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Migration and Human Capital Formation: Theory and Evidence from the U.S. High School Movement

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Abstract

In 1910, 12 percent of American 14–17 year olds were enrolled in high school; by 1930, enrollment had increased to 50 percent; enrollment in Britain was 12 percent in 1950. This paper argues that by increasing the skill premium, the massive inflows of European unskilled immigrants at the turn of the twentieth century engendered America's sharp rise in human capital investment. The increased enrollments raised the supply of schools, leading to continued schooling investment. Cross section evidence and a VAR analysis of the time series data support the hypothesized role of immigration in generating the high school movement.

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Contents Page

I. INTRODUCTION

America's industrialization at the dawn of the last century was swift and dramatic. And as early as 1941 many observers proclaimed the twentieth century "the American Century."[2] But foreshadowing America's economic rise was an unparalleled increase in educational attainment at the turn of the century. In 1910, 12 percent of American 14–17 year olds were enrolled in high school; by 1930 this number had increased by over fourfold to 50 percent (see Fig. 1). To put this achievement in context, in Britain secondary enrollment was just 12.5 percent in 1950.[3] This dramatic rise in high school enrollment in the U.S. has been termed the "high school movement," and it gave the U.S. a lead of some three decades in educational attainment compared with Europe. Understanding the causes of the high school movement is important for several reasons. With education's potentially casual impact on economic growth, the high school movement may well have been a key reason behind the rise in America's economic dominance. Moreover, very much like the current era, the dawning of the 20th century witnessed massive international movements in capital, labor and goods. Thus, knowing how those forces can influence development may be especially relevant today.

Indeed, this paper argues that the high school movement offers a compelling view of how, absent centralized government coordination, large scale factor movements—in this instance massive population movements, can alter the private incentives of individuals and transform an economy's production structure. Using a general equilibrium model of educational investment with endogenous schooling costs, I argue paradoxically that the massive immigration of *unskilled* labor in the late nineteenth and early twentieth century (Fig. 2) triggered the U.S. high school movement.[4] The increased supply of unskilled labor depressed the wages of the unskilled[5] and increased the skill premium. This raised the private return to education and engendered schooling investment. Moreover, this initial shock was then propagated through a schooling investment externality. Increased enrollments led to a greater supply of schools. With the limited

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[2] Henry Luce, the founder of Time Magazine, is reputed to have been the first to use that phrase.

[3] These numbers are taken from Goldin and Katz's (1998a,b) excellent survey of America's educational transformation at the turn of century.

[4] From 1900 to 1917, over 14 million immigrants entered the U.S. To put this number in perspective, the U.S. population in 1900 was about 76 million, but by 1917 it had climbed to 103 million and roughly 50percent of that increase is attributable to direct immigration. The large majority of these new immigrants were unskilled laborers or were listed as having no occupation; only 160 thousand or 1% were classified as professional. In addition, most of the new immigrants during this period were male, and between the ages of 15–40. Also, of the foreign born, 56% participated in the labor market during the period 1900–1920. This compares with a participation rate of 37% for the native born [see Carter and Sutch (1997)].

[5] Goldin (1994), Peck (1992), and Hatton and Williamson (1992) document the negative impact of immigration on the wages of the unskilled at the turn of the century.

transportation infrastructure of the era, the increased supply of schools greatly improved access, leading to continued schooling investment.

The extent to which mass migration can transform an economy depends on the strength of the schooling externality and on differences in diminishing marginal labor productivities across the skilled and unskilled sectors. If the schooling externality is strong, and diminishing marginal labor productivity is disproportionately felt in the unskilled sector, then an influx of unskilled labor can ultimately increase the *fraction* of skilled labor in the new equilibrium. To understand this result, consider the extreme assumption of constant marginal productivity in the skilled sector. An influx of unskilled labor reduces the wage in the unskilled sector and increases the skill premium, inducing educational investment. Through the schooling externality, the increase in educational attainment lowers the cost of schooling for the other agents in the economy. At the same time, marginal productivity rises in the unskilled sector as an increasing number of agents migrate into the skilled sector. But because marginal productivity does not diminish in the skilled sector while at the same time schooling costs fall, the rate of return to education decreases more slowly in response to the accumulation of skilled labor. The economy is then able to absorb more skilled workers, and the percentage of skilled labor in the population can rise in response to an absolute increase in the stock of unskilled workers.

The empirical component of the analysis uses both the time series evidence drawn from the mass immigration of unskilled labor into the U.S. from 1890–1926, and the cross section evidence generated by migration patterns across the contiguous states. In both instances, there is broad support for the hypothesized role of immigration in the high school movement. The time series evidence demonstrates that from 1894–1926 there was a robust long-run relationship between immigration flows, schooling attainment and proxies for the skill premium and the cost of schooling. In addition, a vector error correction framework indicates that immigration affected the high school movement in two important ways. Firstly, immigration flows appears to have been a significant determinant behind movements in the skill premium. Also, movements in the skill premium were positively associated with the growth in schooling attainment over time. But independent of relative factor prices and in keeping with the idea of egalitarianism, there is also evidence that immigration was positively associated with increases in schooling expenditures, perhaps as part of a larger attempt to assimilate new immigrants and the internal population movements of the era. In turn, schooling expenditures are positively associated with schooling attainment.

The state level cross section results also find a large positive and significant association between migration and high school attainment. To identify the impact of population movements on education attainment, the analysis relies on the differential impact of factor price movements on the schooling investment decision across both wealth and gender. Simply stated, compared with poorer families, wealthier families' educational investment decision may have been less sensitive to movements in the skill premium, as status and other factors may have figured more prominently. Similarly, during this period, women were primarily concentrated in the clerical and service sectors, and thus, compared with men, were less likely to face competition from unskilled migrants. In addition, because of the social mores of the time and the prevalence of gender discrimination in the work place, upon marriage, women tended to quit the labor force at a greater rate than men. Hence, for these reasons, female educational attainment may have been much less sensitive to changes in the skill premium stemming from unskilled migration. Consistent with the idea that migration affected attainment through factor prices,[6] the analysis finds that migration's impact on male attainment was about two and half times larger than on female attainment. In like vein, migration's influence on attainment in wealthier states was significantly more limited. Thus, the interaction of poverty and emigration may help explain why the Southern regions of the U.S. lagged in schooling attainment.

This paper builds on a series of pioneering papers by Goldin and Katz (1999, 1998, 1997) on the high school movement. That body of work suggests that the relative cultural and wealth propinquity of early twentieth century America significantly explain the observed pattern of educational attainment. In particular, the authors argue that the high levels of wealth, its relatively equitable distribution and the homogenous nature of the culture in the Western and Pacific states, as well as parts of New England made the financing of school construction possible, and thus engendered the expansion in education. Aside from socioeconomic factors, attention has also been focused on the effects of compulsory schooling legislation on educational attainment. However, this relationship remains uncertain. Some researchers have argued that these laws have made little difference in teen attendance, for their enforcement was lax, and in most cases the law reflected rather than altered private behavior. But some evidence does exist (Margo and Finegan (1996)) which suggests that compulsory schooling legislation combined with child labor laws did have a positive effect on schooling enrollment.[7]

The analysis herein differs from the literature in that it takes a dynamic general equilibrium approach to understanding the high school movement, enabling it to make precise the relationship between schooling attainment, the skill premium and the development of the schooling infrastructure. The model itself is related to the literature on the role of externalities in shaping private investment decisions (Carrington et al. (1996), Krugman (1991), and Matsuyama (1991, 1988)), but focuses instead on a technological externality that operates through the supply of human capital rather than exclusively in the production side of the economy. The paper also differs in its empirical approach: in addition to cross section analysis, this paper systematically develops a vector error correction model of the time series data that suggests that while cultural effects may have been important, immigration played a heretofore unremarked upon role in generating this pattern of educational attainment. The paper is organized as follows. Section 2

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[6] There is also evidence that the returns to schooling were high on the eve of the civil war (Goldin and Margo (1992) and Margo (1992)). While the high school movement did not occur then, during the 1800s the U.S. did lead the world in primary schooling. The limited availability of data makes it difficult to test, but it seems reasonable to conjecture that the immigration boom before and after the Civil War may have played an important and similar role in helping engender primary schooling investment, laying the foundation for the high school movement.

[7] See Landes and Solomon (1972), Eisenberg (1994) and more recent work by Schmidt (1996) and Lleras-Muney (2001).

develops and analyzes the model, while Sections 3 and 4 use cross section and time series evidence, respectively, to test the main predictions of the model. Section 5 concludes.

II. Model of Educational Investment with Endogenous Schooling Costs

A. Setup

In this economy, there are two grades of labor: the unskilled and the skilled. There is no population growth, and without loss of generality, the population is fixed at some constant *a*. Labor is the only factor of production and both skill grades independently produce an identical consumption good, supplying an inelastic unit of labor. Production occurs using a constant returns to scale technology subject to the standard 'Inada' assumptions. Let $u(t)$ and $s(t)$ denote the stock of workers who are unskilled and skilled, respectively, at time *t*. Equation 1 summarizes the aggregate production relationship at time *t*:

$$Y(t) = f(s(t)) + g(u(t)) \tag{0.1}$$

The labor market is competitive, and workers receive their marginal product:

$$w(s(t)) = f'(s(t)), \text{ and } w(u(t)) = g'(u(t)) \tag{0.2}$$

Human capital investment requires a sunk cost; after which, the agent can produce in the skilled sector. Preferences, family background, innate ability and other individual characteristics affect the size of this sunk cost. These personal traits are summarized by the index $\theta \in \Phi$, and $m(\theta)$ denotes the fraction of the population of type less than or equal to θ. I assume that $m(\theta)$ is strictly increasing and everywhere differentiable. Aside from personal characteristics, the quality and size of the education infrastructure also impose significant costs on the individual student. For example, without a school nearby, the cost of educational investment may be too costly to undertake. I make the assumption that the education infrastructure expands as schooling attainment rises. This implies that the private or access cost of schooling diminishes as the stock of attainment grows:

$$c(\theta, s(t)), \quad c_1(\cdot,\cdot) > 0, c_2(\cdot,\cdot) < 0. \tag{0.3}$$

I assume that agents are endowed with perfect foresight and that the decision to invest in education and change employment sectors is irreversible.[8] Let $V(\theta, s(t))$ be the maximum present discounted value of income for a skilled agent of type θ in period *t*. Let *r* denote the exogenously

