# An Exceptionally Simple Theory of Industrialization*

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**Abstract**

Historically, industrialization has been associated with falling relative returns to skills. This fact is at odds with most theories of industrialization, which tend to imply rising skill premia as natural concomitants to economic growth. This paper develops a very simple model of historical growth to help solve this puzzle. Assuming that human capital is both a consumption good and an investment good, the model demonstrates how rising education levels, non-monotonic fertility rates, and falling skill premia can all be explained within one theory.

- *Keywords*: endogenous demography, skill premium, unified growth theory
- *JEL Codes*: J11, J31, N33, O33, O41

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# 1 Introduction

To many, world economic history is surprisingly simple - for the last few hundred years technological progress has allowed some societies to lift themselves out of their timeworn Malthusian-based poverty (Clark 2007). Yet while this history may be simple, the challenge to theoretically explain it has been anything but. The difficulty has been to capture the qualitative *effects* of these technological changes. In particular, the accessories of today's growth are in many ways completely different from those at the dawn of technological growth. Today progress is associated with a stable (or even falling) population, high rates of education, rapid income growth on average and great income disparities within the economy. The world's first foray into modernity two and a half centuries ago, on the other hand, witnessed something very different - exploding population, stagnant education, modest increases in average income and *falling* income inequality. Traditional growth theories, able to capture present-time growth, are nevertheless consistent only with a small fragment of human history.

What to make of such disparate pictures? To extrapolate forward from the Industrial Revolution would be to predict a fairly egalitarian society of 40 billion illiterate souls of very modest means.[1] To extrapolate backwards from our modern world would be to suggest an industrial "big bang" of immediate fertility control and skill acquisition. Both exercises are misleading; ostensible discontinuities in historical growth patterns frustrate these kinds of simple forward and backward inductions.

This paper attempts to link both worlds by employing a very simple model of growth and demography. Using a unified approach such as this has been the *cri de coeur* of Oded Galor, who entreats growth economists to use micro-founded theories to capture the entire process of development, not merely an episode of it (Galor 2005, 2009). This creates a formidable but important intellectual challenge - constraining oneself to a single theory to account for the whole process of development will arguably enhance the viability of growth theory overall.

An even greater challenge in unified growth theory is to link different episodes of industrialization in different economies. First the U.K. and then the U.S. led the world in labor productivity from the mid-eighteenth to mid-twentieth centuries (Broadberry 1994), yet few theories can reasonably capture the growth stories of both. In particular, the industrialization histories of these and many other economies show falling relative returns to skilled labor (at least until the latter half of the 20th century). Yet most theories of industrialization imply that rising skill premia are the natural concomitants to economic growth and modernization (see for example Galor and

[1] Or so might conclude those at *Scientific American*, who published an article in 1976 suggesting that the earth could support a population of 40 billion on a diet of 2,500 calories per day. Of course, the nation of Utopia in H.G. Wells's *Men Like Gods* sounds like an extrapolation of this kind into the *very* distant future: "[the people] spent the great gifts of science as rapidly as it got them in a mere insensate multiplication of the common life. At one time in the Last Age of Confusion the population of Utopia had mounted to over two thousand million."

Weil 2000; Jones 2001; Hansen and Prescott 2002; Lucas 2002). A truly unified approach should endeavor to account for such falling relative returns to skills in these economies.

Specifically, we develop an overlapping-generations model where households choose the number of their children and their levels of education. To this we add two simple and plausible assumptions. One is that skilled and unskilled labor are grossly *substitutable* in production (so that increases in either can produce large aggregate income gains). The other is that income and human capital are grossly *complementary* in household utility (so that human capital can be considered a consumption good as well as an investment good). With these assumptions, we demonstrate how technological progress can produce the characteristics of historical growth in one parsimonious theory - gradual increases in education, non-monotonic changes in fertility, and declines in skill premia.

We hasten to mention that we are only studying the consequences of technological progress, not the sources.[2] Nor are we attempting to account for the timing of industrialization, or motivate the reasons why it happened in England, and not China, India or Japan. For these reasons we treat technological advances as exogenous.[3] However, we should nevertheless investigate the deus ex machina of both the Industrial Revolution and the Demographic Transition simultaneously, for this can help explain some of the historical concomitants of industrialization. Do they each arise from different sources, or do they result from the same underlying forces? The unified approach that follows conjectures the latter to examine what possible forces could have shaped the world into the one in which we currently find ourselves.

The rest of the paper proceeds as follows. Section 2 enumerates some of the "stylized facts" of the first and second industrial revolutions. Section 3 goes through the model of technology and demography. Section 4 simulates the model to see if it can adequately capture the major qualitative aspects highlighted in section 2. Section 5 concludes.

## 2 The Facts to Fit

Galor (2005) asks some of the fundamental questions that unified growth theories aim to answer, one of the most important being "What are the underlying behavioral and technological structures that can simultaneously account for these distinct phases of development?" In this paper we impose a certain behavioral structure, motivated by available historical evidence, that uniquely accounts for these phenomena. The phenomena we wish to address constitute a new set of "stylized facts" that beg explanation by unified growth theories on industrialization in

[2] See however O'Rourke et al. (2008) for one such study that endogenizes technological growth in history.

[3] Mokyr and Voth (2006) draws from Isaiah Berlin's "The Hedgehog and the Fox" to distinguish between two kinds of researchers - "hedgehogs" looking for a single Theory of Everything, and "foxes" looking for solutions to smaller problems. In keeping certain things exogenous in order to explain some other large phenomena, this paper strives to merge the grand vision of the hedgehog with the talents of the fox.

England and other regions.

## 2.1 The Rise and Fall of Fertility

The first challenge for a model of the Industrial Revolution is to account for its apparent *un*-revolutionary beginnings, for personal income increases were very minor in the early stages of industrialization. One major reason for this was the link between productivity and population growth during the years 1750-1850 (often called the "first Industrial Revolution"). The English population for example rose from six million in the 1740s (roughly the maximum attained throughout the previous millennium) to twenty million by the 1860s. Most of this population increase came from increases in fertility, as mortality declined very modestly during the first Industrial Revolution (falling only to where it had been during the mid-seventeenth century). Crude birth and death rates for England are depicted in Figure 1.

The relationship between income per capita and population growth in England and much of Western Europe however evolved non-monotonically. While the first Industrial Revolution witnesses a dramatic increase in birth rates along with increases in per capita incomes, this pattern reversed during the "second Industrial Revolution" (roughly 1850-1910), where further per capita income gains accompanied rapidly falling birth rates (see Figure 1).

For the United States, Jones and Tertilt (2006) document both the sharp fall in fertility throughout most of the 20th century as well as the strong negative relationship between income and fertility for all cohorts. Thus it appears that 20th century American growth continued the late 19th century European trend of general demographic transition (see Figure 3).

