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AN ESTIMABLE DYNAMIC GENERAL EQUILIBRIUM MODEL OF WORK, SCHOOLING, AND OCCUPATIONAL CHOICE*

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This article develops and estimates a dynamic general equilibrium overlapping-generations model of career decisions. The model is fit to data on life cycle employment, schooling, and occupation decisions and on life cycle labor earnings, within and between cohorts observed in the United States between 1968 and 1993. Based on the estimates of the model, the impact of cohort size on skill prices and the general equilibrium effect of a tuition subsidy are assessed.

1. INTRODUCTION

This article develops and estimates a dynamic general equilibrium overlapping-generations model of career decisions. The model is fit to data on life cycle employment, schooling, occupation decisions, and on life cycle labor earnings, within and between cohorts observed in the United States between 1968 and 1993. The purposes of this article are: (1) to extend previous partial equilibrium models of human capital accumulation to a general equilibrium setting, (2) to use the model's estimates to determine the impact of cohort size on human capital investment behavior and labor market outcomes, and (3) to contrast the estimates of a college tuition subsidy on career decisions in partial equilibrium and general equilibrium settings.

Figure 1 shows the actual size of birth cohorts in the United States from 1910 to 2000 and a hypothetical cohort trend, the dotted line, over the same period. The fluctuation in actual cohort sizes around this trend is large; the size of the baby boom generation (the 1945–1964 birth cohort) is above the trend line by as much as 27% (in 1957) and the size of baby bust generation (the 1925–1940 birth

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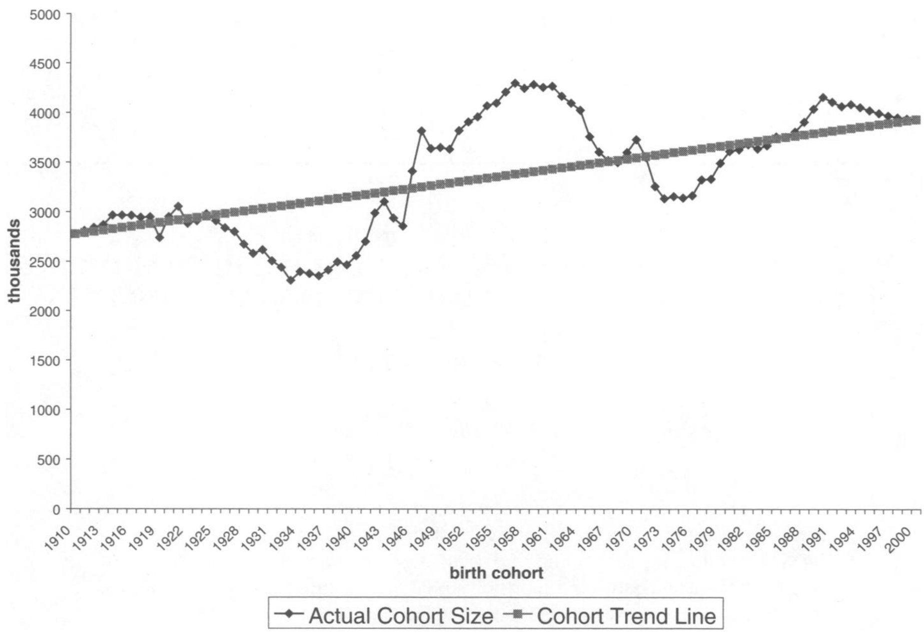

FIGURE 1

U.S. BIRTH COHORT

cohort) is below by as much as 25% (in 1933). The model permits an evaluation of the impact of cohort size on the skill prices faced by birth cohorts over their lifetimes and, consequently, on their career decisions.

Based on the estimates of the model, the impact of cohort size on skill prices and career decisions is assessed. Compared to a baseline case in which cohort size increased at a steady (average) rate and the fertility process was stationary, it is found that the male baby bust generations born in the 1930s and 1940s faced higher skill prices (by as much as 2.0%), completed college at a higher rate (by as much as 0.3 percentage points), and worked more over the lifetime (by as much as 0.1 years). In contrast, males from the baby boom generations born in the 1950s and 1960s faced lower skill prices (by as much as 1.5%), completed college at a lower rate (by as much as 1.0 percentage points), and worked less over the lifetime (by as much as 0.1 years). The impact of cohort size is found to differ across gender due to the differential impact of fertility on the value of home production: Unlike for males, the baby boom generations for females completed college at a lower rate (by as much as 1.5 percentage points) and worked less over the lifetime (by as much as 0.5 years) whereas similarly for males, the baby boom generations for females completed college at a lower rate (by as much as 1.5 percentage points) but worked more over the lifetime (by as much as 0.2 years).

A tuition subsidy experiment is also performed both in the general equilibrium setting in which skill prices are endogenous and the partial equilibrium setting with fixed skill prices. Based on the estimated model, a 1% increase in college tuition would reduce college enrollment rates by 1.27% in partial equilibrium and by 1.05% in the general equilibrium case. Thus, for this policy experiment, the partial equilibrium effect would not differ significantly from the general equilibrium effect.

The model comprised people between the ages of 16 and 65 making decisions each year based on current and future white- and blue-collar skill prices, their initial skill endowments at age 16, and current payoffs associated with each alternative about whether or not to (1) work in a white-collar occupation, (2) work in a blue-collar occupation, (3) attend school, or (4) stay home. Working in a particular occupation provides labor earnings in the current period, which is the product of the occupation's market skill price in that period and the person's skill level in that occupation. Working in either occupation also increases skill levels in future periods through learning by doing, potentially in both occupations. Attending school provides direct consumption value, but entails the payment of a tuition cost in the case of post-secondary education. Schooling also increases skill levels, differentially in the two occupations, and thus future earnings as well. Staying home (neither working nor attending school) provides utility with no future payoff. Decisions are made by comparing the sum of current and discounted expected future utilities associated with the four mutually exclusive alternatives and choosing the best one.

Skill prices are determined endogenously in the market. The aggregate supply of white-collar skill in a period is the sum of white-collar skill supplied by individuals who choose the white-collar employment alternative in that period. The aggregate demand for white-collar skill is given by the marginal product of aggregate white-collar skill derived from the aggregate production function. The aggregate supply of and demand for blue-collar skill is similarly derived. Aggregate output is produced with homogenous capital and the two aggregate skills according to a constant returns to scale Cobb–Douglas specification. Capital and skill shares are estimated each year from actual data. To obtain the skill supplies, the dynamic programming problem for the decision problem described above is solved assuming that individuals have perfect foresight about future skill prices, but imperfect foresight about future shocks associated with the utility of each of the alternatives. The path of equilibrium skill rental prices for each occupation is determined by equating aggregate skill supplies with aggregate skill demands in each period. Given that cohort size varies over time, equilibrium skill prices are not stationary.

This article is most closely related to Flinn (1993) and to Keane and Wolpin (1997). I extend Flinn's equilibrium schooling choice model in a number of important directions. Individuals not only decide on whether to attend school, but also whether to work and in which occupation. In Flinn (1993), heterogeneity arises only across cohorts; within cohorts, people choose the same level of education, work the same number of periods, and earn the same amount over their lifetime. In the present model, individuals differ in their initial endowments of occupation-specific skill and alternative-specific utilities and are subject to random shocks in each period that induce people within the same cohort to follow different career paths by making different schooling, work, and occupational decisions.