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[8] This assumption simplifies the Bellman equation, but is nonbinding. See Ramcharan (2001) for a proof.

given rate of interest which is assumed to be identical to the rate of time preference, then the present discounted value of education in period *t* is:

$$V^s\left(s(t)\right)=\int_t^{\infty} w^s\left(s(z)\right)e^{-r(z-t)}dz \tag{0.4}$$

The unskilled must chose the optimal date on which to incur the sunk cost and invest in education:

$$V^u\left(\theta,u(t),s(t)\right)=\max_{\tau}\left\{\int_t^{\tau} w^u\left(u(z)\right)e^{-r(z-t)}dz+e^{-r(\tau-t)}\left(V^s\left(\theta,u(\tau)\right)-c\left(\theta,s(\tau)\right)\right)\right\} \tag{0.5}$$

It can then be shown that the behavior of educational attainment along a perfect foresight equilibrium path can be described by the differential equation:[9]

$$\dot{s}=\frac{w\left(s(t)\right)-w\left(u(t)\right)-rc\left(s(t)\right)}{-c_1\left(s(t)\right)} \tag{0.6}$$

And in equilibrium, the level of educational attainment, s*, is defined by:

$$\frac{\gamma\left(s^*\right)}{r}=c\left(s^*\right) \tag{0.7}$$

Society accumulates skilled labor if the skill premium net of the cost of schooling is positive. Otherwise, due to the irreversibility assumption investment ceases if its net return is negative. The size of the externality, $c_1\left(s(t)\right)$, determines the sensitivity of aggregate behavior towards the return to education. And unless the externality is zero, convergence towards the equilibrium stock of education is gradual, implying that educational attainment occurs slowly over time. Intuitively, if the benefit from waiting to invest in schooling—the size of the externality—is large, then convergence towards the equilibrium stock of educational attainment is slow. An equilibrium occurs when the present discounted value of the skill premium equals the cost of schooling. Moreover, as educational attainment proceeds, it must be the case that the rate of return to schooling diminishes in order for the resulting equilibrium to be asymptotically stable.[10]

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[9] The interested reader is referred to the appendix for a derivation.

[10] The interested reader is referred to the appendix for a more precise statement of this idea.

Proposition 1 develops the key argument of the paper: an exogenous increase in the level of unskilled labor can paradoxically lead to an equilibrium with a greater percentage of skilled workers. Figure 4 illustrates this argument. The economy is initially at equilibrium point 1. An exogenous rise in the number of unskilled increases the population and shifts the economy to point 2 on the $s+u=a'$ population line. But at point 2, the economy is no longer in educational equilibrium: $w(s)-w(u)>rc(s)$. This leads to renewed educational investment and the skill composition changes as the economy adjusts along the $s+u=a'$ line. Investment proceeds until the skill premium equals the discounted cost of schooling; graphically, the new equilibrium is achieved when the population constraint line: $s+u=a'$ and the equilibrium investment condition $w(s)-w(u)-rc(s)=0$ intersect at point 3. The rays drawn from the origin indicate that in the new equilibrium, the ratio of unskilled to skilled has *fallen* relative to the original, pre-shock equilibrium. This result depends on the extent to which diminishing marginal productivity differ across the two sectors, as well as the size of the schooling externality. To understand this argument, suppose that diminishing marginal productivity is a prominent feature of the production process in the unskilled sector. An influx of unskilled labor would then severely depress wages in that sector, magnifying the skill premium. This produces a jump in educational attainment. This increase in the stock of skilled workers minimally impacts the rate of return to education if diminishing marginal labor productivity is weakly felt in the skilled sector, and schooling costs fall rapidly with previous enrollment. The economy is thus able to absorb large flows of labor into the skilled sector. Ultimately, in the new equilibrium the exogenous increase in the unskilled workforce leads to a rise in the fraction of skilled labor. The proposition below formalizes this idea:

Proposition 1: *Suppose s^* is a stable equilibrium. If*

$$\frac{\partial\gamma(s^*,a)}{\partial a}>\left[\frac{s^*}{a}\right]\left[r\frac{dc}{ds^*}-\frac{\gamma(s^*,a)}{\partial s^*}\right] \qquad (0.8)$$

then an exogenous rise in the number of unskilled increases the fraction of the skilled labor in the population.

III. Cross-Section Analysis

Building on the idea that an influx of unskilled labor can increase the percentage of skilled labor, this section exploits the significant variation in high school attainment across the contiguous states, including the District of Columbia, to understand better the factors behind the high school movement. As Figure 4 indicates, high school attainment was concentrated in the Mountain, Pacific and New England states. Tables 1 and 2 present descriptive statistics of some of the state level variables used in the analyses for 1910 and circa 1928, respectively. These variables include migration; high school attainment rates as a fraction of the number of 17 year olds in the population; per capita wealth levels; and state level education expenditures per pupil.

In addition, following Goldin and Katz (1998), to capture the notion of community stability and social capital I also include such measures as the fraction of Catholics in the population; the fraction of individuals over 65; the per capita motor vehicle registrations, and the percent of manufacturing in the workforce. A listing of the variables, their definitions and sources is in Appendix I.

From Table 1, the Southern regions were the poorest, had the smallest fraction of elderly and Catholics in the population and the lowest expenditures per pupil. In addition, the southern regions experienced net total emigration, as very few foreign immigrants moved in to the south, while both blacks and native born whites left the region. The New England and Middle Atlantic regions witnessed a significant inflow of immigrants. The data in Table 2 reveal a similar regional pattern for the period 1928.

To get a rough understanding of the data, Table 3 looks at the correlation between some of these variables in 1910. The level of high school attainment is positively correlated with per capita wealth, expenditures per pupil, and to a lesser extent the level of total migration. Noteworthy is the strong positive correlation between total migration and per capita wealth. But it is unlikely that this correlation implies that total migration was strongly caused by differences in wealth. Wealth levels were highest on the Eastern seaboard, which was also geographically closest to Europe, and thus experienced the most intense waves of non-native migration. Of greater interest is the high correlation between per capita wealth and expenditures per pupil. Thus, the potential for multicolinearity is present whenever both variables are included as repressors, as per capita wealth may be causally related to expenditures per pupil.

A. Growth in Attainment

The theory predicts that the inflow of unskilled migrants magnified the skill premium, leading to increased educational attainment. Motivated by the theory at the cross section level, I first consider the most general specification:

$$\Delta ED_i = c + \beta_1 MIG90_i + \beta_2 ED1910_i + \beta_3 EX_i + \beta_4 MIG_i * WEA_i + \beta_5 WEA_i + X_i'\theta + e_i \qquad (0.9)$$

The average annual growth in high school attainment from 1910 to 1928 within each state (ΔED_i) is regressed on the inflow of migrants from 1890 to 1910 $(MIG90_i)$, and the level of per capita schooling expenditures in 1910 (EX_i). The latter variable proxies for the private cost of schooling. For higher schooling expenditures are expected to translate into more and better schooling infrastructure, which in turn would improve access and lower the cost of schooling. To further proxy for schooling costs, state per capita wealth in 1910 (WEA_i) is included. On average, wealthier families would be better able to afford both the actual and opportunity cost of schooling; thus at the state level, the growth in schooling attainment should be positively associated with this variable. In addition, compared with poorer families, wealthier families' decision to invest in education maybe less sensitive to movements in relative factor prices, as status and other similar factors may figure more prominently. Therefore, because migration is posited to affect schooling through factor price changes, its impact may vary by state wealth level. The interaction term between wealth and migration captures this possibility. Also, I include a vector of control variables (X) for measures of social capital and other relevant state characteristics: the fraction of old in the state population, the fraction catholic and the percent employed in manufacturing. Lastly, attainment is bounded from above at 100 percent and the distance from this level may affect its subsequent growth rate; including the initial level of attainment controls for this possibility $(ED1910)$.

Table 4 presents the results from the regression suggested by Equation (0.9). In column 1 the average annual growth in high school attainment from 1910 to 1928 is regressed on the variables claimed by the theory, excluding the social capital measures suggested by Goldin and Katz (1997). As the theory posited, migration, defined as the net number of migrants from 1890 to 1910, is positively and significantly (p-value = 0.05) associated with the subsequent growth in high school attainment. For a median wealth level, a one standard deviation increase in migration adds 0.5 percentage points to the average annual growth in high school attainment, or a 7 percent increase relative to the sample's median growth rate. However, the impact of migration was more pronounced in poorer states, for the interaction term is both significantly (p-value= 0.03) and negatively associated with the growth in attainment. Hence, in contrast to the case of median per capita wealth level, for a state at the 25th percentile of the per capita wealth distribution in 1910 (New Mexico), a one standard deviation increase in migration is associated with a 0.8 percentage point increase in the subsequent growth rate in attainment—11 percent relative to the median growth rate, suggesting that because the schooling decision of wealthier families was less sensitive to shifts in factor prices, migration's impact on schooling attainment in the wealthier states was more limited.

The second column includes the social capital measures and the percent of manufacturing—a proxy for the state economic structure; all are individually and jointly insignificant (p-value=0.16), and the point estimates on the migration variables are little changed. Instead, the per capita wealth point estimate is now smaller and less precisely estimated, suggesting some inter correlation between the social capital measures and wealth.

This framework also helps in understanding the Southern education experience. It suggests that poverty magnified the negative impact of emigration on the growth in attainment in those regions. In particular, unskilled emigration reduced the skill premium in the South; and being more sensitive to movements in relative factor prices than their wealthier counterparts, poorer families were probably much slower to invest in education. For example, given the mean wealth of the South Central region, a one standard deviation reduction in immigration—an increase in emigration—is associated with a 0.9 percentage point reduction in the growth of high school attainment, a 13 percent fall relative to the mean growth rate. Additionally, this specification seems to capture the southern experience reasonably well; the Southern Dummy (in column 2), is insignificant.