## 2.2 The Role of Education

One of the most difficult challenges for would-be unified growth theorists is attempting to explain education's non-role during the early stages of industrialization. While most theories of industrialization imply that growth and skill accumulation go hand in hand,[4] the first Industrial Revolution appears to be compatible with greater use of *unskilled* labor instead of skilled labor. During this time rates of formal education and training either remained stagnant or rose very modestly. There is much evidence of this pattern. For example, David Mitch suggests that in key expanding sectors of the British economy, such as cotton textiles, rates of education were declining. For the general economy, elementary school enrollment figures based on parochial surveys between 1818 and 1833 show enrollment perfectly steady at 42 percent (Mitch 1982). Indeed, according to Sanderson (1995), literacy rates did not increase at all through the whole first wave of industrialization (1750 - 1830; see Figure 2). Landes (1969) sums it up best: "Although certain workers - supervisory and office personnel in particular - must be able to read

[4] See for example Becker et al. (1990), Hansen and Prescott (2002), and Lucas (2002).

and do the elementary arithmetical operations in order to perform their duties, a large share of the work of industry can be performed by illiterates as indeed it was, especially in the early days of the Industrial Revolution." In short, formal education barely rose during the heart of the first Industrial Revolution, the period between 1750 and 1830.

This makes the contrast between the first and second Industrial Revolutions all the more striking, for education grew rapidly later on. For example, Schofield (1973) shows very sluggish increases in signature rates at marriage from 1780 - 1830, but these subsequently skyrocket, and England achieves near-universal literacy a mere 70 years later. And Flora et al. (1983) documents that while only 11 percent of children aged 5-14 were enrolled in primary school in 1855, this figure explodes to 74 percent by the turn of the century (see Figure 2). Thus it appears that education became more and more important in production only during the latter stages of industrialization.

America's growth in the 20th century only reaffirms the importance of human capital in the post mid-19th century world. Goldin (1999) documents the prominent role education played in the U.S. economy during the 20th century (see Figure 3). At the start of the century very few people could afford to attend school; by the end of the century very few could afford *not* to attend school. This dramatic transformation in America's focus on education leads Goldin and Katz (2007, 2008) to dub the 20th century the "human capital century." Any theory attempting to unify the stages of growth has to account for this transformation of education's immaterial role in the eighteenth century to its indispensability in the twentieth.

## 2.3 Inequality and the Skill Premium

Based on the evidence on education, one would perhaps suspect that earnings for educated people were quite low during England's first Industrial Revolution and at the dawn of the American 20th century, thus inducing families to keep their children uneducated. Only higher relative earnings for educated children would induce parents to provide their children a formal schooling. But the evidence suggests just the opposite - from 1700 up to the Great War, the premium on education in England was at its peak *before* industrialization and modernization ever happened. Similarly in the United States, the relative return of a high school diploma was at its peak at the turn of the *20th* century, not the 21st.

As can be seen in Figure 4, the skill premia generally fell during both of England's Industrial Revolutions. Williamson (1982) produces a variety of skill premia for different classifications of workers - here we see that even when farmers are included as unskilled laborers (a group whose wages were relatively stagnant in the first half of the 19th century), skill premia do not reach their 1755 highs even a century later. These figures also indicate falling premia between 1781 and 1815, right during the heart of the Industrial Revolution. Mitch (1999) reaffirms this, showing that premia were either stagnant or declining during this time. And Clark (2003) illustrates that premia continue to fall even during the second Industrial Revolution, a time that many suggest was when human capital played a critical role in production.

As for the United States, an extensive literature exists on the pre-Second World War wage premium for skilled to manual workers. Almost all papers in this literature find a compression of the wage structure before 1950.[5] Goldin and Katz (2008) suggest a general pattern of falling premia prior to 1950, relatively stagnant premia from 1950 to 1980, and rising premia only after 1980 (see Figure 5).

Thus historically industrialization appears to be conducive to falling returns to skilled labor relative to the returns to unskilled labor. This is also true when looking across countries at different *stages* of industrialization (see Figure 5). There are still other sources of evidence. For example, there is no sign that the rewards to numeracy and literacy were any higher in England in 1800 than they were in 1200. The premium for these and other skills in the labor market seems to have outright declined through the Industrial Revolution. There is simply no evidence of any market signal to parents that they needed to invest more in the education or training of their children during any part of the 19th century (Clark 2003, 2007).

A rather formidable puzzle emerges when attempting to reconcile all these pieces of industrialization. Although human capital is often center stage in stories of modernization, we see a very poor match between the elements that enter into a human capital story of early industrialization: the role of education, the average size of families, and the premium paid in the labor market for skills. Explaining the evolution of the relative returns to skilled labor is particularly challenging. Why does the skill premium fall with an economy's launch into sustainable economic growth?

# 3 A Simple Model of Industrialization

Here we offer a theoretical solution to the above-mentioned puzzles. Two general assumptions are necessary to achieve this. First, final output is produced both by skilled and unskilled labor. The second is that households derive benefits from both income (generated from both skilled and unskilled labor) and human capital (generated from the education obtained by children). The next sections make specific some of these ideas, and simulate an economy to replicate the key features of Western industrialization.

## 3.1 Production

Total production in the economy combines the efforts of both unskilled and skilled labor. These labor-types are imperfectly substitutable; thus we assume that aggregate production can

[5] A partial list of this literature includes Bell (1951), Keat (1960), Lebergott (1947), Ober (1948), Woytinsky (1953), and Lindert and Williamson (1980).

be described by the CES production function:

$$Y = A_t \left( L_t^{\frac{\sigma-1}{\sigma}} + H_t^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{1}$$

where $L_t$, $H_t$, and $A_t$ are respectively unskilled labor, skilled labor and the Hicks-neutral technology level at time $t$. Following many labor studies on the elasticity of substitution between skilled and unskilled labor, we will assume that $\sigma > 1$, so that these factors are grossly substitutable in aggregate production.[6]

Factors are paid their marginal products in competitive markets. Assuming this, we define unskilled and skilled wages, $w_l$ and $w_h$, as

$$w_{l,t} = A_t \left( L_t^{\frac{\sigma-1}{\sigma}} + H_t^{\frac{\sigma-1}{\sigma}} \right)^{\frac{1}{\sigma-1}} L_t^{-\frac{1}{\sigma}} \tag{2}$$

$$w_{h,t} = A_t \left( L_t^{\frac{\sigma-1}{\sigma}} + H_t^{\frac{\sigma-1}{\sigma}} \right)^{\frac{1}{\sigma-1}} H_t^{-\frac{1}{\sigma}} \tag{3}$$

Note that here *relative* factor payments are simply inversely related to relative factors (that is, technology is not *biased* in any way towards any particular factor, so technology does not influence relative factor payments).

## 3.2 Endogenizing Demography

Economic theory of fertility and education suggests that household demand for children and their education will depend on family preferences, in many ways similar to preferences over standard economic "goods." Thus the demographic choice for a society stems from the perceived price or opportunity cost of child-rearing, and from levels of family income. The question for theorists of unified growth is how to model stable family preferences that are consistent with the very different patterns of behavior observed in history.

We will assume that agents care both about their current consumption of the final good, and the level of human capital of their children. We assume an over-lapping generations framework with two stages of life - young and old. Young individuals work strictly as unskilled workers, but also accumulate human capital. Old individuals work as both skilled and unskilled laborers, and have children of their own. Only old individuals make decisions regarding demography. Specifically, the representative household is run by an old person who decides two things: how many children she wishes to have (denoted $n_t$) and the level of education each child will receive (denoted $e_t$).