I extend Keane and Wolpin in two ways. First, skill prices are allowed to change over time as the result of cohort size variation, capital growth, and technical change. Second, skill prices are endogenously determined in the model in general equilibrium. The importance of these extensions stems from the fact that, in general, the partial equilibrium effect of a given policy intervention or exogenous change in the economic environment with constant skill prices will differ from the general equilibrium effect with endogenous skill prices. For example, consider evaluating the effect of a college tuition subsidy. The first-order effect is to directly increase the enrollment rate in colleges. However, the second-order effect will be to increase the aggregate skill supply in at least one occupation in the future and, thus, to decrease the equilibrium skill price in that sector. This feedback effect mitigates the incentive to attend college. Therefore, the partial equilibrium effect of a tuition subsidy will exceed the general equilibrium effect. A quantitative assessment of the difference requires empirically implementing the general equilibrium model. As noted above, based on the estimates of the model, the effect of the subsidy based on a partial equilibrium analysis overstates the effect that takes into account general equilibrium feedbacks by only about 10% . Thus, in this case, it turns out that the Keane and Wolpin partial equilibrium estimate is not very misleading.

Heckman et al. (1998) were the first researchers to empirically estimate a general equilibrium model of human capital investment and they also perform a similar comparison of partial and general equilibrium effects of college tuition changes on schooling. Contrary to the finding in this article, they find that the partial equilibrium effect, which is of similar magnitude to that found in this article and in the preceding nonstructural literature, is almost completely negated by the effect of the aggregate skill supply induced by changes in skill rental prices; the general equilibrium effect is estimated to be close to zero. Potential explanations for the marked difference in this result are discussed in a later section.

The rest of the article is organized as follows. Section 2 presents the structure of the general equilibrium model. The components of the model include the specification of the aggregate technology as well as the preferences and constraints of individuals in the economy. Equilibrium is defined and it is demonstrated how equilibrium skill prices are determined in the skill market. Section 3 discusses the method adopted for solving the general equilibrium model. Section 4 describes the data used for the estimation and Section 5 presents and discusses the estimation results. Sections 6 and 7 are devoted to the policy experiments of evaluating the effects of cohort size and of a college tuition subsidy. Section 8 discusses how much the increase in female employment between 1968 and 1993 is attributable to the decrease in the fertility rate and the increase in the capital stock. Section 9 concludes this article.

2. THE MODEL

The economy starts at some initial time ($t = 1$). In each period, the labor market consists of overlapping generations with many people aged 16 to 65. The number of people of a given age reflects their initial cohort size. At $t = 1$, each cohort's schooling distribution, white-collar work experience distribution, and blue-collar work experience distribution are taken as exogenous initial conditions. From $t = 2$ forward, those distributions are endogenously determined as a result of people's optimizing behavior, although each cohort's initial conditions at age 16 are taken as exogenous. The model's description begins with the specification of the aggregate technology.

2.1. *Aggregate Production Function.* Aggregate production is given by a Cobb–Douglas, constant returns to scale, production function,

$$Y_t = A_t S_{1t}^{\alpha_{1t}} S_{2t}^{\alpha_{2t}} K_t^{1-\alpha_{1t}-\alpha_{2t}} \tag{1}$$

where Y is output, S_1 is the aggregate amount of white-collar skill used in production, S_2 is the aggregate amount of blue-collar skill used in production, and K is the capital stock in the economy.[2] Given that skill units cannot be measured and that the output shares, α_1 and α_2, are allowed to vary over time, the Hicks-neutral technology parameter, A_t, is normalized to unity in all periods. The capital stock is assumed to evolve exogenously. Note that the above Cobb–Douglas production function specification with changing output shares can mimic the usual finding that capital is more complementary to skilled than to unskilled labor (capital–skill complementarity). With capital exogenously increasing over time, capital–skill complementarity is captured by an increasing white-collar skill output share, α_{1t}, and a decreasing blue-collar skill output share, α_{2t}. However, it should be admitted that this assumption of constant elasticity among all the inputs limits the usefulness of the model for such things as simulating the effect of changing the capital stock on educational wage differentials.

The aggregate stock of white-collar skill employed at period t, $S_1^s(t)$, is the sum of white-collar skill units over each cohort and each individual in the economy at t.

$$S_1^s(t) = \sum_a \sum_i s_{1i}(a)\, d_{1i}(a) \tag{2}$$

where $d_{i1}(a)$ is an indicator variable taking on the value of one if an individual who is of age a at calendar time t chooses to work in a white-collar occupation, and is zero otherwise. The labor market is assumed to be competitive, so the white-collar skill price at t, r_{1t}, is given by the marginal product of white-collar skill:

$$r_{1t} = \alpha_{1t} S_{1t}^{\alpha_{1t}-1} S_{2t}^{\alpha_{2t}} K_t^{1-\alpha_{1t}-\alpha_{2t}} = \frac{\alpha_{1t} Y_t}{S_{1t}} \tag{3}$$

[2] As Hamermesh (1986) reports, evidence on the degree of substitution in production between white- and blue-collar labor is contradictory, with estimates ranging between the extremes of perfect substitutability to fixed coefficients.

and the white-collar skill demand function is thus

$$S_1^d(t) = \frac{\alpha_{1t} Y_t}{r_{1t}} \tag{4}$$

The blue-collar skill supply, $S_2^s(t)$, and demand, $S_2^d(t)$, are similarly defined, namely

$$\begin{aligned} S_2^s(t) &= \sum_a \sum_i s_{2i}(a)\, d_{2i}(a) \\ S_2^d(t) &= \frac{\alpha_{2t} Y_t}{r_{2t}} \end{aligned} \tag{5}$$

where r_{2t} is the blue-collar skill price at t and $d_{2i}(a)$ is an indicator variable of choosing to work in a blue-collar occupation.

2.2. *Individual Utility Maximization.* People enter the labor market at age 16 and retire between the ages of 60 and 65. The exact retirement age is taken to be exogenous.[3] At age 16, each agent is endowed with an initial education level and zero years of work experience in both occupations. It is assumed that individuals have perfect foresight about future skill prices. Taking the sequence of skill prices that an individual will face over his lifetime as given, each person maximizes the expected present value of remaining lifetime utility by choosing at each age a one of the four mutually exclusive career alternatives: (1) work in a white-collar occupation, (2) work in a blue-collar occupation, (3) attend school, or (4) remain at home.

The problem at age a is

$$\begin{aligned} &\max_{d_m(a)} E\left[\sum_{\tau=a}^{A} \delta^{\tau-a} u(a) \mid S(a)\right] \\ &u(a) = \sum u_m(a) d_m(a) \end{aligned} \tag{6}$$

where $S(a)$ is the vector of state variables at age a, $u_m(a)$ is the utility from choosing an alternative m at age a ($m = 1, 2, 3, 4$ as ordered above), $d_m(a) = 1$ if career alternative m is chosen at age a and equals zero otherwise, A is the stochastic retirement age, and δ is the discount factor and $u(a) = u_m(a)$ if alternative m is chosen. After retirement, utility is assumed to be zero. The alternative-specific utility functions are specified as follows:

[3] It is assumed that a constant fraction of people retire between ages 60 and 64 and the rest retire at age 65. The fraction of people retiring between 60 and 64 is estimated as a parameter of the model.