B. Attainment Levels

The theory also offers a framework to assess migration's impact on the *level* of schooling attainment. Linearizing the differential equation—Equation (0.6)—around its steady state s^*, and solving gives the following expression for the level of attainment at time *t*:

$$s(t) = s^* + \left[s(0) - s^*\right] e^{\left[\frac{\gamma'(s^*) - rc'(s^*)}{-c'(s^*)}\right]t} \tag{0.10}$$

where $s(0)$ is the initial stock of skilled labor and $\gamma'(s^*) - rc'(s^*) < 0$ is the change in the return to education with respect to the stock of skilled labor, evaluated at the steady state level of attainment s^*. If the initial stock of high school graduates is zero, then rearranging Equation (1.17) provides a useful expression:

$$\frac{s^* - s(t)}{s^*} = e^{\left[\frac{\gamma'(s^*) - rc'(s^*)}{-c'(s^*)}\right]t} \tag{0.11}$$

The distance from the steady state stock of attainment narrows or converges over time at a rate proportional to the change in the return to education: $\gamma'\left(s^*\right) - rc'\left(s^*\right) < 0$. For a given steady state, an increase in the stock of unskilled labor accelerates the rate of convergence towards the potential or equilibrium level of schooling attainment.

To make this idea operational with respect to the data, assume that for all states the steady state level of high school attainment for any cohort of 14–17 year olds is 100 percent.[11] Then the education gap observed in 1910 for state i, around the start of the high school movement is:

$$\tilde{s}_i(1910) = \frac{s^* - s_i(1910)}{s^*}, \tag{0.12}$$

Not surprisingly from Figure 4, it is clear that the Northeast region was the closest to the steady state level of attainment in 1910.

[11] This is an abuse of notation. The skill premium depends not on the percent of high school graduates in the 14-17 year age group, but on the stock or number of high school graduates in the population. That said, it serves well to motivate the empirical specification.

To understand the factors behind the cross state variation in the education gap, I use equation (0.11) to generate a semi log empirical specification. In this setup, the regressors affect the percent change in the education gap.[12]

$$\ln\left(\tilde{s}(1910)_i\right) = \beta_0 + \beta_1 WEA_i + \beta_2 EPX_i + \beta_3 MIG80_i + \beta_4 MIG80_i * WEA_i + X_i'\theta + e_i \qquad (0.13)$$

The OLS results are reported in column 3 of Table 5,[13] where the combined (male and female) education gap is the dependant variable. While all of the coefficients have the expected signs, there is strong evidence of heteroscedasticity. Column 5 corrects for this problem with weighted least squares, where the state population in 1910 is used as the weighting factor. The point estimates across the two procedures are similar, and several results are striking. Both migration and its interaction with wealth are individually (at the 10 and 1 percent level respectively) and jointly (p-value=0.00) significant. And from the point estimates, for median wealth, a one standard deviation increase in the number of migrants is associated with a one percent narrowing of the education gap—the distance from full attainment for the 1910 cohort. To put this in context, the mean gap from full attainment was about 91 percent—a 9 percent attainment level; so for the average state, a one standard deviation increase in migration is associated with a 0.91 percentage point increase in the attainment level.

Because of the significant negative interaction term, migration's impact was more limited in the wealthier Western and Pacific regions; for the average wealth level in the West, a similar increase in the number of migrants is associated with only a 0.3 percent reduction in the education gap. As in the growth regressions (Table 4), this finding helps in understanding why the Southern education gap in 1910 was so large. The much lower wealth levels of the south interacted with large net emigration to retard schooling investment. Indeed, the southern dummy is highly insignificant and of the wrong sign.

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[12] I make the identifying assumption that at this early stage of the high school movement, expenditures per pupil were not determined by the level of high school attainment. I also assume that population movements were the main source of inter state variation in the skill premium and that the interest rate was constant across states That is, the technological and other factors behind the skill premium were constant across states.

[13] To facilitate comparison with the existing literature, in columns 1 and 2 of Table 5 I replicate the Goldin and Katz (1997) results. There are some slight differences in the coefficient estimates, but more importantly, that framework appears to suffer from significant misspecification problems. The Ramsey RESET test (with 3 fitted terms) F-statistic is 2.45 (p-value=0.07) and the log likelihood ratio statistic is 8.44 (p-value = 0.03). That said, the impact of migration and expenditures on attainment levels (column 2) are little different compared with the specification suggested by the theory.

That said, there are important reasons to believe that migration point estimates generally underestimate migration's actual impact on attainment. Firstly, attenuation bias from the inherent difficulty in accurately measuring state population movements is likely to bias the estimates. More importantly, due to language, cultural and other differences, the children of migrants are less likely to attend school than their native born counterparts.[14] Therefore, a large number of migrants may have increased the skill premium and induced schooling investment *en masse* among the native population. But in the aggregate, because the children of immigrants were not likely to attend school, the education gap would not appear to have narrowed much. Hence, this would impart an upward bias between the number of migrants and the education gap. Thus, when using aggregate state data, the migration point estimates should best be treated as only a lower bound of migration's actual impact.

In addition to migration, expenditures per pupil appear also to be a large and significant (p-value=0.00) determinant of the education gap. And a one standard deviation increase in the level of expenditures per pupil is associated with an almost 4 percent reduction in the high school attainment gap, indicating that because the education infrastructure of the time was quite limited, the marginal impact of per pupil expenditures on attainment was quite high. That said, contemporaneous compulsory schooling laws were probably positively correlated with per pupil expenditures. While at this early stage in the high school movement, the evidence on the effectiveness of these laws in narrowing the education gap is mixed, omitting them from the specification may lead to an overestimate of the impact of expenditures per pupil on the education gap.

To gauge the impact of omitted variable bias on the per pupil expenditures estimate, I use the legal schooling leaving age[15] (CSL) in 1915 to proxy for state level variation in compulsory schooling laws. Because of poor data quality, roughly 15 percent of the observations are unusable—mainly from the Southern states. Therefore, the potential for selection bias is substantial. The results with the truncated sample from both including and excluding the CSL measure are reported in columns 5 and 6 respectively. The point estimate on the per pupil expenditures variable is identical across the two regressions, and the CSL measure is negative, but highly insignificant, making it less likely that the specification suffers from that form of omitted variable bias.

Aside from the variables suggested by the theory, there is some evidence that social capital, as proxied by the percent of old people in the population, may have helped narrow the

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[14] Borjas (1993) illustrates a variant of this point using contemporary data on ethnicity.

[15] There are other proxies available in the literature, such as the age required for a work permit. However, these other measures produce similar results. In interpreting these results, it should be noted that cross state variation in compulsory schooling laws is only a weak proxy for the cross state effective enforcement of those laws. States with stronger laws may have much weaker enforcement.

education gap. A one standard deviation increase in this variable is associated with a 3 percent decline in the education gap. The other proxy for social capital—the percent of Catholics in the population—and industrial structure, the percent of manufacturing in the labor force, are both individually and jointly insignificant.

I analyze also the variation in the education gap in 1928 (Figure 4)—some two decades after the high school movement began. Table 6 presents the OLS results for the standard specification, where migration in this case is defined as the total number of migrants from 1890 to 1930. In contrast to 1910, there is little evidence that either migration or schooling expenditures played any significant role in the cross state variation in attainment in 1928. Instead, per capita wealth, percent over 65 and the per capita motor vehicle registrations are the only significant correlates. But the OLS results are likely to suffer from both omitted variable bias and simultaneity. Firstly, by 1928, the effectiveness of compulsory schooling laws may have increased significantly and become quite correlated with education expenditures. Secondly, as suggested by the theory, and unlike 1910—when the high school movement was still quite nascent—by 1928, education expenditures and attainment are likely to have been simultaneously determined, as more attainment may have led to more schooling expenditures.

To address these problems, I use the 1910 expenditures per pupil as an instrument for its 1928 counterpart. The factors that led to the cross state variation in 1910 schooling expenditures are likely to persist into 1928, leading to a high correlation across the two variables. And the reduced form estimates bear this latter point out; there is a large and positive association between the two variables.[16] In addition, there is little theoretical reason to believe that the 1910 expenditures per pupil would be correlated with the schooling attainment level almost two decades later, outside of its correlation with the 1928 expenditures levels. Indeed, from Table 4, the 1910 per pupil expenditure level is insignificantly related to the subsequent growth in attainment.

The IV results are depicted in Column 5 and a simple Hausman test[17] rejects the exogeneity of the 1928 expenditures per pupil variable (p-value=0.02) in the OLS regression reported in column (1) of Table 6. In the IV estimates, the percent over 65 in the population is the only significant variable, and the standard errors of the variables are large. In particular, the expenditures per pupil variable has the expected sign, and its magnitude is nearly identical to the 1910 estimate, but this coefficient is imprecisely estimated (p-value= 0.25), implying that 1910 expenditures may be a weak instrument. That said, the point estimates on the migration variables are quite small and of the wrong sign, suggesting that by 1928 population movements were no longer a significant determinant of educational attainment. Instead, factors such as social capital, either directly or through compulsory school laws may have became more prominent.

[16] These estimates are available upon request.

[17] This test is based on the procedure described by Davidson and MacKinnon (1993, p. 237).

C. Gender

These results suggest that population movement was an important factor in the state level variation in high school education. However, apart from the interaction term between wealth and migration, there is little evidence linking migration, relative factor prices and the decision to invest in education. For example, in an attempt to assimilate non-native immigrants, states may have more vigorously enforced their existing compulsory schooling laws; thus, migration's impact on attainment would be observationally equivalent to the one posited by theory. This section uses the differences in attainment between males and females to better identify migration's impact on schooling attainment.

The structure of the labor market and the cultural mores of the time justify this approach. Firstly, because of the large differences in the occupational distribution across gender, women and unskilled migrants were primarily noncompeting groups in the labor market. For example a large share of the women who participated in the labor force did so in the service or clerical sectors—as typists, bookkeepers etc. In contrast, most men worked in either agriculture or manufacturing, the very sectors that attracted non-native unskilled labor. Table 7, from Goldin (1990), illustrates this point: in 1900, the service sector absorbed 35.5 percent of working women, but only 3.1 percent of working men; likewise, 19 percent of working women were employed in agriculture, compared with 42 percent of working men. For this reason, if migration affected the education investment decision through movements in factor prices, then women's education attainment would be much less sensitive to population movements than men's.