Our modeling of demography is as follows. An individual born at time $t$ spends fraction $e_t$ of her time in school (something chosen by her parent), while devoting the rest of her time as an

[6]See for example Katz and Murphy (1992), Autor et al. (1998), Heckman et al. (1998), Ciconne and Peri (2005), and Autor et al. (2007).

unskilled laborer in the unskilled sector. At $t+1$, the individual (who by this time is mature) provides one unit of labor inelastically in the unskilled sector, and uses whatever human capital she accumulated as a child in the skilled sector. After incurring the resource costs of child-rearing, the adult consumes all the income she and her family have generated. After this she expires and exits the economy.

Given this, we specify a household objective function. We assume that agents care about both their income and their children's future level of human capital,[7] and that these two things are imperfectly substitutable.

The utility of the parent $U$ is given by

$$U_t = \left(\lambda \left(I_{p,t} + I_{c,t} - C_t\right)^{\varepsilon} + (1-\lambda)\left(h_{t+1}\right)^{\varepsilon}\right)^{1/\varepsilon} \tag{4}$$

where $I_p$ is the income generated by the parent, $I_c$ is the income generated by her children, $C$ is the opportunity costs associated with child-rearing, and $h$ is the average human capital endowed to each child. These variables are functions of fertility and eduction choices made by the parent, as well as functions of wages paid to skilled and unskilled labor. Specifically, we assume that $\frac{\partial I_{c,t}}{\partial n_t} > 0$, $\frac{\partial I_{c,t}}{\partial e_t} < 0$, $\frac{\partial I_{p,t}}{\partial e_{t-1}} > 0$, $\frac{\partial C_t}{\partial n_t} > 0$, $\frac{\partial C_t}{\partial e_t} > 0$, and $\frac{\partial h_{t+1}}{\partial e_t} > 0$. That is, increasing fertility will raise the income produced by children and raise the costs of child-rearing; increasing education on the other hand will raise bequests of human capital to children and raise the costs of child-rearing yet at the same will lower income from children (essentially pulling children out of work and into school).

Thus we are treating human capital as both an *investment* good (as adults rely on their education to generate greater returns to their labor) and a *consumption* good (as families derive benefits from educated children unrelated to family income). Goldin (1999) summarizes the complex nature of education this way: "Education directly enhances productivity, and thus the incomes of those who receive schooling, by providing individuals with useful skills....Schooling is also a pure consumption good, enabling people to better understand and enjoy their surroundings." The approach taken here is simple enough to be incorporated tractably into an inter-generational setup, yet still able to highlight this multi-dimensional nature of education.

The parent will maximize this expression with respect to fertility and education. The first order condition with respect to fertility is simply

$$\frac{\partial C_t}{\partial n_t} = \frac{\partial I_{c,t}}{\partial n_t} \tag{5}$$

[7] Utility based on the education of children need not solely be motivated by altruism. For example, educated children may produce a pleasant and stimulating living environment, or may produce a source of retirement income. Acemoglu, in his recent book *Introduction to Modern Economic Growth*, would call this an example of "impure altruism," or "warm glow preferences." "Warm glow preferences assume that parents derive utility not from the future utility of their offspring, but from some characteristic of their offspring." (Acemoglu 2008, pg 840).

This states that the marginal cost of an additional child (in the form of higher child-rearing costs) must equal the marginal benefit of an additional child (in the form of greater unskilled-labor income). Note that because fertility is only in the first term of equation (4), the first order condition for fertility is simple and takes no account of education levels.

The first order condition for education on the other hand is slightly more involved:

$$\frac{\partial C_t}{\partial e_t} - \frac{\partial I_{c,t}}{\partial e_t} = \left(\frac{1-\lambda}{\lambda}\right)\left(\frac{I_{p,t}+I_{c,t}-C_t}{h_{t+1}}\right)^{1-\varepsilon}\frac{\partial h_{t+1}}{\partial e_t} \tag{6}$$

The left hand side is the marginal cost of education. This cost arises from two sources - increasing the level of education per child raises the opportunity cost of child-rearing ($\frac{\partial C}{\partial e}$) and lowers the income generated from unskilled-child labor ($\frac{\partial I_c}{\partial e}$, which is negative). The right hand side is the marginal benefit of education. Education raises the level of human capital per child, which is a positive input in the parent's welfare function. Notice however that these gains from education are augmented by the term $\left(\frac{I_{p,t}+I_{c,t}-C_t}{h_{t+1}}\right)^{1-\varepsilon}$ - which captures the importance of *balance* between total income and average human capital per child. The greater is net household income relative to human capital per child, the greater are the marginal benefits from additional education. The exponent $1-\varepsilon$ magnifies this effect - the smaller is $\varepsilon$ (that is, the more complementary are net income and human capital per child), the greater are the net benefits from education when net income is large relative to human capital. Indeed, these income-human capital complementarities will be a key feature that drives human capital accumulation throughout the Industrial Revolution.

Finally, income levels change with wage changes. These wage shocks arise from technological developments and are exogenous to the family planner.

In order to simulate the economy we will need to explicitly state how the variables in the welfare function ($I_{p,t}$, $I_{c,t}$ ,$C_t$ , and $h_{t+1}$) are functions of both control variables ($n_t$ and $e_t$) and current wages ($w_{l,t}$ and $w_{h,t}$). We specify the following simple forms:

$$I_{p,t} = w_{l,t} + w_{h,t}h_t \tag{7}$$

$$I_{c,t} = w_{l,t}\left(1-e_t\right)n_t \tag{8}$$

$$C_t = w_{h,t}\phi n_t^{\gamma}\left(1+e_t\right)^{\gamma} \tag{9}$$

$$L_t = pop_t + n_t\left(1-e_t\right)pop_t \tag{10}$$

$$H_t = h_t pop_t = \Lambda e_{t-1}^{\alpha} pop_t \tag{11}$$

$$pop_{t+1} = n_t pop_t \tag{12}$$

where $0 < \alpha < 1$, $\gamma > 1$ and *pop* is the adult population. (7) - (9) respectively depict the unskilled and skilled income generated by the parent, the unskilled income generated by children, and forgone skilled income due to child rearing. (10) and (11) illustrate how fertility and education translate into unskilled and skilled factors of production (note that $L$ includes both adults and children, while $H$ includes only adults). Here we have a simple production function for human capital that increases in education but experiences diminishing returns, and costs of child rearing (in the form of foregone skilled income for the parent) that rise in both fertility and education. Further, notice that (8) captures our fertility-education tradeoff mentioned above - more education, while increasing $h_{t+1}$, will necessarily decrease $I_{c,t}$. So long as these relationships are true our results will hold, so the qualitative conclusions we get will not be sensitive to the precise forms or parameter values in (7) - (11). Finally, (12) shows the law of motion of the adult population, dictated by the fertility rate.

# 4 Simulating the Past

## 4.1 Static Equilibrium - Before the Industrial Revolution

In order to simulate the economy we must first establish the appropriate initial conditions. Here we will treat the onset of industrialization as the moment when technological growth becomes positive. Thus we treat our pre-industrial economy as a purely static one, where technology coefficient $A$ is fixed at some pre-determined level. This is of course not an entirely accurate depiction of pre-industrial society, as technologies glacially improved for millennia prior to industrialization. The fact that technological growth was much slower before the Industrial Revolution is what is important, however, and hence we lose nothing in assuming the extreme case of zero growth as our starting point.