Work in a white-collar occupation ($m = 1$) or a blue-collar occupation ($m = 2$):

$$
\begin{aligned}
(7) \qquad u_{mt}(a) &= r_{mt}s_m(a) + \alpha_{m7} \\
&= r_{mt} \exp\big(\alpha_{m1} + \alpha_{m2}E(a) + \alpha_{m3}x_1(a) + \alpha_{m4}x_2(a) + \alpha_{m5}x_1^2(a) \\
&\qquad + \alpha_{m6}x_2^2(a) + \varepsilon_m\big) + \alpha_{m7}
\end{aligned}
$$

where r_{mt} is the equilibrium skill price at calendar time t in occupation m, $s_m(a)$ is the amount of occupation-specific skill possessed at age a, α_{m7} is the nonpecuniary benefit of working in occupation m, E is the education level, x_m is the years of work experience in occupation m, and ε_m is an idiosyncratic shock to skill in occupation m in that period. Note that u_m is a function of calendar time because the skill price, r_m, changes over time. Choosing one of these alternative provides current earnings and increases work experience in that occupation by 1 year.

Attend school ($m = 3$):

$$
\begin{aligned}
(8) \qquad u_{3t}(a) &= \alpha_{31} - \alpha_{32}I(d_3(a-1) = 0) - tc_1 I(E(a) \geq 12) \\
&\quad - tc_2 I(E(a) \geq 16) + \varepsilon_3.
\end{aligned}
$$

where α_{31} is interpreted as the consumption value of attending school, α_{32} is a school reentry cost that arises if the individual did not attend school in the previous period, $(d_3(a-1) = 0)$, tc_1 is a college tuition cost, tc_2 is the additional tuition cost for attending graduate school, and ε_3 is a random shock attached to the consumption value of schooling. Attending school increases education by 1 year in the next period, that is, $E(a+1) = E(a) + 1$.

Remain home and engage in home production ($m = 4$):

$$
(9) \qquad u_{4t}(a) = \alpha_{41} + \alpha_{42}NC(a) + \varepsilon_4
$$

where α_{41} is the consumption value of staying home, $NC(a)$ is the number of preschool children, α_{42} is the increase in the value of home production per preschool child, and ε_4 is a random shock attached to the consumption value of staying home. The number of preschool children is assumed to follow a known exogenous stochastic fertility process that depends on an individual's cohort, sex, current age, and schooling level.[4]

In order to solve the individual's optimization problem, it is necessary to specify the joint distribution of the four shocks, the two skill shocks, and the two preference shocks. They are assumed to be distributed joint normal with mean 0 and given (age and time-invariant) variance–covariance matrix.

[4] Preschool children are defined to be children under age 6, the age at which children normally start primary school. For simplicity, we require that $NC(a)$ takes a value from 0 to 2. We assume that $NC(a)$ follows a Markovian process from the individual's perspective. The actual number of preschool children an individual will have at any age is thus stochastic. The $NC(a)$ process is estimated directly from the data and employed in solving the model. Since the fertility process also depends on education level, individuals can exercise some control over their fertility by choosing their education level.

2.3. *Skill Market Equilibrium.* An equilibrium skill price series $\{r_t^*\}_{t=1}^{\infty} = \{r_{1t}^*, r_{2t}^*\}_{t=1}^{\infty}$ is a rational expectation equilibrium that satisfies the following two conditions:

1. People make their decisions based on the skill price, $\{r_t^*\}_{t=1}^{\infty}$
2. $\{r_t^*\}$ clears the skill market every period.

$$S^s(t) = S^d(t) \quad \text{for all } t \tag{10}$$

where $S^s(t) = \{S_1^s(t), S_2^s(t)\}$ and $S^d(t) = \{S_1^d(t), S_2^d(t)\}$.

Assuming a rational expectations equilibrium requires that individuals have perfect foresight about future rental prices. In order that individuals be able to obtain such a forecast requires knowledge of the future sequences of the capital stock, aggregate technology parameters, and cohort sizes. Cohort size, like the fertility process, is exogenously determined outside the model.[5]

3. MODEL SOLUTION

We divide the model solution into two parts. The first part demonstrates the solution method used for the individual's decision problem for a given skill price sequence. The second part demonstrates the method for solving for the equilibrium skill price sequence that clears the skill market in every period.

3.1. *Solution of the Individual Career Decision Problem.* The individual's optimization problem is solved recursively from the final age A. Let $S(a)$ be the vector of state variables at age a, variables known at age a that determine the remaining expected present value of lifetime utility. Given the structure of the model, the state space at any age a includes the current and future equilibrium skill rental prices up to age 65, current levels of school attainment, white- and blue-collar work experience, preschool children, white- and blue-collar skill shocks, and school attendance and home preference shocks, and lagged school attendance, that is,

$$S(a) = \{E(a), x_1(a), x_2(a), d_3(a-1), NC(a), \varepsilon(a), r(a)\}$$

where $r(a)$ represents the current and future equilibrium skill rental prices up to age A and $\varepsilon(a)$ is a vector of alternative-specific random shocks at age a. Let

[5] In the model, both mortality and migration are ignored. Since relative cohort size matters for the analysis, not the absolute level, as long as mortality and migration do not change the relative size of each cohort, the use of birth cohort alone as the measure of cohort size can be justified. The data show that even though the proportion of immigrants in the U.S. population increased dramatically between 1960 and 1995 for those around age 30 from less than 5% to more than 15%, this increase evenly affected wide ranges of age groups at the same time. The proportion of immigrants across ages does not vary much in any 1 year. For example, in 1960, the proportion of immigrants was least at age 20, 2%, and greatest at age 50, 7%. In 1995, it was least at age 50, 12%, and greatest at age 29, 18% (between ages 20 and 50).

$V(S(a))$, the value function at age a given state vector $S(a)$, denote the maximal value at age a over all the possible career decisions given $S(a)$. Similarly, define $V_m(S(a))$ to be the alternative-specific value function at age a, the expected present value of remaining lifetime utility given that alternative m is chosen. Therefore,

$$V(S(a)) = \max_m [V_m(S(a))] \tag{11}$$

Notice that calculating $V(S(a))$ is equivalent to solving for the optimal sequence of career decisions. The decision rule is to choose the alternative with the highest alternative-specific value function at each age.

In order to solve for a person's decision rule at age 16, we need to know $\text{Emax}(S(a))$ for all ages from 17 to 65 and at every $S(a)$ that can be reached from $S(16)$. To do that, begin at age 65 and calculate the Emax function for every possible state vector, S(65). Because this is the last period, the alternative-specific value function, $V_m(S(65))$ is simply the current utility for each alternative.

$$V_m(S(65)) = u_m(S(65))$$

and

$$\text{Emax}(S(65)) = E\left[\max_m (u_m(S(65)))\right] \tag{12}$$

After calculating the Emax function at age 65, go back to age 64 and calculate $\text{Emax}(S(64))$ for every possible $S(64)$,

$$\begin{aligned}\text{Emax}(S(64)) &= E\left[\max_m [V_m(S(64))]\right] \\ &= E\left[\max_m [u_m + \delta \text{Emax}(S_m(65))]\right]\end{aligned} \tag{13}$$

This backward solution for the Emax functions is repeated until age 17. The decision at age 16, then, involves choosing the maximum of $V_m(S(16))$ where

$$V_m(S(16)) = u_m(16) + \delta \text{Emax}(S_m(17)) \tag{14}$$

and $m = 1, 2, 3, 4$.

