and brass products, Copper products, Shop construction and repairs, chemicals, Coke, Electrical machinery, Electroplating, Steam gas and water engines, Explosives, Foundry products, glass, iron and steel, Lithographing, Patent medicines and compounds, Rubber, Steam fittings, Stoves and furnaces, Structural ironwork, Sulfuric, Nitric and mixed Acids, Wire and Wirework. Oil and Petroleum firms are not listed until 1919, and therefore are not included here.

Table 3C
Summary of Technological Endowment Factors for the Returns to Education, 1900-1930

State	Internal Combustion Horsepower, 1900	Horsepower Per Establishment 1904	Internal Combustion Engines per Establishment, 1919	Electric Motors per Establishment, 1919
California	3744	30.76	0.09	0.33
Georgia	365	68.47	0.13	0.42
Illinois	8758	49.70	0.06	2.34
Iowa	4524	24.67	0.14	0.69
Ohio	14230	81.03	0.17	2.87
Texas	968	52.13	0.19	0.54
Wisconsin	4358	51.44	0.16	2.08

State	Internal Combustion Horsepower, 1910	Horsepower Per Establishment 1914	Internal Combustion Engines per Establishment, 1929	Electric Horsepower per Establishment, 1929
California	10115	48.82	2.7	14.1
Georgia	3780	77.04	2.5	12.2
Illinois	37025	71.02	6.9	55.7
Iowa	8025	34.04	1.6	33.5
Ohio	103801	127.91	10.1	127.1
Texas	15745	66.05	11.7	32.2
Wisconsin	19531	74.95	1.3	57.6

Sources:
Establishment counts from the 1925 Statistical Abstract of the United States
Internal Combustion Horsepower: Abstract of the 14th Census of the United States
Horsepower per Establishment: 1916 Statistical Abstract of the United States
Internal Combustion and Electric Motors per Establishment: Abstract of the 14th Census of the United States
Internal Combustion and Electric Motors Horsepower per Establishment: Abstract of the 15th Census of the United States

Table 4
Summary Statistics from Thorndike Report

	California	Georgia	Ohio, Illinois, & Wisconsin	Texas
Mean Annual Salary (Overall)	1142	828	848	733
	(316)	(377)	(379)	(278)
Mean Annual Salary (Men)	1375	1001	918	823
	(344)	(331)	(403)	(290)
Mean Annual Salary (Women)	1020	474	757	575
	(219)	(145)	(323)	(159)
Mean Years Schooling (Overall)	13.8	12.6	12.6	12.6
	(1.4)	(1.7)	(1.9)	(1.9)
Mean Years Schooling (Men)	13.9	12.9	12.4	12.8
	(1.6)	(1.6)	(2.1)	(2.0)
Mean Years Schooling (Women)	13.7	11.9	12.9	12.2
	(1.4)	(1.6)	(1.6)	(1.6)
Mean Years Experience (Overall)	8.3	8.2	9.1	9.6
	(7.0)	(5.8)	(7.2)	(7.1)
Mean Years Experience (Men)	10.6	9.2	10.0	10.3
	(7.3)	(6.1)	(7.1)	(7.3)
Mean Years Experience (Women)	7.1	6.2	8.0	8.3
	(6.5)	(4.6)	(7.1)	(6.6)
Fraction Male	0.34	0.67	0.57	0.64
Number of Observations	658	137	3141	381

Source: Authors' Calculations from Thorndike Report
Standard errors are listed in parentheses.

Table 5
Mincerian Regressions for the Returns to Education by State, 1909

	California	Georgia	Ohio, Illinois, & Wisconsin	Texas
Schooling	0.005	0.033	0.070	0.071
	(0.006)	(0.016)	(0.003)	(0.009)
Experience	0.034	0.012	0.048	0.034
	(0.004)	(0.013)	(0.004)	(0.007)
Exper. Squared	-0.0007	0.0004	-0.0008	-0.0009
	(0.0001)	(0.0006)	(0.0001)	(0.0003)
Male Dummy	0.22	0.64	0.16	0.27
	(0.02)	(0.06)	(0.01)	(0.03)
Intercept	6.67	5.63	5.35	5.26
	(0.08)	(0.20)	(0.04)	(0.10)
R^2	0.45	0.61	0.39	0.42
N	658	137	3141	381

Source: Authors' Calculations from Thorndike Report
Dependent variable is the log of the wage in all regressions.
Robust Standard errors are listed in parentheses.