Beyond this, the static equilibrium requires a stable demographic structure. The conditions necessary for this are: $n_t = 1$, and $e_t = e_{t-1}$ at some very small level. That is, the typical dynasty simply reproduces itself, and parents and children have the same low education levels. The four equations we must satisfy are the first order conditions on production (2) and (3), and the first order conditions on utility (5) and (6). To obtain the static equilibrium, we set $n_t = 1$ and $e_t = e_{t-1} = 0.0001$, and solve for $w_{l,t}$, $w_{h,t}$, $A_t$, and $\alpha$ for $t = 1$, setting all other parameters equal to plausible values.[8]

[8] These are $\sigma = 2$, $\lambda = 0.5$, $\varepsilon =$ -10, $\Lambda = 2$, $\phi = 0.5$, $\gamma = 2$. Note that the key parameters here are those that affect the substitutability of skilled and unskilled labor in production ($\sigma$) and the substitutability of income and human capital in utility ($\varepsilon$). While values of $\varepsilon$ are purely speculative, much work has been done to estimate $\sigma$. The literature tends to value this somewhere between 1 and 2.5 for contemporary labor markets (see Katz and

Our specific functional forms will allow such a solution; this constitutes our static equilibrium.[9] With these values as our initial condition, all remains static - as households have no incentive to change demographic behavior given current wages, $L$ and $H$, and thus wages themselves, remain fixed. That is, until technologies begin to improve.

## 4.2 Dynamic Equilibria - the Industrial Revolution and the Demographic Transition with Exogenous Technological Growth

Here we run the simulation for 50 time periods to roughly capture economic and demographic trends for our hypothetical industrializing economy. Each time period we grow $A$ exogenously by 2 percent and *pop* by the rate $n_{t-1}$, and solve the system of equations (2), (3), (5) and (6) for $w_{l,t}$, $w_{h,t}$, $n_t$ and $e_t$.

Figures 6 and 7 illustrate the results of the simulation. At the moment of technological growth, the population is stable, education is extremely low and the skill premium is quite large. With early productivity increases, fertility rises and education rises very slightly as well. How is this possible in the context of a quality-quantity model of demography? Given (11) and the fact that $0 < \alpha < 1$, we know that the production of human capital follows the *Inada conditions* ($\lim_{e\to 0} \frac{\partial h}{\partial e} = \infty, \lim_{e\to\infty} \frac{\partial h}{\partial e} = 0$). Thus if early rates of education are "small enough," human capital will rise even with very small increases in education. Households can then raise the human capital of their offspring as their income rises. But because it does not cost them a lot to do this, they can also afford to have more children (to take advantage of increases in the unskilled wage). Throughout this process the ratio of skilled to unskilled labor rises, allowing the skill premium to continually fall.

Note that Galor (2005) labels this period the "post-Malthusian" era; this is because productivity increases still translate into population increases. This is precisely what we show here. Even though education is explicitly modeled as a normal good, increases in productivity creates a lot of fertility with only minuscule increases in education. Income *per capita* growth is very modest as a result of population growth. Thus early growth dynamics appear to be dictated by a classic "Malthusian trap."

As exogenous technological progress continues, however, there is an endogenous transition where further increases in productivity result in less fertility and more education. Why does the switch occur? Once education reaches some critical level, diminishing returns to further education are such that these increases become quite expensive. Households are willing to pay this expense as their incomes rise further. But to lower the overall expense for education they have fewer and

Autor 1999 for a review of this literature). We also run a variety of other simulations with alternative parameter values (not illustrated). In general our qualitative results remain consistent so long as $\sigma > 1$, $\varepsilon < 0$, and $\gamma > 1$.

[9] We get initial values of $\alpha \approx 0.1$, $A_1 \approx 0.05$, $w_{l,1} \approx 0.07$, $w_{h,1} \approx 0.17$, $L_1 \approx 2$, and $H_1 \approx 0.3$. Note that the parameter $\alpha$ is then held fixed at its original value, while all other variables evolve with technological progress.

fewer children. So households become less reliant on the unskilled income generated by their offspring, and more reliant on their own income. This is in essence the transition to modernity; a classic quantity/quality tradeoff of child rearing emerges. And as the demographic transition proceeds, income per capita begins to grow faster than overall GDP.[10]

The simulation stresses that in order to truly unify the stages of economic growth, models must account for constant injections of skilled labor over time. An implicit result of important unified theories such as Galor and Weil (2000), and Galor and Mountford (2006, 2008) is that transition to modern growth is associated with rising relative returns to skilled labor (Voth 2003). But we know this did not happen - skill premia at best remained stagnant. Galor (2005) acknowledges the role of supply of human capital in explaining low skill premia, but must rely on exogenous injections of skilled labor (such as those from compulsory schooling laws enacted in the late 19th century). But one might suggest that these so-called exogenous shocks did not come randomly, but rather were the results of political pressures both from industry (who increasingly saw the importance of a skilled work force to exploit productivity improvements, discussed in Galor and Moav 2006) and from households (who saw the "value" of educated children in increasing the well-being of the family, discussed in Horrell and Humphries 1995). These were changes in the economic incentives for education that arguably should be *endogenous* in any model of unified growth.

# 5 Conclusion

Explaining the non-monotonic evolution of fertility, initial stagnation and subsequent growth of education, and fall in relative returns to skilled labor in the Industrial Revolution has constituted one of the major puzzles of economic history. Here we have offered an hypothesis to explain the evolution of these variables, suggesting that the substitutability between skilled and unskilled labor and the familial preferences for educated children must play pivotal roles in the explanation.

Arguably human history is more challenging to explain than natural history, partly because the data for humans can be scanty, and partly because humans are far less regular in their behavior than natural phenomena. But the approach of the natural historian, to pre-suppose some consistent "laws" of behavior to explain historical events, can serve the growth theorist who is bent on unifying the history of industrialization. The theorist, playing God by setting up the initial laws of behavior, should cease playing God once the model is under way, and discipline him or herself by not arbitrarily changing preferences or exogenously shocking things to fit facts. The aim of the unified growth theorist is precisely that - to understand the connections between

[10]Indeed, population declines are so dramatic that total GDP ultimately falls. Of course in reality immigration would likely occur with such wage increases, thus keeping total population from outright falling.

technological progress, the formation of human capital and demographic change by creating a faux universe and letting it run its course. It is a challenging task, and the temptation to intervene is strong. But hopefully by “endogenizing” certain variables, the faux worlds we create can aid the empiricists who are uncovering facts from the real one.