There are two computational difficulties involved in calculating the sequence of Emax functions. First, calculating the $\text{Emax}(S(a))$ function for any given value of the state space involves a four-dimensional integration with respect to the ε vector. This calculation is performed by Monte Carlo integration, i.e., for each draw of the ε vector from the joint distribution, $\max_m[V_m(S(a))]$ is obtained and the sample mean is used as a numerical approximation of $\text{Emax}(S(a))$.

The second complication is the "curse of dimensionality" that arises because the number of elements in the state space is too large to be feasible in the context of solving the general equilibrium model and estimating the parameters of the model, both of which are iterative procedures. Recall that the Emax functions must be obtained for every element in the state vector. This computational problem is circumvented by calculating Emax($S(a)$) for a subset of state space points and interpolating the nonsimulated state space points by regression (see Keane and Wolpin, 1994).[6]

Given the sequence of Emax functions, the choices that individuals make over their life cycles are determined by their initial conditions at age 16 and the sequence of shocks that are drawn. At age 16, an individual receives a set of skill and preference shocks, chooses from among the four alternatives the one with the highest alternative-specific value function, and updates the state space given that choice. A new set of draws is received at age 17, the optimal choice is made, the state space is updated and the process is repeated at ages 18, 19, and so on until retirement.

3.2. *Solution Method for Equilibrium Skill Price* $\{r_t^*\}$. Because it is assumed that there are many, possibly an infinite number of people in the population of the economy, the individual shocks attached to career choices average out. Given the assumption that there are no shocks to aggregate production, there is no uncertainty at the aggregate economy level. Therefore, the equilibrium skill price sequence actually follows a deterministic path, despite the existence of individual stochastic shocks. Each person in each cohort solves the decision problem under the deterministic path of skill prices. However, the skill price series each cohort faces is different. Therefore, it is necessary to solve for the optimal career decision rule for each cohort, i.e., for the cohort-specific set of Emax functions. The degree of computational burden is, thus, dramatically greater with varying skill prices compared to a model with constant skill prices (as in Keane and Wolpin, 1997).

It is possible to solve for optimal career decisions for each cohort and, consequently, for the occupation-specific supply of skills for each cohort at each age, given any skill price sequence, $\{r_t\} = \{r_{1t}, r_{2t}\}$, on and off the equilibrium path. To do that, I simulate N people for each cohort and calculate the white- and blue-collar individual skill supplies, $s_{mi}(t, a)d_{mi}(a)$ for $i = 1, \dots, N$ and $m = 1, 2$. Since cohort sizes differ, to calculate the aggregate white- and blue-collar skill supply, $S_m^s(t)$, each person is given a weight proportional to his cohort size, $C(t, a)$. So the aggregate white- and blue-collar skill supply at t given skill price series, $\{r_t, r_{t+1}, \dots\}$ is

$$S_m^s(t) = \sum_a \sum_i C(t, a) \frac{s_{mi}(t, a)\, d_{mi}(a)}{N} \tag{15}$$

[6] In the actual simulation, 300 state points are drawn for each age and each period for the Emax function interpolation and 200 random shocks are drawn for each Monte Carlo integration of Emax function.

For the interpolation, the Emax($S(a)$) regressions are specified as second-order polynomial functions in the state variables. Increasing the number of state points to 1000 only slightly affects the simulated individual decisions. Increasing the number of Monte Carlo simulation to 500 only slightly affects the Emax function values.

To obtain the rational expectations equilibrium, we need to find the equilibrium skill prices, $\{r_t\}$ such that

$$S^s(t) = S^d(t) \quad \text{for all } t$$

The method we use to obtain the rational expectations equilibrium, $\{r_t^*\}$, is to start from a constant skill price and update it until the skill price sequence converges. In the first iteration, we solve the individual career decision problem at period t assuming that future skill prices will be the same as current ones; that is, we start from a constant skill price sequence, namely [7]

$$\{r_t\}_{t=1}^{T} : r_1 = r_2 = \cdots = r_t = r_{t+1} = r_{T-1} = r_T$$

and calculate the aggregate skill supply, $S^s(1)$, and skill demand, $S^d(1)$, respectively. The equilibrium at $t = 1$, r_1, is determined so that the skill market at $t = 1$ clears.

$$S^s(1) = S^d(1)$$

and we denote this equilibrium by $r_t^{(1)}$, where the superscript (1) denotes the iteration number. We go to the next period, $t = 2$, and keep the restriction of the constant skill price from that period on.

$$r_2 = r_3 = r_4 = \cdots$$

As above, $r_2^{(1)}$ is determined in the same way to satisfy

$$S^s(2) = S^d(2)$$

Notice that in general $r_2^{(1)}$ is not the same as $r_1^{(1)}$, which violates the expectation of the constant skill price. We continue this process to the final period T to obtain the first iteration equilibrium, $\{r_t^{(1)}\}_{t=1}^{T}$. Notice that $\{r_t^{(1)}\}$ is an equilibrium; however, it is not the rational expectations equilibrium because $\{r_t^{(1)}\}$ is not constant over time as was assumed in solving for the two aggregate skill supplies. The rational expectation equilibrium, $\{r_t^*\}$, is one which clears the skill market and, moreover, the one that people use to make their career decisions. Therefore, finding the rational expectations equilibrium, $\{r_t^*\}$, is equivalent to finding the fixed point skill price sequence in the model.

When we obtain the first iteration equilibrium, $\{r^{(1)}\}$, we go to the second iteration. Now we assume the ratio of skill price series is the one obtained from the first iteration,

$$\frac{r_{t+1}}{r_t} = \frac{r_{t+1}^{(1)}}{r_t^{(1)}}, \quad \forall t \tag{16}$$

[7] Although the model is an infinite horizon model, for computational purposes I set a final period T which is far enough into the future. $t = 1$ corresponds to year 1865 and $t = T$ corresponds to year 2050.

where $\{r_t^{(1)}\}$ is obtained from the first iteration.[8] This relationship yields a sequence of skill rental prices that can be written solely in terms of r_1. The value of r_1 is determined by equating skill supply and demand in period 1. Then a new r_2 is calculated by writing all of the skill rental prices from $t = 2$ on as a function of r_2 and the new value of r_2 is determined by equating skill supply and demand in period 2. This procedure is repeated to the final period T and yields a second iteration for the sequence of skill prices that clears the skill market in each period, denoted by $\{r^{(2)}\}$. This process is continued, obtaining repeated iterations of the skill price sequences, $\{r^{(3)}\}$, $\{r^{(4)}\}, \dots$, until a sequence $\{r^{(n)}\}$ is close enough to $\{r^{(n-1)}\}$ under some criterion. The converged skill price sequence $\{r^*\}$ is the rational expectations equilibrium, where people's expectation about future skill prices is realized as the equilibrium skill price sequence.[9]

4. DATA

To estimate the model, we would ideally need longitudinal data on individuals from many overlapping generations where employment, schooling and occupational decisions and labor earnings were reported from age 16 to retirement. In that case, all of the state variables and choices could be calculated from histories of school attendance, occupational-specific employment, and earnings. Based on these data, it would be possible to calculate the likelihood of observing the life cycle choices and labor earnings of individuals in the sample data. Then the parameters could be estimated by maximizing the sample likelihood. Unfortunately, such extensive data do not exist.