Secondly, this asymmetry was reinforced by both gender discrimination in the workplace, and the social mores of the time that expected marriage to end a woman's labor force participation; in 1930, the labor participation rate for married women was just 11.7 percent (Table 7). By abrogating a woman's time in the labor force, these social norms lower the returns to education compared with men. In turn, this makes the education investment decision of girls less sensitive to changes in the skill premium. Therefore, if migration affected schooling attainment through factor prices, then both differences in the occupational distribution across gender and cultural mores suggest that migration's impact would be much smaller on female than on male high school attainment.

I exploit this asymmetry in analyzing migration's impact on the annual average growth in attainment from 1910 to 1928 for males and females separately (Table 8). The results—in columns 2 and 3 of Table 8—bear out the asymmetry. There are large and significant[18] differences in the migration point estimates across the two equations. In particular, in the female regression the migration coefficient is not significantly different from zero (p-value=0.13); in the case of male attainment, this variable is highly significant (p-value=0.04). Using the point

[18] The F-test statistic for identical parameters jointly across the two regressions is 16.084; this is extremely large and leads to the rejection of identical coefficients across the two regressions at any significance level.

estimates to help quantify the asymmetry, for median state per capita wealth, a one standard deviation increase in migration is associated with a 250 percent greater increase on the growth in male compared with (0.4 percentage points) female high school attainment (0.12 percentage points)! To a lesser degree, the per capita wealth estimate in the male attainment equation is noticeably smaller. Therefore, if as suggested, the impact of wealth on attainment operated largely through the household channel, then relative to girls, the growth in boys' attainment was driven much more so by forces outside the home, such as relative factor price changes.

A similar asymmetry is observed in the education gap in 1910. While the cumulative migration from 1880–1910 appears to be a highly significant determinant of the male education gap (both variables are jointly and individually significant with a p-value=0.00), its impact on the female attainment gap is much less robust (p-value=0.10). To highlight the substantial variation in migration's impact by sex, from the point estimates, for median wealth a one standard deviation increase in the number of migrants is associated with a one and a half percent reduction in the male attainment gap; in contrast, a similar increase is associated with a 0.3 percent *increase* in the female education gap. The percent of Catholics also appears to have an asymmetric impact; it is insignificant and quite small in the case of male attainment, but a one standard deviation increase is associated with 1.1 percent reduction in the female attainment gap, suggesting some link between Catholics and the willingness to educate females. In contrast to 1910, the 1928 results offer little insight, again implying that by this time, other factors may have become more prominent. The next section uses time series data to establish a more direct link between migration, factor prices, and attainment.

IV. Time Series Evidence

In this section, I use time series data to investigate how the skill premium, immigration and the private cost of schooling influenced educational investment from 1893 to 1926. Although the number of observations is somewhat limited, in many ways this interval is ideal for an examination of the high school movement. The interval precedes the most intense period of the high school movement—1910 to 1930—by about a decade and a half, but largely excludes the extraordinary effects of the Great Depression, and minimizes the potential biases possible from the increasingly effective compulsory education and child labor laws in the late 1920's. It also encompasses large variations in the skill premium and exogenous changes in the size of immigration flows. However, the lack of national level data linking individual educational attainment and income during this era poses a significant problem.

As a crude proxy for the skill premium, I consider the percent difference between annual average earnings of clerical workers in manufacturing and railroad versus wage earners in the manufacturing sector.[19] In addition to the skill premium, many of the other variables used in the

[19] Goldin and Katz (1995) follow a similar strategy in their analyses of early 20th century wage structure. The interested reader is referred to those authors' discussion of the many biases and pitfalls inherent in the use of this measure of the skill premium.

analysis are also only rough approximations of their theoretical counterpart. For example, during this period there is very little information on the private cost of secondary schooling, such as the distance from home to school. Instead, I try to indirectly measure this cost by using real expenditures per pupil, for in principle, the level of spending per student should be proportional to the size of the education infrastructure: the number of schools, the number of teachers and the other factors that reduce the private cost of schooling. Indeed, because the education infrastructure during this period was quite limited, the marginal dollar's impact on the student's incentive to attend school would have been quite high, making this variable a useful proxy of the private cost of schooling. That said, disaggregated educational expenditures data are unavailable. Thus, I use total educational expenditures for K–12 grades, with the caveat that deflating this variable by the number of high school graduates overstates the level of expenditures per high school student and that the biases induced by this mis-measurement need not be constant over time, as the relative shares in the spending mix between the primary and secondary grades may have changed over the sample.

Figure 5 plots the variables used in the analysis—the three-year moving average of the skill premium proxy (SP); real total educational expenditures per high school pupil (EP); the number of high school graduates (HG); and the annual number of immigrants into the United States (IM). All variables are log transformed. It is clear that after rising sharply in the 1890's, the skill premium declined at the turn of the century, and leveled off until the advent of WWI, upon which, it steeply declined. In contrast, expenditures per pupil has a steady upward trend, quickly recovering after the wartime interruption. As discussed in section 2 , after declining throughout much of the late 1800's, immigration dramatically intensified at the turn of the 20th century, peaking around 1910 but steadily declining thereafter due to legal restrictions and to a lesser degree, the perils of travel during WWI.

The theory specifies that the flow of schooling investment is proportional to the contemporaneous levels of the skill premium and the cost of schooling, and that exogenous immigration, by magnifying the skill premium, precipitated the observed large schooling investment flows. But in practice, many of these assumptions may not hold in the data. It is difficult to be certain *a priori* whether immigration was in fact exogenous with respect to the data. For the skill premium in the 1890's may well have attracted unskilled immigrant labor from Europe, in the hope that their yet to be conceived children may benefit from these higher wages. Moreover, as the theory itself argues, schooling costs decline with the level of attainment. But the relationship between schooling costs and attainment may hold only with some lag, the length of which is uncertain. Similarly, the timing of the relationship between the number of high school graduates and the skill premium is subject to uncertainty.

Motivated by these considerations, I pursue a modelling approach that specifies a statistical dynamic system that is first congruent with the I(1) data:[20]

[20] Tests for innovation of errors are only approximate in I(1) space, but provides a useful guide in practice. See Hendry and Mizon (1993).

(0.14) $$z_t = \sum_{j=1}^{p} \prod_j z_{t-j} + \Phi D_t + v_t \quad v_t \sim IN(0,\Omega)$$

where $z_t = (sp, hg, im, ep)'$ is a (4x1) vector of the I(1) variables, and $D_t = (WWI)'$ is a dummy for World War I (1917-1919). Utilizing $\Delta z_t = z_t - z_{t-1}$, a convenient reformulation of (0.14) is:

(0.15) $$\Delta z_t = \sum_{i=1}^{p-1} \Pi_i^* \Delta z_{t-j} + \Pi^* z_{t-p} + \Phi D_t + v_t, \text{ with}$$

(0.16) $$\Pi_i^* = \sum_{j=1}^{i} \Pi_j - I$$
$$\Pi^* = \sum_{j=1}^{p} \Pi_j - I$$

This vector autoregression (VAR) approach is used to investigate the cointegration properties of the system.[21] That is, I determine whether as posited by the theory, a long-run relationship exists between the number of high school graduates, the skill premium, immigration and schooling costs. Although the cointegrated relationship is not identified, I am able to test various hypotheses generated by the theory: in the long run, were immigration levels structurally related to the high school movement? Were schooling costs and high school attainment related? I also consider the crucial question of whether immigration was in fact exogneous with respect to the model's information set. Testing these hypotheses relies on the idea that in equation (0.15) since v_t is stationary, the rank ρ of the long-run matix Π^* determines how many linear combinations of z_t are stationary. And for $0 < \rho < 4$, there exists ρ cointegrating vectors or ρ stationary linear combinations of z_t. In this case, Π^* can be factored as $\alpha\beta'$ with both α and β being $(4 \times \rho)$ matrices, where the cointegrating vectors of β are the error correction mechanisms in the system, while α contians the adjustment parameters. Heureustically, a variable is weakly exognous with respect to the model's information set if its adjustment parameter is not statistically different from zero.[22] Building on the exogeneity of certain variables and the stationarity of the long-run relationship, I first difference the data, reducing the analysis to I(0) space. I then test for specific structural relationships: the impact of immigration on the skill premium, as well as the impact of high school attainment on school spending and on the skill premium.

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[21] See Johansen (1988) and Johansen and Juselius (1990).

[22] See Engle and Granger (1987) and Hylleberg and Mizon (1989).

The cointegration results in Table 10 are derived from a VAR with a lag order $p = 3$. Based on the evidence from the tests for normality and autocorrelation the system does not appear to suffer from misspecification problems, and is reasonably congruent with the underlying data generating process. That said, there is some evidence that the residuals in the expenditures per pupil (ep) equation are not normally distributed.[23] From Table 8, there is only one cointegrating vector present in the data. After imposing this restriction, I normalize the stationary eigenvector with respect to ep:

$$ep = 0.61hg + 0.55sp + 0.07im \tag{0.17}$$

The direction and magnitudes of the long-run elasticities seem quite intuitive. Over the period 1895 to 1926, a one percent increase in the number of high school graduates is associated with a 0.61 percent in the schooling expenditures per pupil, illustrating the positive link between attainment and schooling expenditures. Although the long-run elasticity is somewhat less, increases in the skill premium are also positively associated with expenditures per pupil. Underlying this positive relationship is the idea that increases in the skill premium make education investment more attractive; and the increased demand for education would in turn lead to greater education expenditures. In addition, the positive association between immigration and education expenditures suggests that public spending increased in an effort to absorb the mass inflow of immigrants. But as would be expected, compared with attainment and the skill premium, immigration's effect on education expenditures was much smaller: a one percent increase in the number of immigrants is associated with a 0.07 percent increase in expenditures per pupil.