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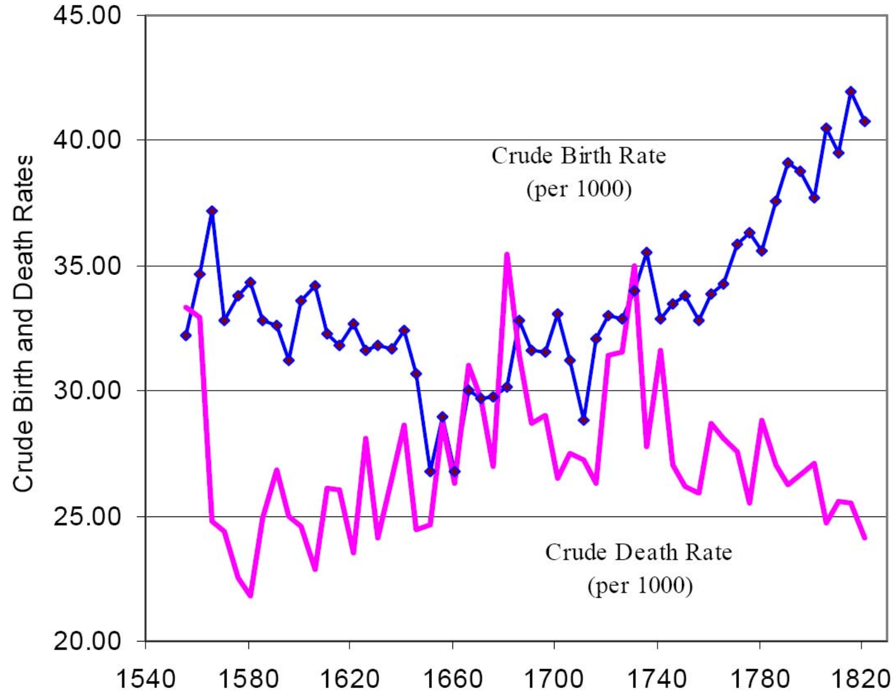
Figure 1: Birth and Death Rates in England (top); Birth Rates in Europe (bottom) [sources: Galor (2005), based on Wrigley and Schofield (1981), Andorka (1978) and Kuzynski (1969)]



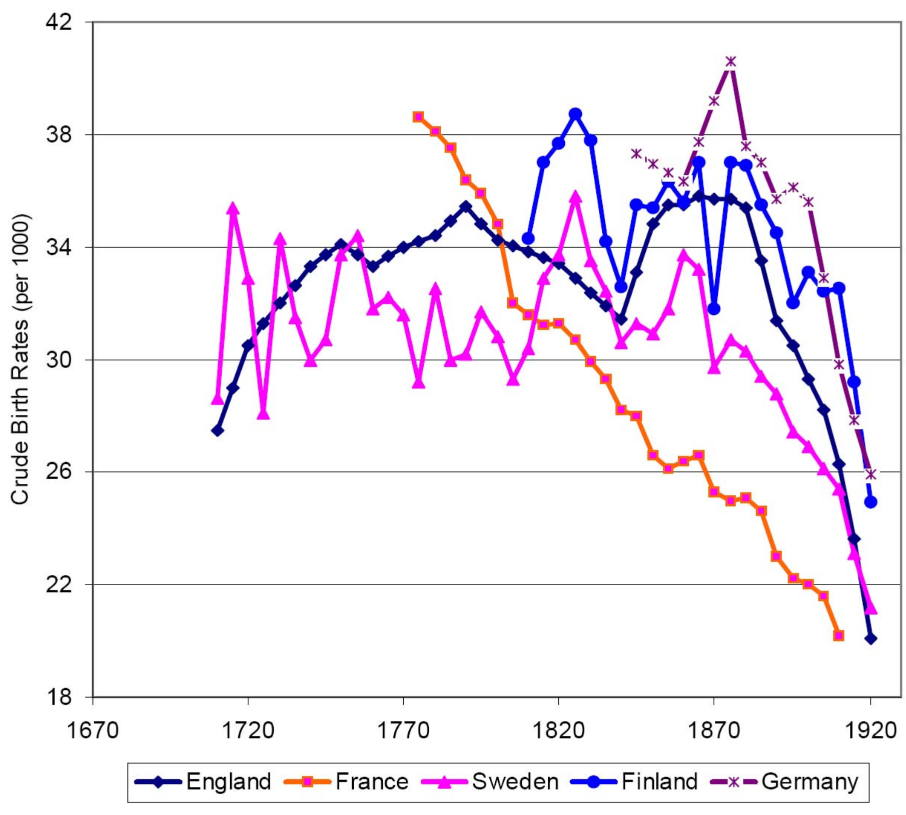
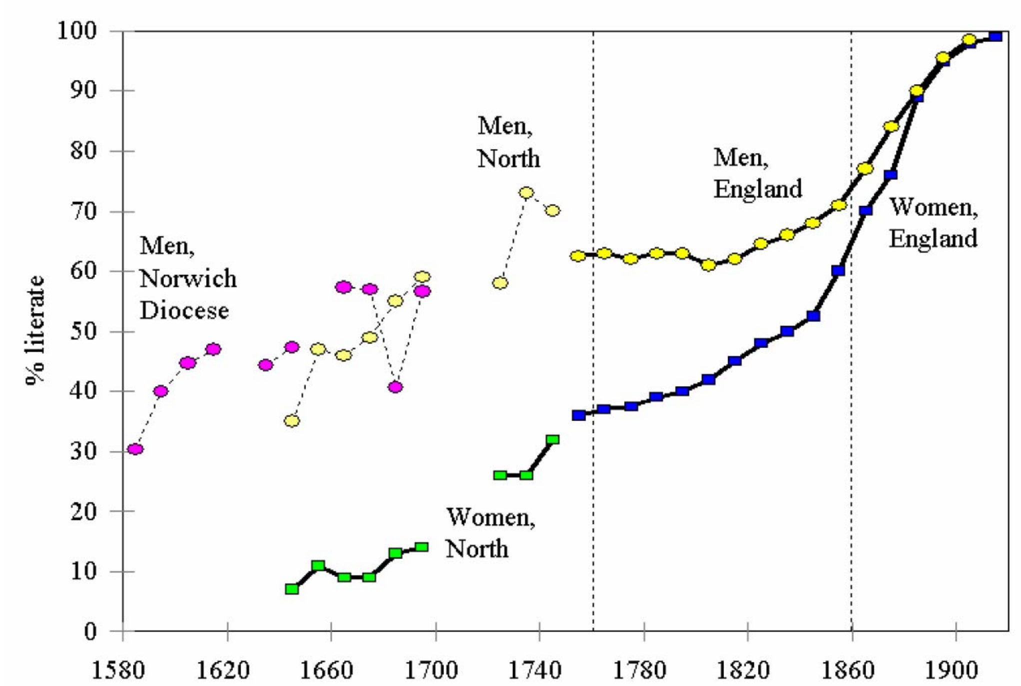



Figure 2: Literacy Rates in England (top) [source: Clark (2005), based on Schofield (1973), Houston (1982), and Cressy (1997)]; Primary School Enrollment Rates in England and France (bottom) [source: Galor (2005), based on Flora et al. (1983)]