The analysis in this article is based on 26 years of the March Current Population Survey (CPS), from 1968 to 1993.[10] The CPS is a repeated cross-sectional sample of about 60,000 U.S. households. Schooling and employment information is obtained about all household members. Although the CPS has a short panel feature, it is useful primarily as a single year cross section. It is not possible to use the CPS to calculate the state variables necessary to obtain the likelihood for the choices made at the individual level. However, one can combine the set of CPSs to calculate the unconditional choice distributions for a large number of cohorts over significant portions of their lifetimes. Indeed, the data from the CPS span individuals who are between the ages of 16 and 65 from cohorts born as early as 1903 and as late as 1977.

The model is estimated by matching sample moments in the series of CPSs related to career choices classified by individual characteristics, age, cohort, sex,

[8] In other words, we restrict the differences in $\{\log r_t\}$ to be the same as $\{\log r_t^{(1)}\}$.

[9] Simulations based on wide range of parameter values show that this method is very quick to find the rational expectations equilibrium in a robust way.

[10] The March CPS is actually available prior to 1968 and after 1993. However, between 1964 and 1967, the CPS asked "How much did you receive in wages or salary?" and after 1967, "How much did you receive in wages or salary before any deductions?" It seems that it recorded after-tax earnings between 1964 and 1967, and before-tax earnings after 1967. After 1993, the variable indicating whether a person currently attended school was dropped from the March CPS. For these reasons, we do not make use of the data before 1968 and after 1993.

TABLE 1

AGGREGATE MOMENTS

Aggregate Moment	Number of Conditional Moments
White-collar employment rate	$26 \times 50 \times 2 \times 4 \times 2$
Blue-collar employment rate	$26 \times 50 \times 2 \times 4 \times 2$
Attending school rate	$26 \times 50 \times 2 \times 4 \times 2$
Staying home rate	$26 \times 50 \times 2 \times 4 \times 2$
Mean white-collar labor earnings	$26 \times 50 \times 2 \times 4$
Mean blue-collar labor earnings	$26 \times 50 \times 2 \times 4$
SD white-collar labor earnings	$26 \times 50 \times 2 \times 4$
SD blue-collar labor earnings	$26 \times 50 \times 2 \times 4$
One-period career decision transition rate	$3 \times 3 \times 26 \times 50 \times 2$
Schooling distribution	$26 \times 50 \times 2 \times 4$

NOTE: 1. The first four choice moments are conditioned on year (26), age (50), sex (2), education level (4), and whether one has a preschool child or not (2). 2. One-period career decision transition rate (from white-collar, blue-collar, outside labor force at period $t-1$ to white-collar, blue-collar, outside labor force at period t) is conditioned on year (26), age (50), and sex (2). 3. The rest are conditioned on year (26), age (50), sex (2), and education level (4).

education level, and whether a preschool child is present in the household to the moments that are predicted through simulation by the model. Estimation is based on the simulated method of moments (SMM). The parameters of the model are estimated to minimize the weighted average distance between the sample moments and the simulated moments. The exact moments used in the estimation procedure are: the proportion who work in the white-collar (blue-collar) occupation, the proportion attending school, the proportion at home, the proportion with completed schooling classified into four education categories, the mean and standard deviation of white-collar log earnings, the mean and standard deviation of blue-collar log earnings, and the one-period transition rate between career decisions (the fraction choosing to work in a white-collar occupation, work in a blue-collar occupation, or stay outside the labor force at t, conditional on choosing to work in a white-collar occupation, work in a blue-collar occupation, or stay outside the labor force at $t - 1$).[11] Education is divided into four categories: less than high school (0–11 years of education), high school graduate (12 years), some college (13–15 years), and college graduate (16 years or more). The distribution of completed schooling is conditioned on cohort, age, and sex. Table 1 provides a complete list of the moments used in estimation.

The model assumes that schooling and employment choices are mutually exclusive. However, within a year individuals may be engaged in several of these activities. For example, some people attend school and work at the same time and some people work only half of the year but stay home for the rest. To assign each

[11] The CPS provides information about which of the four career decisions one chose in the current year of the survey, but whether one worked in a white-collar occupation, worked in a blue-collar occupation, or stayed outside the labor force is provided in the previous year of the survey. From this information a transition matrix of size 3 by 3 is constructed for each conditional variable.

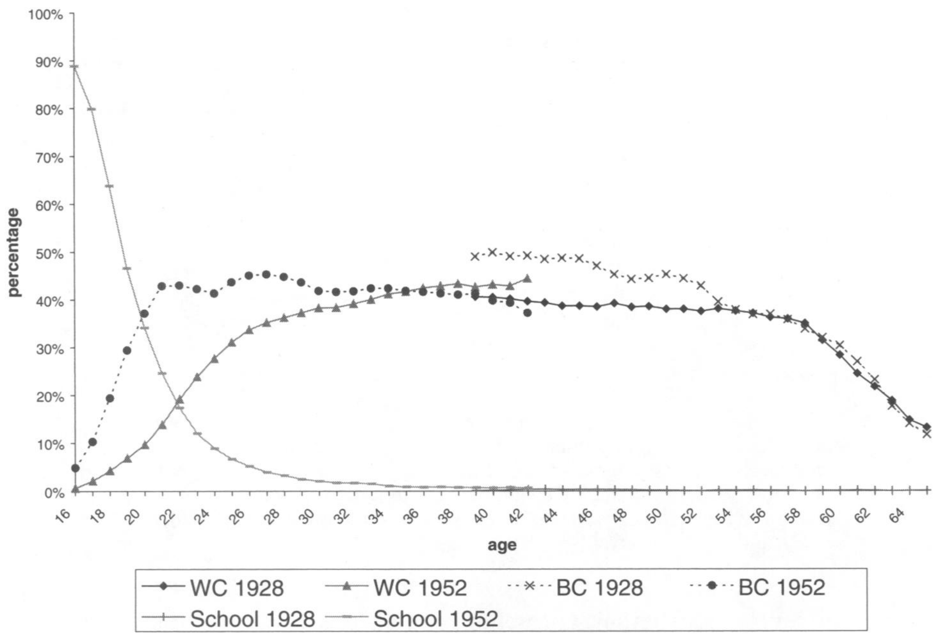

FIGURE 2

MALE CAREER DECISION BY AGE (2 COHORTS)

person to one of the four mutually exclusive and exhaustive alternatives in each year, the following hierarchical rule is used:

1. An individual is assumed to have attended school in the year if they reported that schooling was their major activity.[12]
2. The work alternative is assigned to those not in school, who reported that they worked at least 39 weeks and at least 20 hours per week in the previous year. The assignment is for the year prior to the survey year. When the individual is working, an occupational assignment either to white collar or blue collar is then made.[13]
3. Individuals are classified as having been at home if they were neither working nor in school.

4.1. *Descriptive Statistics.* Figures 2 and 3 present the choice distribution for two cohorts: the cohort born in 1928 and the cohort born in 1952. The 1928 cohort

[12] The survey question asks "What were you doing most of last week?" (1) Working, (2) with a job but not at work, (3) looking for work, (4) keeping house, (5) going to school, (6) unable to work, (7) retired, (8) other (specify).

[13] White-collar workers are professional, managerial, technical, sales, and clerical workers and blue-collar workers are craftsmen, operatives, laborers, service workers, and farm workers.