I now consider various restrictions on the cointegration space. Firstly, I focus on immigration's role in the analysis. In particular, I test whether immigration cointegrates with the other variables. While this test does not identify the specific role of immigration in the high school movement, it does offer the first, most basic test of the theory. For if the theory holds, then in the aggregate, we should observe a long-run relationship between immigration, relative factor prices, the private cost of schooling, and high school attainment. As Table 10 indicates, the hypothesis that immigration flows are outside the cointegration space is rejected (a p-value of 0.00). In addition to testing the relevance of immigration, I also sequentially[24] test whether other variables ought to be excluded from the long-run relationship defined by Equation (21). These tests are all rejected, reinforcing the idea that these variables together played an important role in the evolution of educational attainment. Tests on the adjustment parameters show that education expenditures and the skill premium are weakly exogenous given the information set. Only the numbers of high school graduates and immigrants both respond to deviations from the long-run equilibrium relationship defined by Equation (0.17).

[23] Misspecification tests at the equation level are available upon request.

[24] More general testing combinations were also considered. The results of these tests do not alter the conclusions; and for brevity these results are not reported, but are available upon request.

To better identify the forces behind the high school movement, I analyze the short-run movements of the system using a vector error correction framework. Specifically, because of first differencing, all variables are stationary and transformed into growth rates; in addition, I include the stationary cointegrating vector (Equation (0.17)) to capture how disequilibria in the long-run relationship between the variables (in levels) affect the short-run behavior (growth rates) of the numbers of immigrants and high school graduates. In Table 11, I impose the weak exogeneity restrictions—long-run disequilibrium (the cointegrating vector) is excluded from the expenditures per pupil and skill premium equations. To impose more economic structure and at the same time obtain parsimony, I also impose the restrictions suggested by the theory.[25]

Table 11 presents the maximum likelihood estimates. Underscoring the fact that education investment requires a long time horizon, disequilibria in the long-run relationship between education expenditures and the other correlates are positively and robustly (p-value=0.00) associated with the growth in high school attainment (Dhg)—column 3. Moreover the point estimate suggests a large relationship: a ten percentage point rise in the level of education expenditures above its long-run level is associated with a 2 percentage point increase in the growth of attainment the next year. Beyond long-run factors, there is also evidence that short-run movements in the skill premium also affect the growth in educational attainment. The one year lagged growth in the skill premium is positively and significantly (p-value=0.06) related to growth in the number of high school graduates (Dhg): a ten percentage point increase in the growth rate of the skill premium is associated with 1.7 percentage point rise in the growth of the number of high school graduates a year later. But after controlling for long-run factors and the growth in the skill premium, there is little evidence of a direct impact of the growth in immigration on the growth in schooling investment: both the one and two year lagged growth rates (Dhg_{t-1}) and (Dhg_{t-2}) are not individually and jointly significant (p-value=0.66). Apart from these forces, presumably exogenous events like World War I also had a positive impact on the growth in attainment; perhaps education offered a means to delay entry into the armed forces.

Changes in the skill premium (Dsp) appear to be a first order autoregressive process. However, from Table 11 (Column 4), there is evidence that the growth in immigration lagged by two years is positively and significantly (p-value=0.08) associated with this process. A ten percentage point increase in the growth of immigration in a given year is associated with 0.3 percentage point increase in the skill premium growth two years later. While the short run point estimate is not large, it suggests a significant link between short-run movements in the skill premium and the growth in immigration. The outbreak of WWI had a large negative impact on the growth in the skill premium. Firstly, the large scale mobilization of the armed forces reduced

[25] Note that this more parsimonious system encompasses the more general framework. The LR test of over identifying restrictions, which has a Chi squared distribution (15)=10.37 [p-value=0.80].

the number of civilian unskilled workers. Secondly, the war in Europe effectively stopped mass migration across the Atlantic. By reducing the relative supply of unskilled labor, both these forces would be expected to shrink the skill premium.

Echoing the long-run findings, the evidence in Column 2 strongly suggests that in addition to influencing movements in the skill premium, the growth in immigration was a positive factor behind the growth in education expenditures. Either as an attempt to help assimilate the new arrivals, or in anticipation of the decline in the unskilled wage, or some combination therewith, a one percentage point increase in the growth of immigrants is associated with a 0.2 percentage point increase in expenditures per pupil growth over two years (Dep). The skill premium's net impact on (Dep) is also positive, but somewhat larger. A one percentage point increase in the skill premium in a given year is associated with a net 0.36 percentage point increase in the growth of expenditures per pupil over two years.

The growth in immigration negatively responds to long-run disequilibria. But somewhat surprisingly, the evidence in Table 11 column 5 suggests that lagged short-run changes in expenditures per pupil (Dep), the skill premium (Dsp) and the number of high school graduates (Dhg) are also significantly associated with the growth in immigration. For example, in a given year, a one percentage point rise in the relative price of unskilled labor—a decline in the skill premium—is associated with nearly a nine percentage point rise in the growth of immigrants over the next two years. The other variables are also characterized by such large point estimates. A one percentage point rise in (Dep) in the current year is associated with a nearly five percentage point rise in the growth of immigration over the next two years. Similarly, a one percentage point increase in the growth of high school graduates is associated with a 5 percentage point rise in the growth of immigration the subsequent year. Behind these positive associations is the idea that short-run changes in (Dep) and (Dhg) were probably highly correlated with increases in overall social expenditures and or movements in the business cycle. And large increases in social expenditures or upturns in the business cycle would be expected to attract more immigrants, producing the robust positive association with the growth of immigration. Moreover, the two-year lags are probably correlated with much longer lags. Hence, the significant associations in the two-year lags may also reflect much earlier movements in these variables. That said, because the standard error of the regression is relatively high, the explanatory variables still leave much of the short-run behavior of immigration unexplained. Taken together, the time series evidence offers key support for the theory. At the most general level, it shows that over the period 1895 to 1926, immigration, high school attainment, the skill premium, and schooling expenditures systematically varied together, implying some underlying stable relationship among the variables. Moreover, the vector error correction framework suggests that immigration may not only have affected schooling attainment through factor prices, but in keeping with the idea of egalitarianism and American traditions, it may have also precipitated a rise in public (education) expenditures to help assimilate the new immigrants. As suggested by the analysis, this in turn would have a further positive impact on schooling attainment.

V. Conclusion

This paper has argued that the mass migration of labor at the dawn of the 20th century fundamentally altered the private incentives for educational investment, as changes in relative factor prices induced investment in education. Propagating the initial jump in educational attainment was a schooling investment externality, which lowered the cost of schooling for later cohorts and led to continued educational investment. These arguments were formalized within a dynamic model of schooling investment.

Both the time series and cross-section analyses are remarkably consistent with the general theoretical framework developed in the paper. The cross-section evidence demonstrates that migration flows were positively associated with both the growth in attainment from 1910 to 1928 and the level of attainment in 1910. The asymmetrical impact across gender suggests that migration affected attainment through changes in factor prices. The time series evidence further suggests the possible channels through which immigration may have affected schooling. In particular, it shows that during this era immigration flows were an important determinant of movements in the skill premium. But beyond the skill premium, the evidence also suggests that immigration positively affected schooling expenditures. Therefore, as argued in the literature, the relative egalitarianism of the era may have also played an important role in producing the high school movement.

An important corollary to these results is that in Europe, the long delay in educational investment may have stemmed from the emigration of unskilled labor to the United States. Moreover, in many developing countries such as India, China and many parts of Africa, large cross state population movements and unskilled emigration continue. Assessing the impact of these movements on human capital formation would be an important research goal. In addition, although the debate is ongoing, in the last few decades the large influx of unskilled labor into the United States may also be causally related to the large increases in college investment. Lastly, future research could make use of census data, observed at the individual level, in order to make the cross section estimates in this paper more precise.

A. Mathematical Details

To conserve notation, and without loss of generality, I assume throughout that $s+u=a$; therefore, let $\gamma(s(t)) = w(s(t)) - w(a-s(t))$ denote the skill premium. To derive equation (0.6), note that on the optimal investment date the following conditions must hold:

Lemma 1: *On the optimal investment date τ the following conditions are satisfied:*

(0.18)
$$c(s(\tau)) \leq \int_{\tau}^{\infty} \gamma(s(t)) e^{-r(\tau-t)} dt$$

there does not exists a $\tau' > \tau$ such that

(0.19)
$$c(s(\tau)) - c(s(\tau'))e^{-rt} > \int_{\tau}^{\tau'} \gamma(s(t)) e^{-r(\tau-t)} dt$$

Proof: The first condition is obvious. For example, suppose the optimal investment date did not satisfy condition (0.18), then

(0.20)
$$c(s(\tau)) > \int_{\tau}^{\infty} \gamma(s(t)) e^{-r(\tau-t)} dt$$

the cost of investing in education exceeds the present discounted value of the earnings stream.

To prove condition(0.19), define the net value of investing on date τ_2 as:

(0.21)
$$V(\tau) = \int_{\tau}^{\infty} \gamma(s(t)) e^{-r(\tau-t)} dt - c(s(\tau))$$

This is the present discounted value of the skill premium minus the cost of investing. If date τ is the optimal investment date, then $V(\tau) \geq V(t) \forall t$. If there exists τ' which satisfies condition (0.19), then:

(0.22)
$$c(s(\tau)) - c(s(\tau'))e^{-rt} > \int_{\tau}^{\tau'} \gamma(s(t)) e^{-r(\tau-t)} dt$$

which implies:

(0.23)
$$c(s(\tau)) - c(s(\tau'))e^{-rt} > \int_{\tau}^{\infty} \gamma(s(t)) e^{-r(\tau-t)} dt - \int_{\tau'}^{\infty} \gamma(s(t)) e^{-r(\tau'-t)} dt$$

rearranging:

$$\int_{\tau'}^{\infty}\gamma\left(s(t)\right)e^{-r(\tau'-t)}dt-c\left(s(\tau')\right)e^{-rt}>\int_{\tau}^{\infty}\gamma\left(s(t)\right)e^{-r(\tau-t)}dt-c\left(s(\tau)\right) \quad (0.24)$$

(0.25) $V(\tau')>V(t)$, a contradiction.