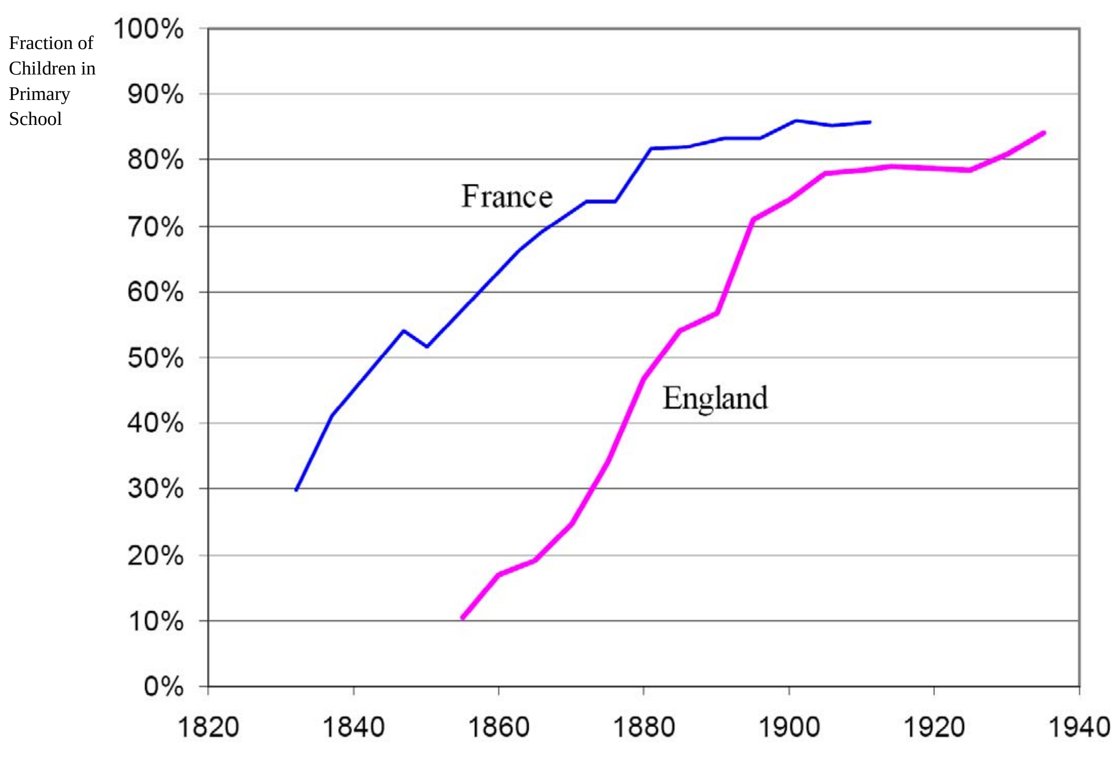
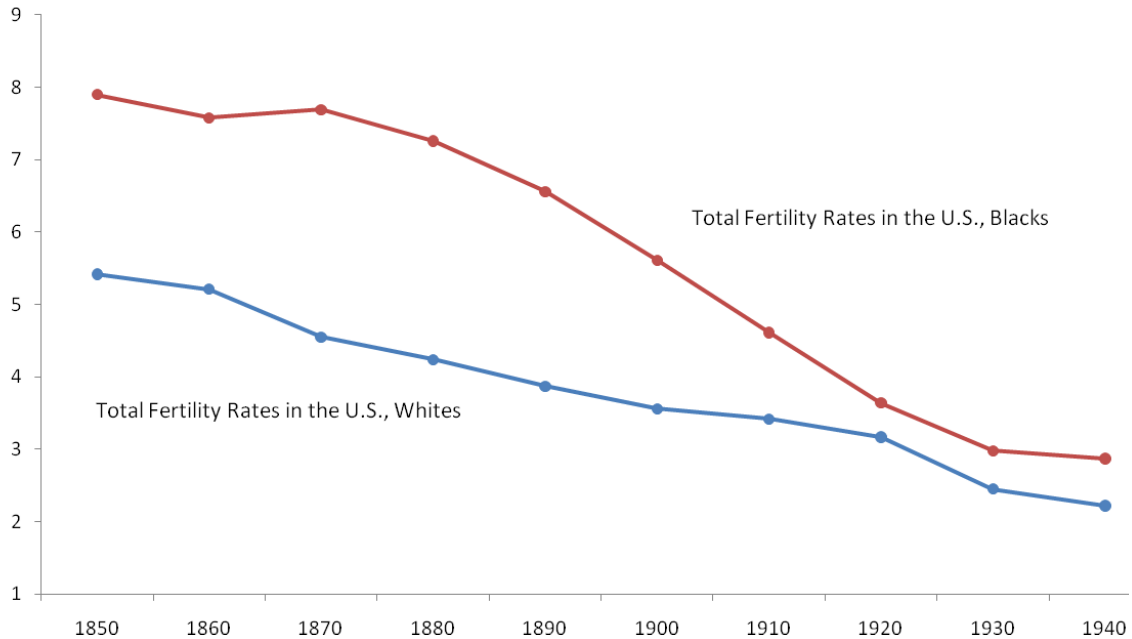



Figure 3: Fertility and Education Rates in the United States [source: eh.net and Goldin and Katz (2008)]



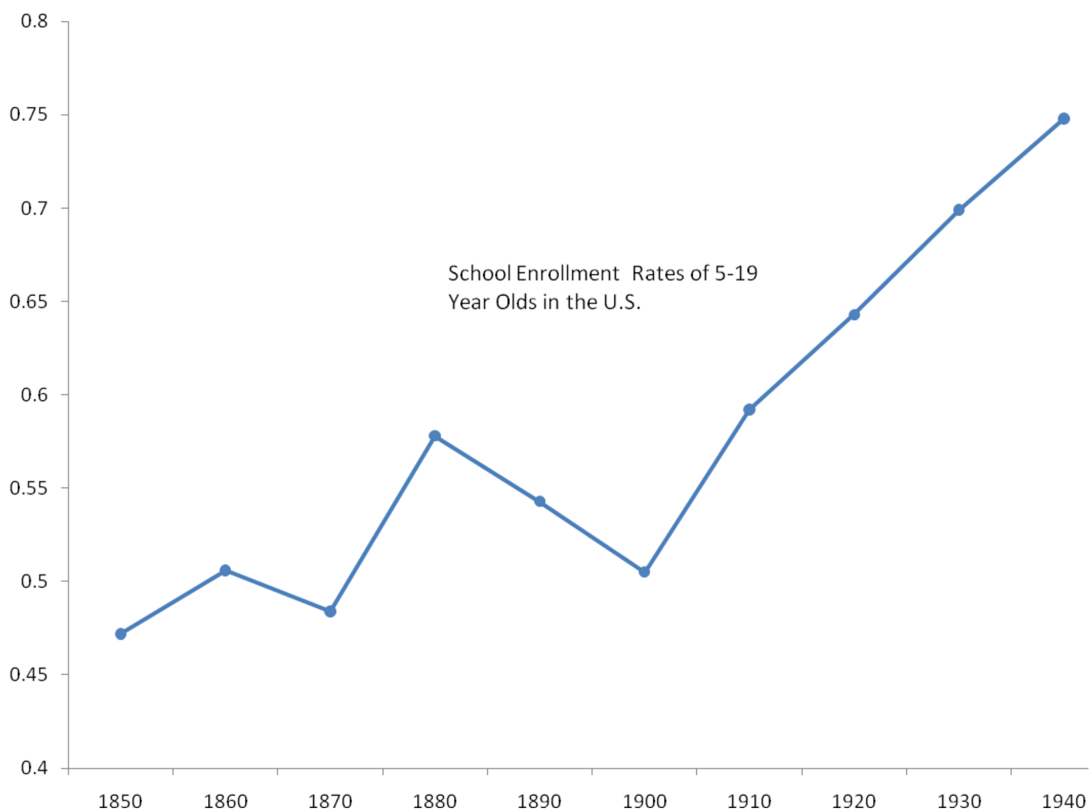
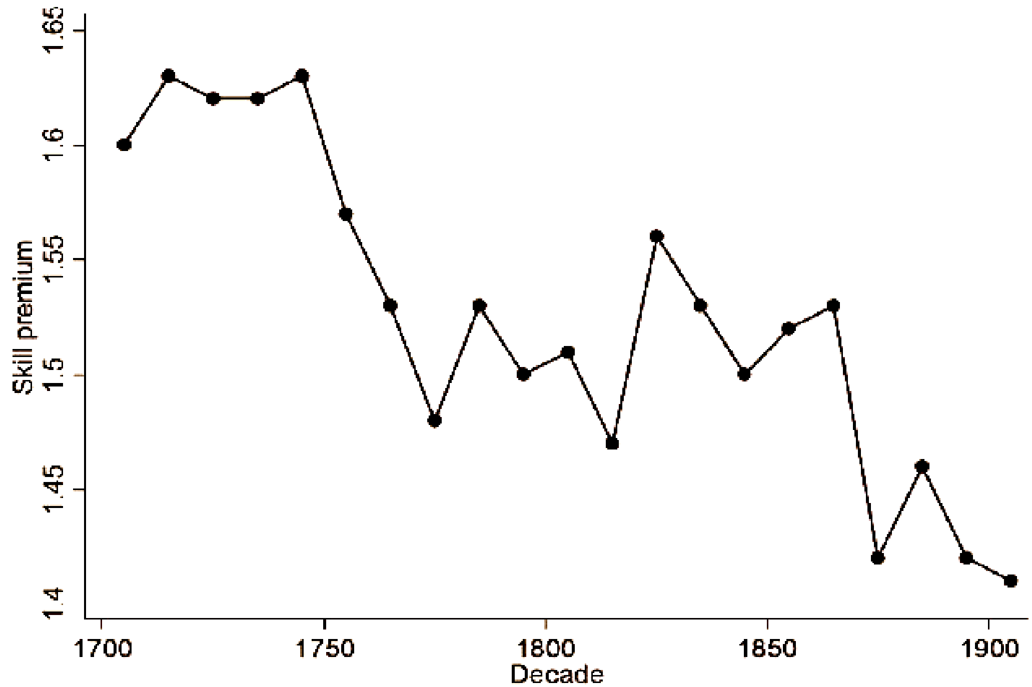