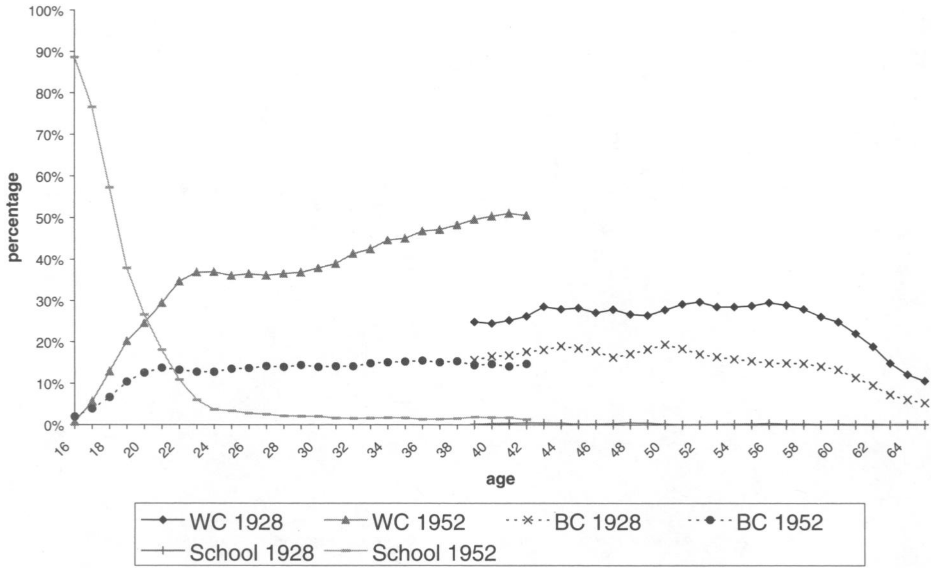

FIGURE 3

FEMALE CAREER DECISION BY AGE (2 COHORTS)

was 16–43 years old and the 1952 cohort was 40–65 years old over the 1968–1993 period. As seen in the figures, the propensity to work increases steadily until the mid-40s and decreases after that for males. Female employment, however, increases until around age 25, then, coinciding with an increase in the fertility rate, slightly decreases until the mid-30s, and increases until the mid-40s and finally, like male employment, declines. Blue-collar employment increases a few years before white-collar employment increases, reflecting the relationship between schooling and occupational choice. School attendance is highly concentrated early in the life cycle. At age 16, the average (over the period) attendance rate is almost 90% for both males and females. By age 18, the normal high school graduation age, the attendance rate falls to 60% for males and to 55% for females. By age 22, the normal college graduation age, it is less than 20%. After age 30, very few people attend school.

Figures 4 and 5 show the choice distribution (averaged over all ages) by year. The main changes between 1968 and 1993 were a decrease in blue-collar employment among males from 44% to 34%, an increase in female white-collar employment from 22% to 37%,[14] and the small increase in school attendance rates among females, from 7% to 9%. Male white-collar employment and female blue-collar

[14] This is also well represented in Figure 5 where only 24% of the 1928 female cohort worked in white-collar occupations at the age of 40 whereas as much as 50% of the 1952 female cohort worked in white-collar occupations at the same age.

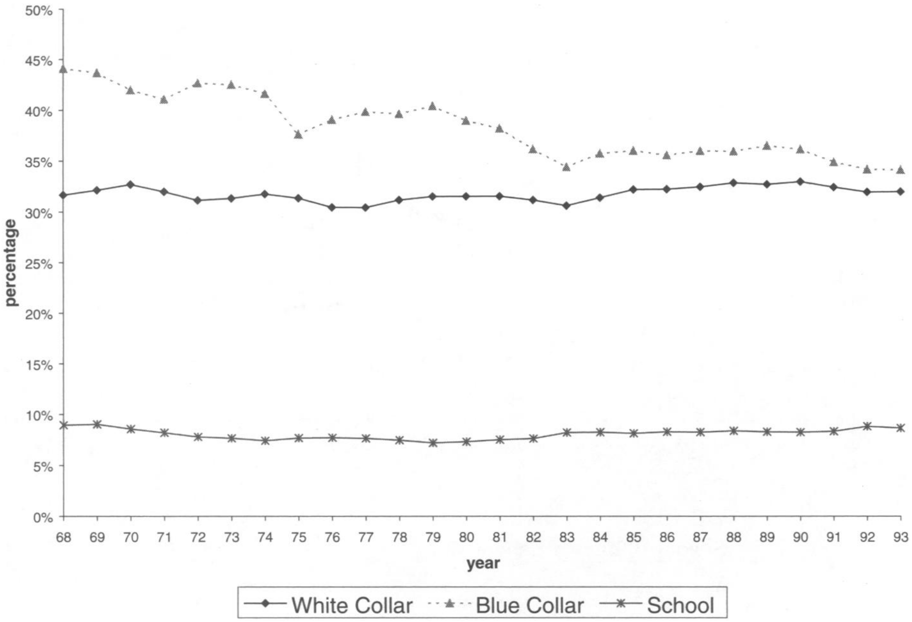

FIGURE 4

MALE CAREER DECISION BY YEAR (AVERAGE)

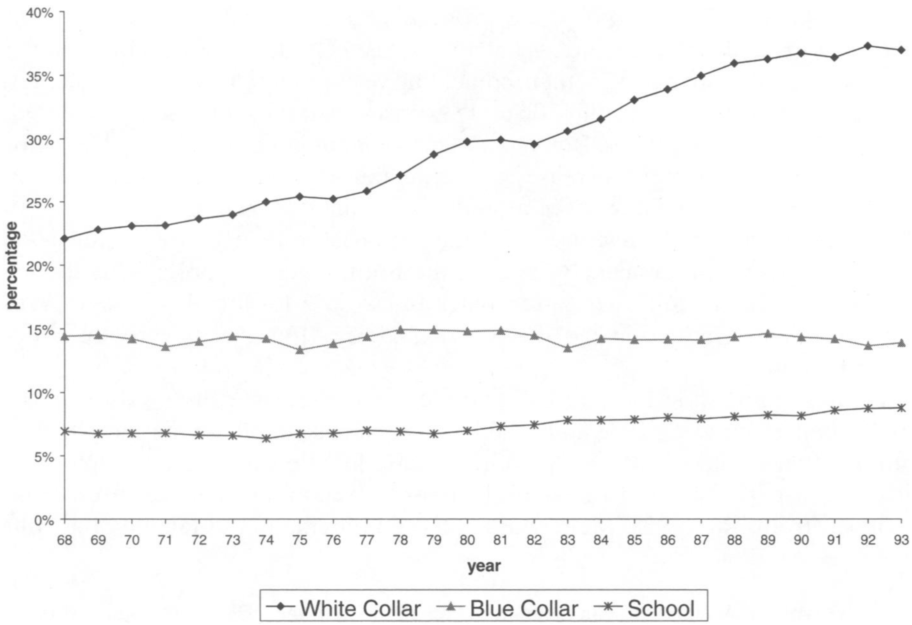

FIGURE 5

FEMALE CAREER DECISION BY YEAR (AVERAGE)