Now using Lemma 1 we know that for any $\tau'=\tau+\Delta t$

$$c\left(s(\tau)\right)-\frac{c\left(s(\tau+\Delta t)\right)}{1+\Delta tr}\leq\frac{\Delta t\gamma\left(s(t)\right)}{1+\Delta tr} \quad (0.26)$$

Rearranging (0.26)

$$\frac{c\left(s(\tau)\right)-c\left(s(\tau+\Delta t)\right)}{\Delta t}\leq\gamma\left(s(\tau)\right)-rc\left(s(\tau)\right) \quad (0.27)$$

and taking the limit as $\Delta t\to 0$ yields

(0.28) $\dot{s}=\frac{w\left(s(t)\right)-w\left(u(t)\right)-rc\left(s(t)\right)}{-c_1\left(s(t)\right)}$

I next provide a condition for stability of the resulting steady state:

Lemma 2: *s^* is a stable equilibrium if $\left[\gamma'(s)-c'(s)\right]<0$ holds in the neighborhood of s^*.*

Proof: Let $R(s)=\gamma(s,a)-c(s)$, then $\dot{s}=\frac{R(s)}{-c'(s)}$. Linearizing the differential equation around the steady state $s^*:R(s^*)=0$, gives $\dot{s}=\frac{R'(s^*)}{-c'(s^*)}(s-s^*)$. This is stable iff $R'(s^*)<0$.

Proposition 1: *Suppose s^* is a stable equilibrium. If*

$$\frac{\partial\gamma(s^*,a)}{\partial a}>\left[\frac{s^*}{a}\right]\left[r\frac{dc}{ds^*}-\frac{\gamma(s^*,a)}{\partial s^*}\right] \quad (0.29)$$

then an exogenous rise in the number of unskilled increases the fraction of the skilled labor in the population.

Proof: An equilibrium occurs when $\gamma(s,a)-rc(s)=0$ and $u+s=a$. Therefore an equilibrium level of skilled labor, s^*, is defined by $\gamma(s^*,a)-rc(s^*)=0$, where I have used $s=a-u$. Using the implicit function theorem, the elasticity of $s*$ with respect to a exceeds one iff:

$$\frac{\frac{\partial\gamma(s^*,a)}{\partial a}}{r\frac{dc}{ds^*}-\frac{\partial\gamma(s^*,a)}{\partial s^*}}>\frac{s^*}{a}$$

. If this condition holds, then a one percent increase in the number of unskilled leads to a greater than one percent increase in the number of skilled labor in the new equilibrium. Hence, the fraction of skilled labor in the population increases despite the rise in the number of unskilled.

B. Data Sources

The aggregate time series data used in this paper is drawn from the Historical Statistics of the United States (1976). In particular, High School Graduates—Series H 598-601; Public Elementary and Secondary Schools—Expenditures, by Purpose: 1870–1970—Series H 492–507; Average Annual Earnings in All and Selected Industries and in Occupations: 1890–1926—Series D 779–793; Immigrants, by Major Occupation Group: 1820 to 1970—Series C 120–137; Patents Applications Filed and Patents Issued, by Type and by Patentee: 1790 to 1970—W 96-106.

Cross Section Data is compiled from various issues of the Statistical Abstract of the United States. Catholics—Series 79 (1906); Wealth: estimated value of all tangible property situated within each state—Series 281 (1912, 1922); Motor Vehicle Registration—Series 418 (1929); Fraction of the population over 65 years old—Series 12 (1910); Total number in manufactures—Series 115 (1909, 1930); Public and Private High Schools: Total Enrollment—Series 127 (1910, 1930).

C. Figures and Tables

Figure 1
U.S. High School Enrollment as a Fraction of 14-17 Year Olds
1900-1930

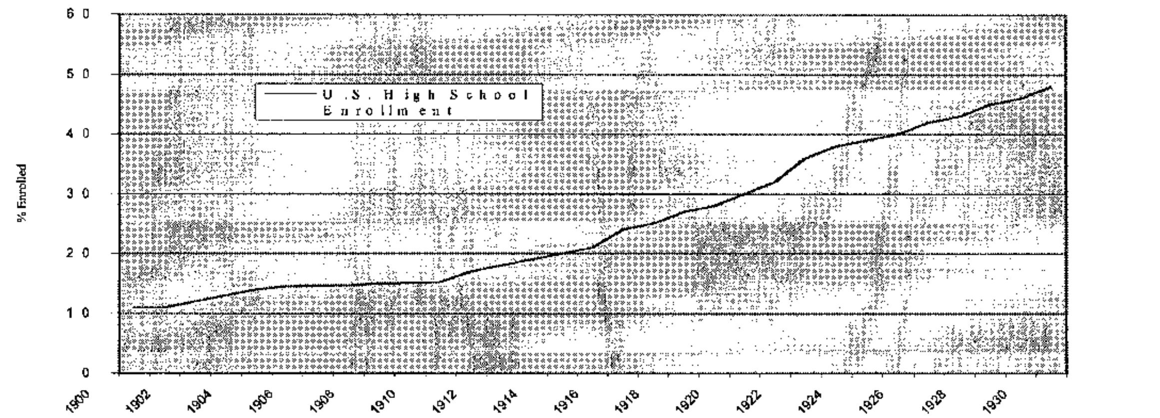


Figure 2
Immigration to the U.S. 1890-1930

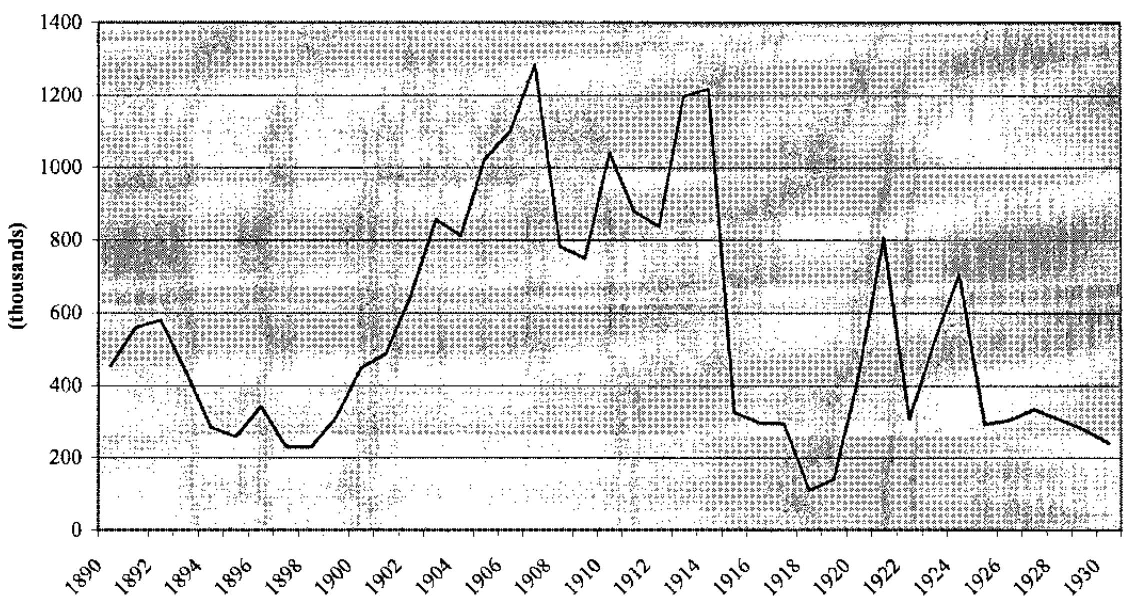


Figure 3
Dynamics of Educational Attainment

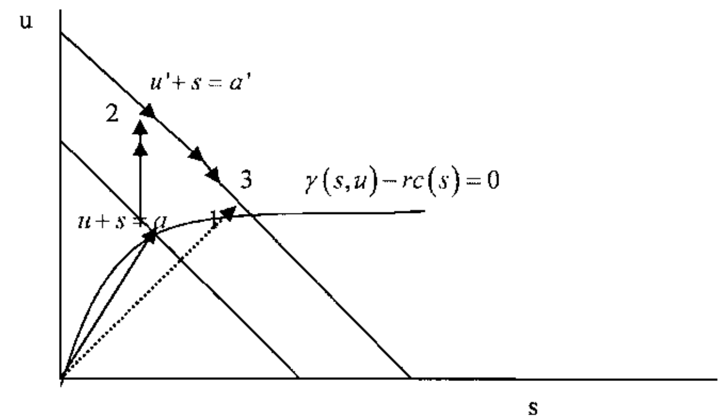
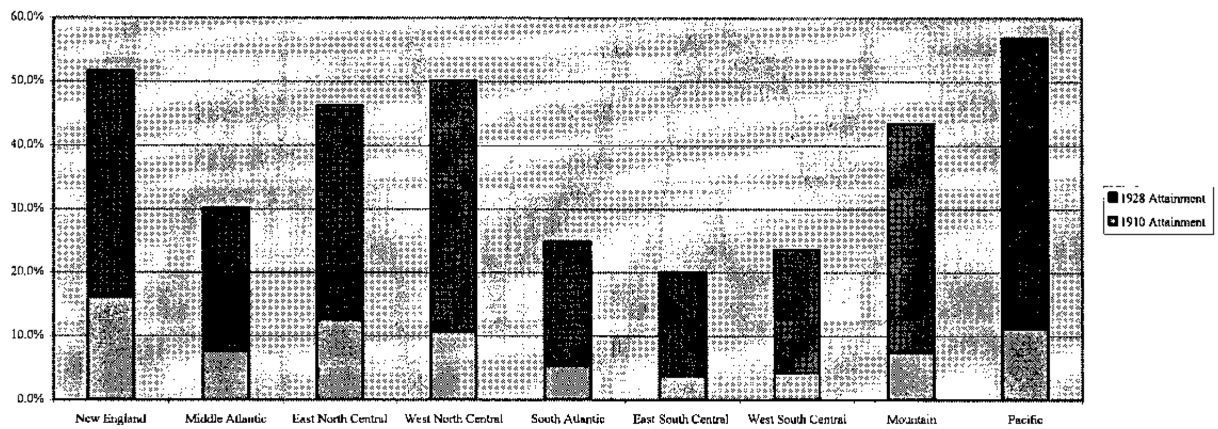
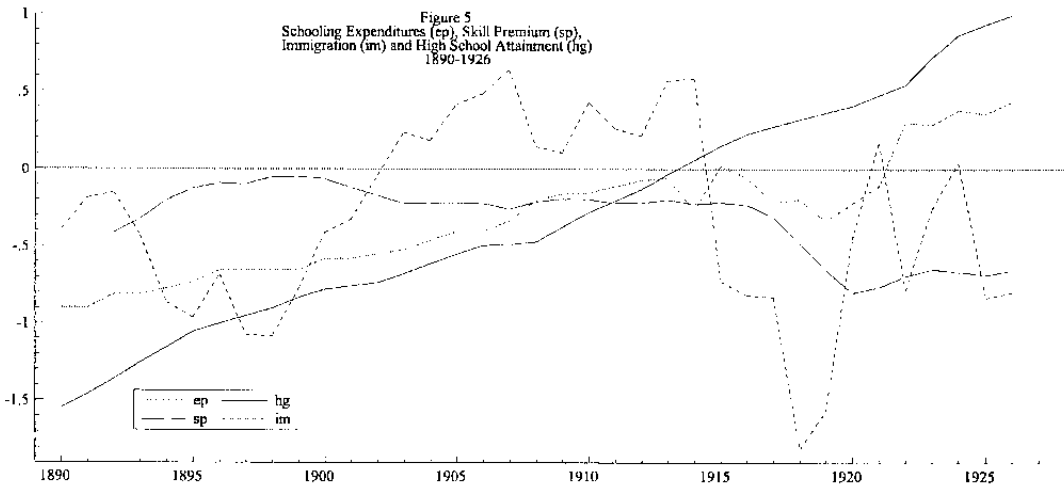