Figure 4: Skill Premium in English Construction (top) [source: Clark (2007)]; Skill Premium in England for Variety of Industries (bottom) [source: Williamson (1982)]



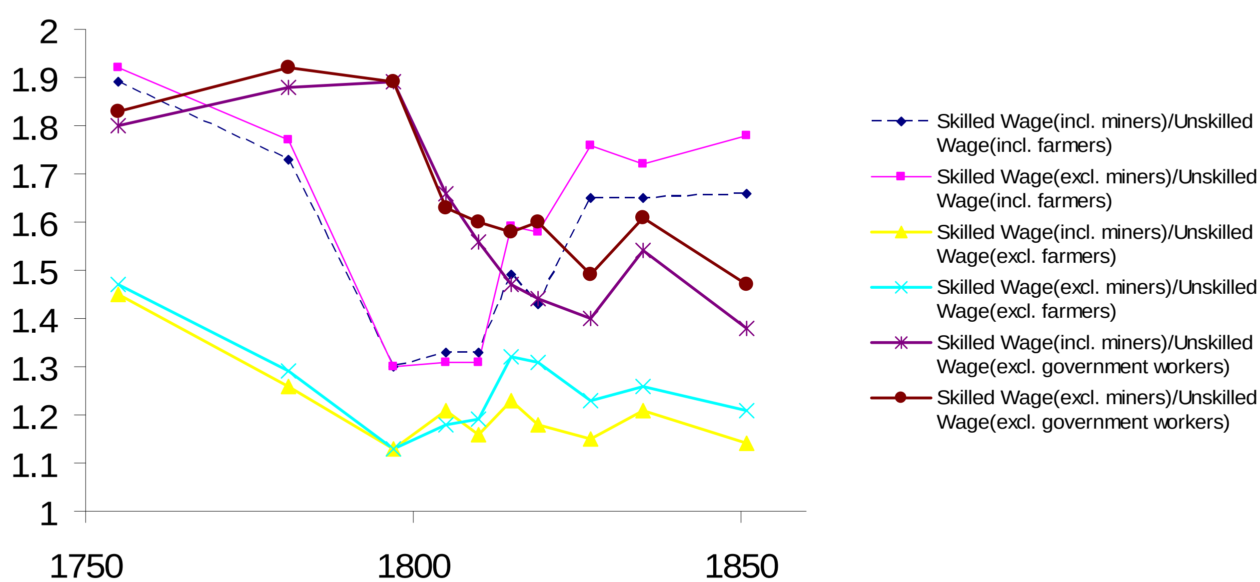
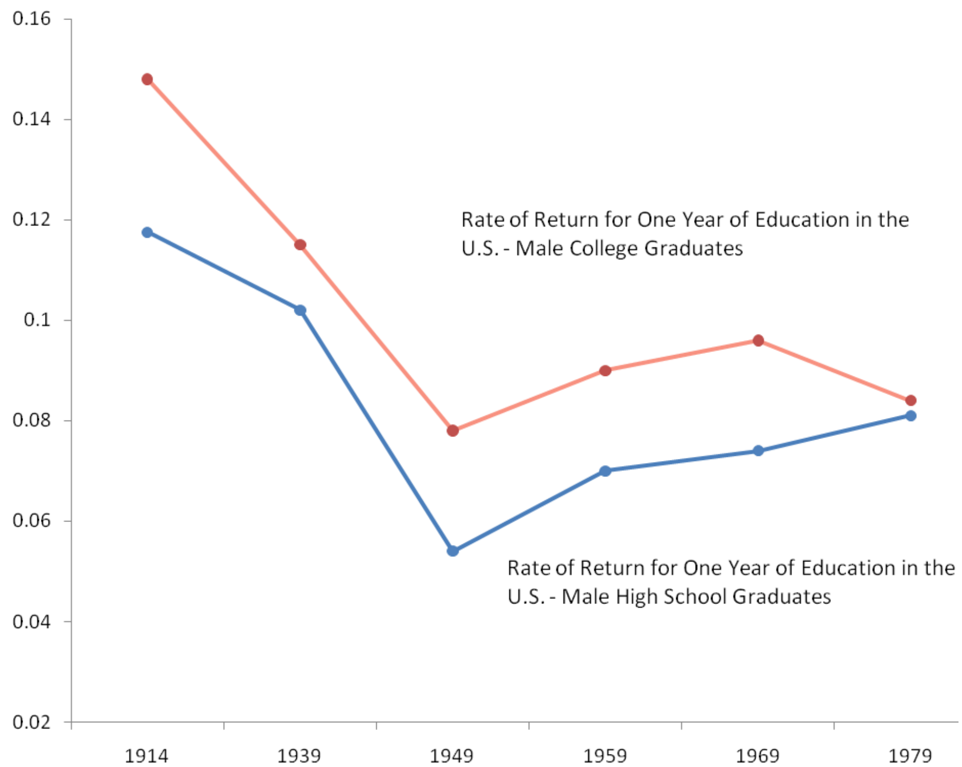



Figure 5: Skill Premium in the U.S. (top) [source: Goldin and Katz (2008)]; Skill Premium in 1750/1820 and GDP in 1913 for Many Countries (bottom) [source: van Zanden (2006)]