Table 6
Comparing Mincerian Regression Estimates From Individual- and Median-Level Regressions

	Schooling Coefficient		Male Coefficient		Intercept	
State	Individual Data	Median Data	Individual Data	Median Data	Individual Data	Median Data
California	0.005	0.013	0.22	0.22	6.67	6.59
Georgia	0.033	0.026	0.64	0.64	5.63	5.70
Ohio, Illinois, & Wisconsin	0.070	0.058	0.17	0.17	5.35	5.52
Texas	0.071	0.071	0.27	0.28	5.26	5.24

Source: Author's Calculations from Thorndike Report.

Dependent variable is the log of the wage in all regressions.

Table 7
Median Mincerian Regression Results for Illinois, Ohio, and Wisconsin, 1909

	Illinois	Ohio	Wisconsin
Schooling	0.073	0.080	0.034
	(0.009)	(0.009)	(0.010)
Experience	0.026	0.030	0.042
	(0.009)	(0.009)	(0.010)
Exper. Squared	0.0001	-0.0003	-0.0006
	(0.0003)	(0.0003)	(0.0003)
Male Dummy	0.192	0.079	0.274
	(0.048)	(0.047)	(0.051)
Intercept	5.819	5.766	6.029
	(0.078)	(0.104)	(0.085)
N	122	133	99
R^2	0.69	0.59	55.00

Source: Authors' calculations from Thorndike Report
Dependent variable is the log of the wage in all regressions.
Robust standard errors listed in parentheses.

Table 8
Mincerian Regressions for Men, Women, and Less Experienced Teachers, 1909

	Individual Data				Median Data		
	California	Georgia	OH, WI, IL	Texas	Illinois	Ohio	Wisconsin
				Men Only			
Schooling	0.004	0.020	0.075	0.085	0.084	0.088	0.044
	(0.010)	(0.021)	(0.004)	(0.009)	(0.013)	(0.011)	(0.015)
Experience	0.041	0.006	0.048	0.035	0.020	0.033	0.040
	(0.007)	(0.017)	(0.004)	(0.009)	(0.013)	(0.124)	(0.014)
Exper. Squared	-0.001	0.001	-0.001	-0.001	0.000	-0.001	0.000
	(0.0002)	(0.0007)	(0.0001)	(0.0003)	(0.0004)	(0.0004)	(0.0005)
Intercept	6.890	6.470	5.480	5.360	5.979	5.816	6.221
	(0.13)	(0.26)	(0.05)	(0.13)	(0.114)	(0.104)	(0.124)
N	226	92	1776	243	60	67	47
R^2	0.22	0.15	0.33	0.34	0.69	0.61	0.58
				Women Only			
Schooling	0.007	0.067	0.063	0.035	0.064	0.072	0.023
	(0.007)	(0.026)	(0.005)	(0.013)	(0.012)	(0.013)	(0.014)
Experience	0.028	0.014	0.046	0.029	0.033	0.027	0.047
	(0.004)	(0.030)	(0.004)	(0.011)	(0.014)	(0.013)	(0.014)
Exper. Squared	0.000	0.001	-0.001	-0.001	0.000	0.000	-0.001
	(-0.0002)	(0.0019)	(0.0001)	(0.0005)	(0.0005)	(0.0004)	(0.0005)
Intercept	6.640	5.190	5.420	5.730	5.834	5.798	6.111
	(0.10)	(0.32)	(0.07)	(0.18)	(0.104)	(0.109)	(0.109)
N	432	45	1365	138	62	66	52
R^2	0.30	0.29	0.41	0.14	0.62	0.57	0.43
				Less Experienced Teachers Only			
Schooling	0.020	0.012	0.052	0.071	0.047	0.059	0.032
	(0.010)	(0.030)	(0.04)	(0.010)	(0.011)	(0.010)	(0.010)
Male Dummy	0.231	0.769	0.201	0.280	0.224	0.152	0.254
	(0.027)	(0.091)	(0.014)	(0.037)	(0.063)	(0.053)	(0.052)
Intercept	6.538	5.884	5.690	5.355	5.799	5.602	6.013
	(0.134)	(0.362)	(0.053)	(0.130)	(0.137)	(0.119)	(0.123)
N	298	54	1278	155	51	54	50
R^2	0.20	0.59	0.20	0.43	0.42	0.48	0.43