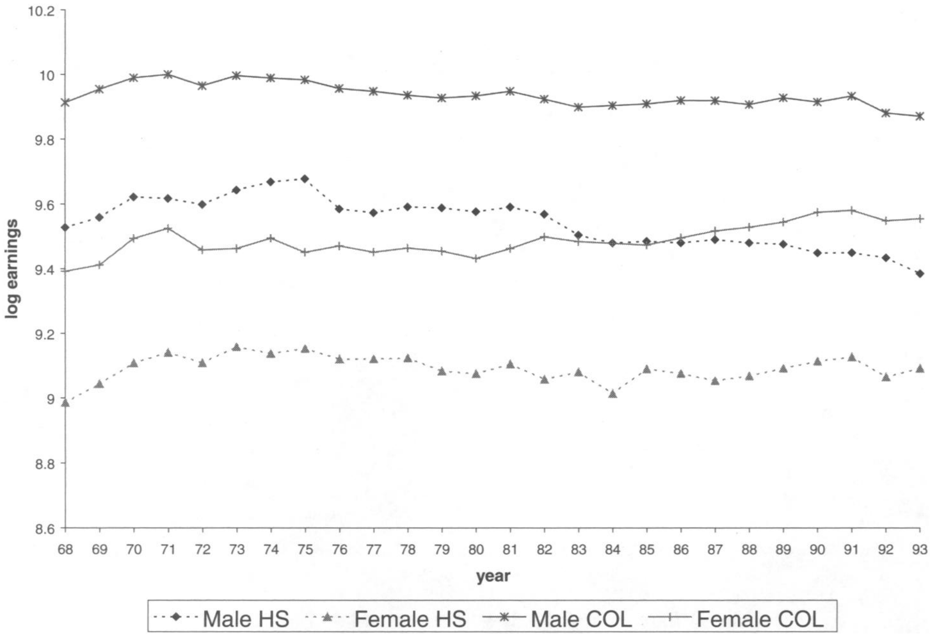

FIGURE 6

AVERAGE LOG EARNINGS BY YEAR (BY EDUCATION LEVEL)

employment were stable. Overall, market participation decreased for males and increased for females over the period.

Figures 6 and 7 show the average real (in 1983 dollars) labor earnings over the same period by education level and by occupation, respectively. Earnings are computed as a full-time equivalent. For those who worked during the year it is calculated by multiplying the average hourly wage times 2080 hours (52 weeks × 40 hours per week). Variation in earnings therefore reflects only variation in the hourly wage. The blue-collar wage remained roughly constant over the period for both sexes as did the male white-collar wage. However, the female white-collar wage increased between 1968 and 1993. Indeed, although the average male wage in blue-collar occupations was higher than the female wage in white-collar occupations by about 20% in 1968, they were basically the same by 1990. With respect to education, as has been noted by others, the male high school wage (high school graduate or lower) decreased and the college wage (some college plus college graduates) was relatively constant. For females, the high school wage was constant and the college wage increased. Thus, the relative college–high school wage rose for both sexes between 1968 and 1993. As the result of these changes, the average male high school wage, which was about 15% higher than the female college wage in 1968, was about 15% lower by 1993.

Those who work in white-collar occupations consistently have completed more years of education than those in blue-collar occupations for both men and women,

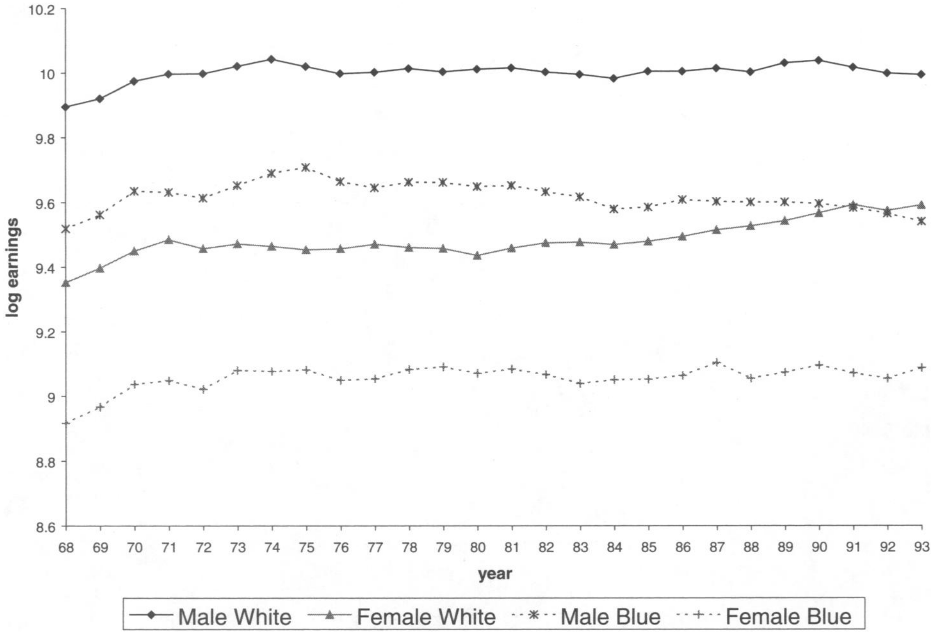

FIGURE 7

AVERAGE LOG EARNINGS BY YEAR (BY OCCUPATION)

as seen in Table 2. For example, in 1991 about 72% of male and 57% of female white-collar workers completed at least one year of college, whereas only about 25% of male and 20% of female blue-collar workers had as much education. However, since 1968 the proportion of both white-collar and blue-collar workers with some college increased. In 1968, only one-half of males and one-third of females working in a white-collar occupation had some college, with the corresponding figures for blue-collar workers being less than 10%.

4.2. *Exogenous Variables*

4.2.1. *Skill and capital shares.* Given the Cobb–Douglas specification of the production function, production parameters can be directly calculated from output shares in each year (recall that the Hicks-neutral technology parameter is normalized to one). Capital's shares between 1968 and 1993 are calculated as residual shares, namely using data on "total compensation of employees" and GDP,[15]

$$\begin{aligned}\text{capital share} &= 1 - \text{skill share} \\ &= 1 - \frac{\text{total compensation of employees}}{\text{GDP}}\end{aligned} \tag{17}$$

[15] Source: Council of Economic Advisors, "Economic Report of the President," February 1998.

TABLE 2
AVERAGE YEARS OF EDUCATION BY OCCUPATION

	Average Years of Education				At Least 1 Year of College			
	Male		Female		Male		Female	
Year	W.C.	B.C.	W.C.	B.C.	W.C.	B.C.	W.C.	B.C.
68	13.4	10.1	12.7	9.8	0.51	0.09	0.33	0.06
69	13.4	10.2	12.7	9.9	0.51	0.10	0.33	0.05
70	13.5	10.2	12.8	10.0	0.53	0.09	0.34	0.05
71	13.6	10.4	12.9	10.1	0.55	0.10	0.36	0.06
72	13.8	10.5	12.9	10.3	0.57	0.11	0.36	0.07
73	13.9	10.6	13.0	10.5	0.58	0.13	0.38	0.08
74	14.0	10.8	13.1	10.5	0.60	0.14	0.41	0.09
75	14.1	11.0	13.1	10.6	0.62	0.16	0.41	0.10
76	14.1	10.9	13.2	10.6	0.63	0.16	0.42	0.10
77	14.2	11.0	13.2	10.7	0.65	0.17	0.43	0.12
78	14.3	11.1	13.2	10.8	0.66	0.18	0.44	0.12
79	14.4	11.2	13.3	10.8	0.67	0.18	0.45	0.13
80	14.4	11.3	13.4	11.1	0.67	0.19	0.47	0.15
81	14.4	11.3	13.4	11.1	0.67	0.20	0.48	0.15
82	14.5	11.3	13.4	11.1	0.68	0.20	0.49	0.15
83	14.6	11.5	13.5	11.2	0.70	0.22	0.51	0.15
84	14.6	11.5	13.6	11.3	0.70	0.22	0.52	0.16
85	14.6	11.6	13.6	11.3	0.70	0.23	0.53	0.16
86	14.6	11.6	13.7	11.4	0.70	0.23	0.54	0.17
87	14.7	11.7	13.7	11.4	0.71	0.23	0.54	0.19
88	14.7	11.6	13.7	11.4	0.71	0.23	0.55	0.19
89	14.7	11.7	13.8	11.5	0.72	0.24	0.55	0.19
90	14.7	11.7	13.8	11.5	0.72	0.25	0.56	0.19
91	14.7	11.7	13.8	11.5	0.72	0.25	0.57	0.20

NOTE: W.C.: white-collar occupation. B.C.: blue-collar occupation.