Figure 4
High School Attainment Across Regions: 1910 and 1928



Source: Goldin and Katz (1997)



Figures 5: Data are log transformed, and means are equalized

Table 1. Circa 1910 Descriptive Statistics

Variables / Regions	Total Migration 1870-1930 (thousands) (MIG70)	High School Attainment (1928)	Per capita Wealth (WEA) ($) (1922)	% of population 65 and over (1930)	Education Expenditures per Pupil (1930)
New England	**3,09**	**35**	**3,185**	**7**	**81**
Middle Atlantic	**2,052**	**22**	**3,352**	**5**	**105**
East North Central	**7,921**	**33**	**3,063**	**6**	**88**
West North Central	**167**	**39**	**3,588**	**7**	**76**
South Atlantic	**-126**	**19**	**2,005**	**4**	**39**
East South Central	**-577**	**16**	**1,437**	**5**	**29**
West South Central	**374**	**19**	**1,857**	**4**	**42**
Mountain	**1643**	**36**	**3,435**	**5**	**86**
Pacific	**1,726**	**45**	**3,934**	**7**	**116**
Mean	**1,499**	**29**	**2872**	**5**	**74**
Minimum	**-577**	**16**	**861**	**4**	**12.5**
Maximum	**7,921**	**45**	**3,002**	**7**	**64.3**

Table 2. Circa 1928 Descriptive Statistics

Variables / Regions	Total Migration 1870-1930 (thousands) (MIG70)	High School Attainment 1910 (HSA)	%Catholic in 1906 (CAT)	Per capita Wealth (WEA) ($) 1910	% 65 and over (OLD) 1910	Education Expenditures per Pupil	Motor Vehicle Registrations per capita (1929)
New England	**1,533.6**	**16.7**	**28.9**	**1,761**	**5.9**	**46.4**	**20**
Middle Atlantic	**3,927.8**	**7.7**	**20.4**	**2,374**	**4.4**	**49.2**	**18**
East North Central	**1,527**	**12.5**	**14.6**	**2,112**	**5.1**	**45.8**	**25**
West North Central	**2,109.6**	**10.1**	**11.1**	**2,587**	**4.6**	**42.5**	**27**
South Atlantic	**-465**	**5.3**	**2.9**	**1,159**	**3.6**	**17.2**	**16**
East South Central	**-1,126.2**	**3.8**	**3**	**861**	**3.5**	**12.5**	**12**
West South Central	**1,544**	**4.3**	**9.7**	**1,422**	**3.5**	**18.0**	**19**
Mountain	**1,242.3**	**7.5**	**14.1**	**2,312**	**3**	**50.7**	**26**
Pacific	**2,347.6**	**11.2**	**11.1**	**3,002**	**4.5**	**64.3**	**33**
Mean	**1,404.5**	**8.8**	**12.9**	**1,954.4**	**4.2**	**38.51**	**22**
Minimum	**-1,126.2**	**3.8**	**2.9**	**861**	**3**	**12.5**	**12**
Maximum	**3,927.8**	**16.7**	**28.9**	**3,002**	**5.9**	**64.3**	**33**

Table 3. 1910 Cross Correlations

	MIG70	EPX	HSG1910	OLD	NWP70	CAT	MAN	WEA
MIG70	**1.00**	**0.51**	**0.22**	**-0.01**	**0.40**	**0.29**	**0.19**	**0.45**
EPX	**0.51**	**1.00**	**0.57**	**0.17**	**0.24**	**0.26**	**0.08**	**0.84**
HSG1910	**0.22**	**0.57**	**1.00**	**0.79**	**-0.02**	**0.38**	**0.41**	**0.39**
OLD	**-0.01**	**0.17**	**0.79**	**1.00**	**-0.31**	**0.39**	**0.59**	**0.05**
NWP70	**0.40**	**0.24**	**-0.02**	**-0.31**	**1.00**	**-0.08**	**-0.26**	**0.26**
CAT	**0.29**	**0.26**	**0.38**	**0.39**	**-0.08**	**1.00**	**0.60**	**0.17**
MAN	**0.19**	**0.08**	**0.41**	**0.59**	**-0.26**	**0.60**	**1.00**	**-0.12**
WEA	**0.45**	**0.84**	**0.39**	**0.05**	**0.26**	**0.17**	**-0.12**	**1.00**

Table 4. The Growth in Attainment, 1910–1928. OLS estimates

	OVERALL (1)	OVERALL (2)
Constant	0.096*** (0.024)	0.0969*** (0.020)
Overall Migration, 1890-1910	4.44×10^{-05} * (2.34×10^{-05})	5.16×10^{-05} ** (2.35×10^{-05})
WEA*MIG90	-2.05×10^{-08} ** (9.42×10^{-08})	-2.14×10^{-08} ** (9.31×10^{-09})
Wealth	7.69×10^{-06} * (4.15×10^{-06})	4.54×10^{-06} (4.38×10^{-06})
Log of expenditures per pupil	-0.001 (0.008)	1.54×10^{-03} (7.54×10^{-03})
Attainment, 1910	-0.365*** (0.059)	-0.262** (0.099)
% in manufacturing	---	-0.056 (0.062)
% catholic	---	-0.024 (0.027)
% over age 65	---	-0.002 (0.003)
South	---	-0.004 (0.007)
R^2	0.587	0.6338
RESET	1.721 [0.178]	2.137 [0.13]
White	1.259 [0.285]	1.374 [0.215]

Standard errors in parenthesis; p-values in brackets adjacent to test statistics. 49 observations, including the District of Columbia. Variables prefixed by "L"denote a logarithmic transformation. Significant at the 1 percent level:***, at the 5 percent level:**, and at the 10 percent level:*. Migration is defined as the net sum of overall migration from 1890 to 1910. The Southern dummy includes: Delaware, DC, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Mississippi, Arkansas, Louisiana, Texas, Oklahoma, Alabama.

Table 5. Overall Education Gap, circa 1910

	Goldin&Katz Dependant Variable: 1910 Attainment Level (OLS) (1)	Goldin&Katz Dependant Variable: 1910 Attainment Level (OLS) (2)	Overall Dependant Variable: 1910 Education Gap (OLS) (3)	Overall Variable: 1910 Education Gap (WLS) (4)	Overall Variable: 1910 Education Gap [Truncated Sample] (WLS) (5)	Overall Variable: 1910 Education Gap [Truncated Sample] (WLS) (6)
C	-0.175** (0.070)	0.072 (0.090)	0.036* (0.017)	0.059 (0.034)	0.075* (0.084)	0.112 (0.069)
EPX	---	0.001*** (0.0003)	-0.001** (0.0004)	-0.002*** (0.0006)	-0.002*** (0.0004)	-0.002*** (0.0006)
LWEA	0.275*** (0.09)	-0.127 (0.132)	---	---	---	---
WEA	---	---	9.58×10^{-06} (7.27×10^{-06})	6.40×10^{-06} (1.087×10^{-05})	3.95×10^{-06} (1.14×10^{-05})	3.23×10^{-06} (1.15×10^{-05})
MIG80	---	0.0002 (0.0001)	-4.22×10^{-05} (2.96×10^{-05})	-5.68×10^{-05} (3.54×10^{-05}) *	-2.18×10^{-05} (2.99×10^{-05})	-1.69×10^{-05} (3.10×10^{-05}))
MIG80*LWEA	---	-3.02×10^{-05} (2.04×10^{-05})	-1.91×10^{-08} (1.17×10^{-08})	-2.36×10^{-08} (7.79×10^{-09}) ***	1.90×10^{-08} (1.03×10^{-08}) *	-1.72×10^{-08} (1.07×10^{-08})
% Catholic	-0.081* (0.043)	-0.056 (0.039)	0.022 (0.047)	-0.058 (0.059)	-0.057 (0.062)	-0.047 (0.065)
% of labor force in manufacturing	-0.173** (0.086)	-0.223** (0.083)	0.134 (0.097)	0.154 (0.137)	0.083 (0.517)	0.056 (0.166)
% $\geq$ 65 years	2.091*** (0.291)	2.250*** (0.255)	-0.029*** (0.003)	-0.021*** (0.005)	-0.023*** (0.006)	-0.023*** (0.006)
SOUTH	-0.029*** (0.009)	-0.020** (0.009)	-0.021** (0.011)	-0.010 (0.017)	---	---
Legal School Leaving Age	---	---	---	---	---	-0.002 (0.004)
New England	0.052*** (0.015)	0.042*** (0.014)	---	---	---	---
R^2	0.852	0.892	0.858	0.744	0.779	0.781
White	0.703 [0.802]	0.479 [0.940]	0.759 [0.006]	1.399 [0.203]	0.123 [0.298]	1.762 [0.083]
RESET	2.445 [0.08]	2.362 [0.090]	2.726 [0.056]	1.938 [0.139]	1.567 [0.212]	1.484 [0.234]

Standard errors in parenthesis; p-values in brackets adjacent to test statistics. 49 observations, including the District of Columbia. Variables prefixed by "L"denote a logarithmic transformation. Significant at the 1 percent level:***, at the 5 percent level:**, and at the 10 percent level:*. Migration is defined as the net sum of migrants from 1880 to 1910. The Southern dummy includes: Delaware, DC, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Mississippi, Arkansas, Louisiana, Texas, Oklahoma, Alabama.