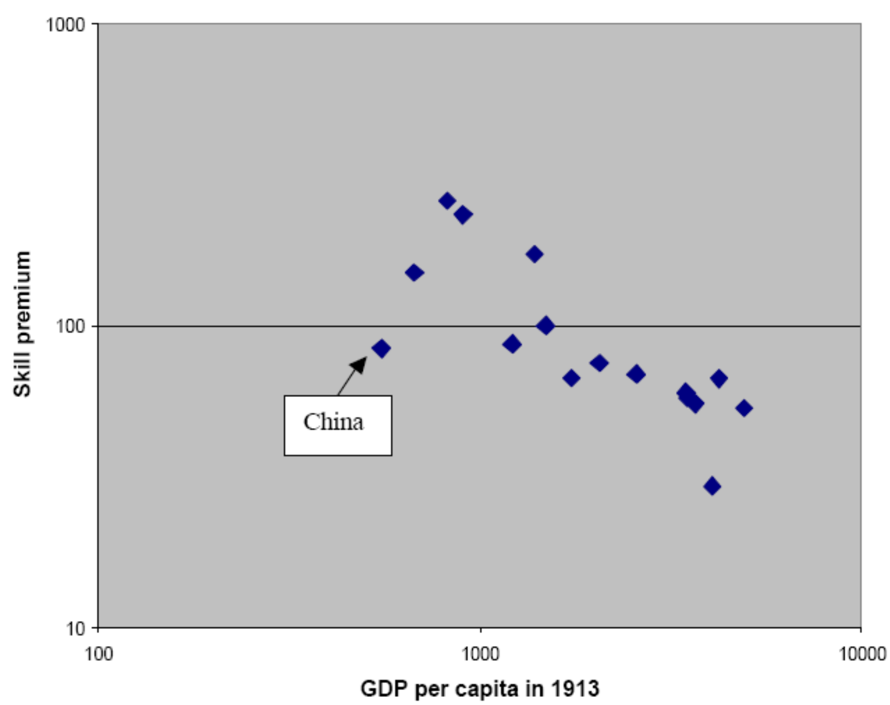
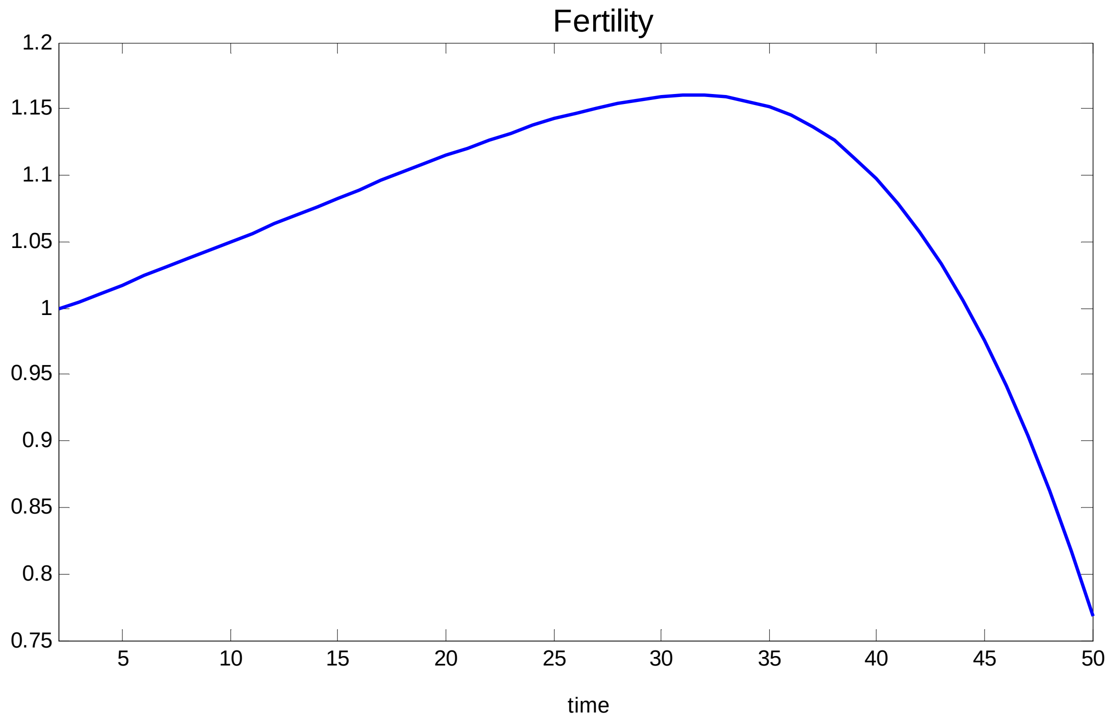



Figure 6: Simulated Values of Fertility and Education



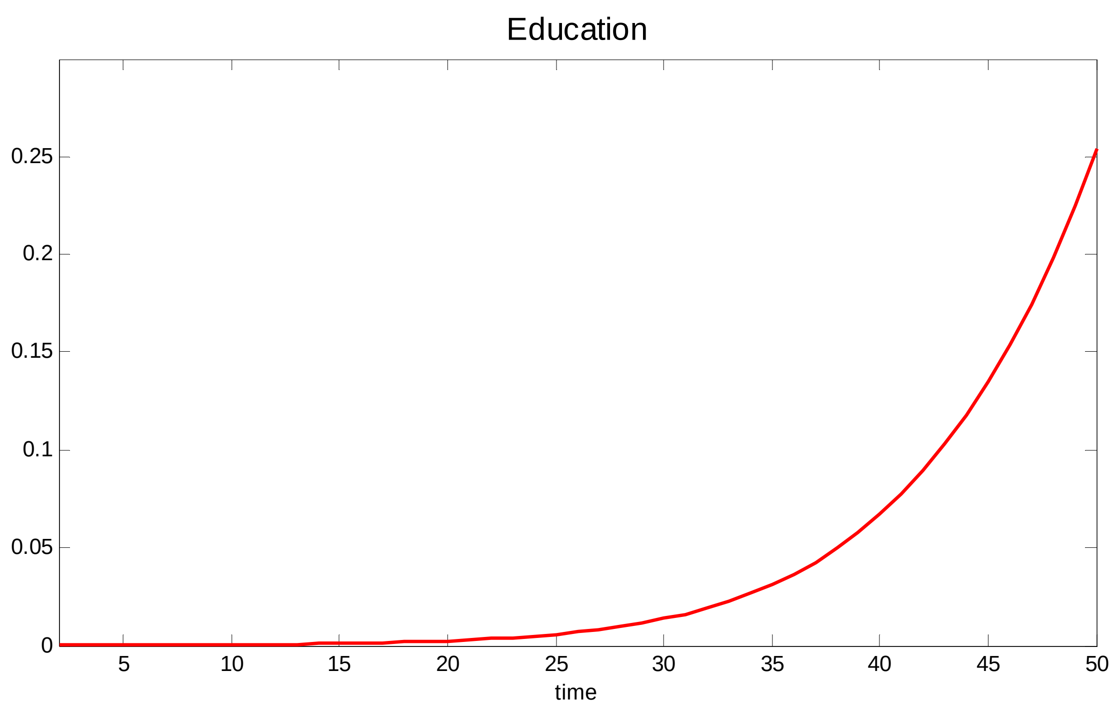



Figure 7: Simulated Values of Skill Premia, Relative Labor Supplies, GDP and GDP per Adult