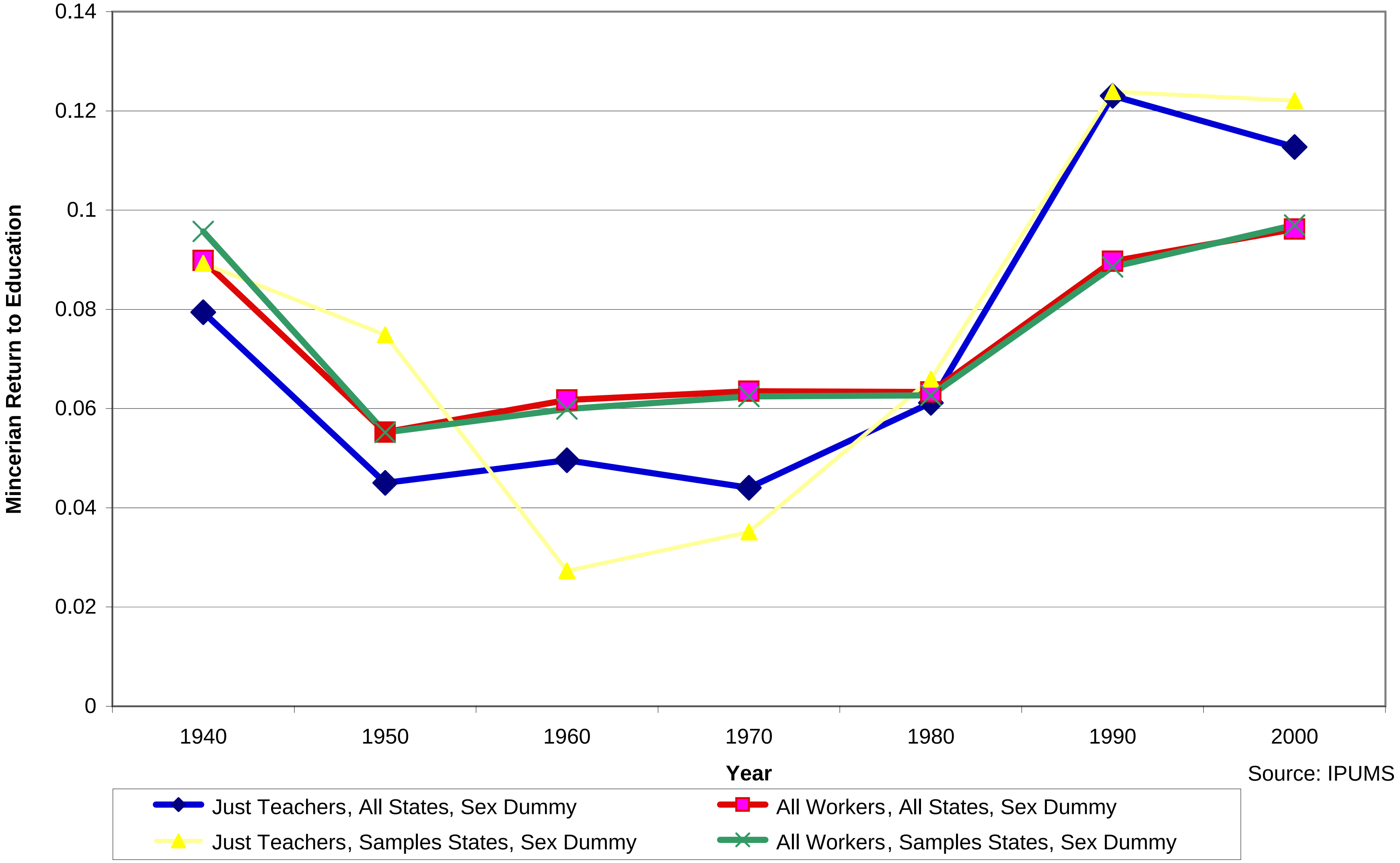
Source: Authors' calculations from Thorndike Report.
Dependent variable is log of the wage in each regression.
Robust standard errors listed in parentheses.
Less experienced teachers are those with less than five years of experience

Table 9
Comparing Mincerian Regression Estimates from 1909 and 1940

Variable	Weighted Teachers, Sample States, OLS (1909)	Teachers Only, Sample States, OLS (1940)	Teachers Only, Sample States, Robust Regression (1940)	All Workers, Sample States, OLS (1940)	All Workers, All States, OLS (1940)
Schooling	0.083	0.091	0.089	0.096	0.090
	(0.003)	(0.010)	(0.008)	(0.001)	(0.000)
Female	-0.145	-0.162	-0.125	-0.452	-0.459
	(0.010)	(.056)	(0.044)	(0.007)	(0.004)
Experience	0.034	0.035	0.039	0.047	0.516
	(0.002)	(0.007)	(0.005)	(0.001)	(0.005)
Exper. Squared	-0.001	-0.001	-0.001	-0.001	-0.058
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)

Source: Author's calculation from IPUMS (1940) and Thorndike Report (1909)
Dependent variable is the log of the wage in each regression.
Robust standard errors are listed in parentheses.

Figure 1: Comparison of Mincerian Returns to Skill Over Time



Source: IPUMS