Table 6. Overall Education Gap, circa 1928

	Overall (OLS) (1)	Overall (IV) (2)
CONS	0149 (0.104)	0.111 (0.122)
MIG90	5.84×10^{-05} (0.0001)	8.03×10^{-05} (0.0001)
MIG90*LWEA	-1.29×10^{-08} (1.29×10^{-08})	-2.40×10^{-09} (3.30×10^{-08})
WEA	-8.34×10^{-05} (3.26×10^{-05})**	-4.76×10^{-06} (5.68×10^{-05})
EPX	0.001 (0.0012)	-0.003 (0.003)
SOUTH	0.059 (0.045)	0.069 (0.052)
% of labor force in manufacturing	0.002 (0.006)	0.008 (0.009)
% ≥ 65 years	-0.031* (0.016)	-0.037* (0.019)
Per capita motor vehicle registrations	-0.010* (0.005)	-0.005 (0.007)
R^2	0.751	0.670
White	0.587 (0.856)	0.483 (0.922)
RESET	2.604 (0.07)*	---

Standard errors in parenthesis; p-values in brackets adjacent to test statistics. 49 observations, including the District of Columbia. Variables prefixed by "L"denote a logarithmic transformation. Significant at the 1 percent level:***, at the 5 percent level:**, and at the 10 percent level:*. Migration is defined as the net sum of migrants from 1890 to 1930. The Southern dummy includes: Delaware, DC, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Mississippi, Arkansas, Louisiana, Texas, Oklahoma, Alabama.

Table 7. Occupational Distribution, 1890–1930

	1890/1900		1930	
Occupation	Men (in percent)	Women (in percent)	Men (in percent)	Women (in percent)
Professional	10.2	9.6	13.6	16.5
Clerical	2.8	4.0	5.5	20.9
Sales	4.6	4.3	6.1	6.8
Manufacturing	37.6	27.7	45.2	19.8
Service	3.1	35.5	4.8	27.5
Agricultural	41.7	19.0	24.8	8.4

Source: Goldin (1990).

Table 8. Male and Female Attainment

	Male (Y=Annual Average Growth in Attainment, 1910-1928) (OLS)	Female (Y=Annual Average Growth in Attainment, 1910-1928) (OLS)	Male (Y=Attainment Gap, 1910) (WLS)	Female (Y=Attainment Gap, 1910) (WLS)	Male (Y=Attainment Gap, 1928) (IV)	Female (Y=Attainment Gap, 1928) (IV)
Constant	0.103*** (0.018)	0.095*** (0.018)	0.045* (0.026)	0.048** (0.019)	0.109 (0.100)	0.131 (0.150)
Overall Migration, 1880-1910			-5.98×10^{-05} (1.81×10^{-05})**	-4.39×10^{-05} (2.65×10^{-05})	---	---
WEA*MIG80			-2.36×10^{-08} (1.81×10^{-09})***	-2.86×10^{-08} (8.84×10^{-09})**	---	---
Overall Migration, 1890-1910	5.19×10^{-05} (2.55×10^{-05})**	3.91×10^{-05} (2.55×10^{-05})	---	---	4.05×10^{-05} (9.60×10^{-05})	0.0001 (0.0001)
WEA*MIG90	-2.25×10^{-08} (1.03×10^{-08})**	-1.97×10^{-08} (1.03×10^{-08})*	---	---	-8.71×10^{-10} (2.73×10^{-08})	-3.39×10^{-09} (4.09×10^{-08})
Wealth	7.86×10^{-06} (4.62×10^{-06})*	8.65×10^{-06} (4.55×10^{-06})*	1.35×10^{-05} (8.51×10^{-06})	8.79×10^{-06} (1.24×10^{-05})	1.15×10^{-05} (4.69×10^{-05})	2.37×10^{-06} (7.04×10^{-05})
Log of expenditures per pupil	-0.002 (0.007)	-0.0003 (0.008)	---	---	---	---
Expenditures per pupil			-0.002*** (0.0005)	-0.003*** (0.0006)	-0.002 (0.002)	-0.004 (0.003)
Attainment, 1910	-0.433*** (0.069)	-0.359*** (0.054)	---	---	---	---
% in manufacturing			0.037 (0.349)	0.257 (0.158)	0.002 (0.007)	0.012 (0.011)
% catholic			-0.019 (0.046)	-0.121* (0.069)	---	---
% over age 65			-0.0172*** (0.004)	-0.022*** (0.006)	-0.036** (0.016)	-0.037 (0.023)
South	---	---	-0.004 (0.0135)	-0.017 (0.021)	0.068 (0.043)	0.065 (0.065)
Motor Vehicle Registrations, per capita	---	---	---	---	-0.003 (0.005)	-0.006 (0.008)
R^2	0.593	0.621	0.717	0.691	0.695	0.633
RESET	4.854 [0.006]	1.816 [0.159]	2.105 [0.116]	1.547 [0.161]	---	---
White	1.393 [0.205]	1.404 [0.199]	1.814 [0.111]	0.377 [0.989]	0.541 [0.887]	0.477 [0.926]

Standard errors in parenthesis; p-values in brackets adjacent to test statistics. 49 observations, including the District of Columbia. Variables prefixed by "L"denote a logarithmic transformation. Significant at the 1 percent level:***, at the 5 percent level:**, and at the 10 percent level:*. Migration is defined as the net sum of overall migration from 1890 to 1910. The Southern dummy includes: Delaware, DC, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Mississippi, Arkansas, Louisiana, Texas, Oklahoma, Alabama.

Table 9. Statistical Properties of the Data, 1892–1926

Variable	ADF Statistic
DEP	-3.29**
DHG	-3.76**
DSP	-3.38*
DIM	-3.14***

Augmented Dickey Fuller Tests for a unit root included a constant, trend and two lags.
*** denotes 1% significance level, **denotes 5 % significance level, *denotes 1% significance level.

Table 10. Cointegration Analysis of the Determinants of the High School Movement, 1894–1926.

Panel A

Eigenvalue	0.74	0.38	0.15	0.00
Max Statistic (95% critical value)	42.62** (27.1)	15.28 (21.0)	5.05 (14.1)	0.03 (3.8)
Trace Statistic (95% critical value)	62.98** (47.2)	20.36 (29.7)	5.08 (15.4)	0.03 (3.8)

Panel B

Estimated Cointegrating Vectors $(\beta' s)$ and Error Correction Coefficients Weights $(\alpha' s)$

	β_1	β_2	β_3	β_4	α_1	α_2	α_3	α_4
cp	1.00	-4.35	1.52	-10.62	0.21	0.09	-0.00	-0.00
Hg	-0.60	1.00	0.04	8.29	0.33	-0.00	0.01	0.00
Sp	-0.55	-4.37	1.00	5.03	0.02	0.02	-0.01	-0.00
im	-0.07	0.72	-1.15	1.00	-3.38	0.07	0.12	0.00

```
Vector portmanteau  4 lags=   59.855
Vector AR 1-2  F(32, 27) =   0.89591 [0.6201]
Vector normality Chi^2( 8)=    14.048 [0.0805]
```

Panel C

Restrictions on the Cointegrating Space

Hypothesis	Likelihood ratio	p-value
$H^1:(b_1,b_2,b_3,0)\in Sp(\beta)$	9.97	0.00
$H^2:(b_4,b_5,0,b_6)\in Sp(\beta)$	19.81	0.00
$H^3:(b_7,0,b_8,b_9)\in Sp(\beta)$	21.18	0.00
$H^4:(0_1,b_{10},b_{11},b_{12})\in Sp(\beta)$	22.52	0.00

Table 11. Full Information Maximum Likelihood, 1895–1926.

Variables	Dcp	DHg	Dsp	Dim
Dcp_1	-0.443** (0.171)	---	---	4.048*** (0.616)
Dcp_2	---	---	---	1.499*** (0.477)
Dhg_1	---	0.414** (0.163)	---	5.121*** (1.183)
Dhg_2	---	-0.449*** (0.109)	---	---
Dsp_1	0.945** (0.387)	0.177* (0.090)	0.448*** (0.132)	-6.424*** (1.186)
Dsp_2	-0.588* (0.328)	---	---	-2.916*** (0.859)
Dim_1	0.067* (0.038)	0.014 (0.013)	---	-0.926*** (0.164)
Dim_2	0.125*** (0.039)	0.013 (0.009)	0.029* (0.017)	---
CI_1	---	0.214*** (0.054)	---	-4.249*** (0.846)
WW1	0.047 (0.061)	0.049** (0.020)	-0.052** (-0.023)	-1.743*** (0.234)
Constant	0.051** (0.021)	2.320*** (0.575)	0.000 (0.008)	-45.117*** (8.999)
	s.e. = 0.091	s.e. = 0.022	s.e.=0.041	s.e.=0.237

Standard errors in parenthesis. Misspecification tests (p-values in brackets): Testing for vector error autocorrelation from lags 1 to 2 Chi^2(32) = 30.826 [0.5259]and F-form(32,53) = 0.6535 [0.9001]; Vector normality Chi^2(8)= 20.066 [0.0101] *; Testing for vector heteroscedasticity using squares Chi^2(180) = 203.06 [0.1147]. LR test of over-identifying restrictions: Chi^2(15) = 10.371 [0.796]

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