The white-collar (blue-collar) skill share is calculated by aggregating individual earnings for the occupation from the CPS, namely

$$\text{white-collar skill share} = (1 - \text{capital share}) \times \frac{\begin{pmatrix}\text{aggregate total compensation of}\\ \text{white-collar employees}\end{pmatrix}}{\begin{pmatrix}\text{aggregate total compensation}\\ \text{of employees}\end{pmatrix}} \tag{18}$$

Between 1968 and 1993, the white-collar skill share has been increasing and the blue-collar skill share has been decreasing. The capital share has been roughly constant.

4.2.2. *Initial schooling and work experience at age 16.* The age 16 decision depends on whether the individual attended school in the previous year and on the level of schooling attained by age 16. The proportion of age 16 people who attended school the previous year was calculated up to 1940 conditional on each schooling level.[16]

The distribution of initial education level at age 16 is obtained from the CPS between 1964 and 1991 and from the U.S. census of various years before 1964.[17] Until the 1950 birth cohort, the average education level attained at age 16 steadily increased, after which it decreased slightly.

4.2.3. *Cohort size.* Cohort size is obtained from Vital Statistics of the United States and from U.S. Census Bureau reports. Cohort sizes between 1909 and 1999 are the actual sizes and cohort sizes after 2000 are based on Census Bureau forecasts.[18] Figure 1 shows the fluctuations in cohort size in the United States between 1910 and 2000.

4.2.4. *Capital stock.* We use a series collected by the Bureau of Economic Analysis for the actual capital stock for the years between 1925 and 1997. According to that data, there had been little growth in the capital stock between 1927 and the end of World War II, but since then the growth in the capital stock has been at a fairly constant 3% rate per annum. Measures of the capital stock prior to 1927 and after 1997 are based on extrapolations.[19]

[16] It was assumed that those who were 16 in 1940 had the same schooling distribution at age 15 in 1939 as those who were 15 in 1940. Those who were 16 before 1940 were given the same distribution of having attended school in the prior year as those who were 16 in 1940 conditional on age 16 initial schooling level. Additionally, initial work experiences at age 16 are assumed to be zero in both occupations.

[17] The distribution of initial education level at age 16 after 1991 is assumed to be the same as in 1991. The following procedure is used for years before 1964. (1) Education levels at age 16 in 1960, 1950, and 1940 are retrieved from the corresponding Census. (2) For years between 1960 and 1964, we use the mixture of the two distributions of the 1960 and 1964 initial education levels by assuming linear weights between the two. For example, for the distribution of 1961, we draw 1/4 from the 1964 distribution and 3/4 from the 1960 distribution, and similarly, for years between 1940 to 1950 and 1950 to 1960. (3) For years before 1940, because there are data containing the age 16 education level distribution, we use the education level of people older than 16 in the 1940 Census. To deflate the education level of older people back to the age 16 level, we assume that the education level at age 16 in 1940 stochastically dominates those before 1940 in the first order sense. For example, to get the education level at age 16 in 1930, we draw 1000 observations each from age 16 and 26 in the 1940 Census, sort each of them from the smallest to the largest, and keep the smaller of the matched pair. In this way, we keep the lower education level of the earlier cohort and remove the higher education level accumulated after age 16. To get the initial education level at age 16 in 1929, we draw the same number of observations from age 16 and 27 in the 1940 Census and do the same.

[18] Approximate cohort sizes from 1800 to 1908 are obtained from cohort sizes between 0 and 4 years reported every 10 years from 1800 through 1910.

[19] The capital stock series before 1925 and after 1997 are extrapolated using the growth rates of 1925 and 1997, respectively. For example, we assume that capital growth rates before 1925 and after 1997 are the same as in 1925 and 1995, respectively. The career decisions in the estimation period is not sensitive to this calculation of the out-of-sample capital stock series. It should be also noted that Krusell et al. (2000) argue for a much more rapid growth in the capital stock than that assumed here because of adjustment for quality changes, especially after 1975.

TABLE 3
EXOGENOUS VARIABLES

Variable	Source	Coverage Years
Education level at age 16	CPS & Census	1865–1991
Cohort size	Census Bureau	1800–2050
Capital stock	Bureau of Economic Analysis	1925–1997
Preschool children	CPS & Census	1871–1995

4.2.5. *The Markov process of number of preschool children.* We use the CPS from 1968 to 1995 and various years of the U.S. Census to estimate the process generating the number of preschool children, which is assumed to differ by cohort, age, sex, and the four educational categories.[20] The average number of preschool children peaked at age 28 for females and at age 30 for males between 1961 and 1995. Over time, the fertility rate decreased rapidly between 1960 and 1980, and since then has continued to decline at a slower rate.

Table 3 summarizes the exogenous variables employed in the model.

5. ESTIMATION RESULTS

I estimate the model by minimizing the weighted squared deviation between the actual moments obtained from the data and the corresponding simulated moments from the model between 1968 and 1993. I sum up the distances over all the conditional moments with proper weights and search for the set of parameters that minimizes this sum.[21]

[20] We estimate the process for preschool children between 1968 and 1995 based on the number of family members between 0 and 6 in the corresponding CPS data. For example, to calculate the transition probability from 0 to 1 preschool children in 1968, we count the number of people who had zero children between 0 and 5 years old in 1967 and calculate the proportion of people with one child between 0 and 5 years old in 1968. We repeat this calculation in each year between 1968 and 1995. To obtain the 1967 transition rate, because the 1967 CPS only has data on family members older than 14, we decrease each individual's age by one from the 1968 CPS and obtain the 1967 transition rate, as if the data represented the family structure in 1967. We repeat this calculation in each year and construct the transition rates between 1961 and 1968 from the 1968 CPS, those between 1951 and 1960 from the 1960 Census, those between 1941 and 1950 from the 1950 Census, those between 1931 and 1940 from the 1940 Census, those between 1901 and 1910 from the 1910 Census, those between 1871 and 1880 from the 1880 Census. The transition rates after 1995 are assumed to be the same as that of 1995 and those before 1871 the same as 1871. Between 1911 and 1930 and between 1881 and 1900, the process is approximated by linearly interpolating the 1910 and the 1931 process and the 1880 and the 1901 process, respectively.

[21] Our estimation method is different from standard GMM. In standard GMM estimation, the same observations are repeatedly used for each different moment condition. But in our case each moment is obtained from different observations. For example, the aggregate choice moments (e.g., the school attendance rate) are obtained from all the individuals in the data, whereas the labor earnings moment is obtained only from those who choose to work. For this reason, the optimal weighting matrix (off-diagonal elements) cannot be calculated and we treat each conditional moment as if it is a single observation. We assume that within one group of moments (e.g., white-collar employment rate) the

To handle the initial conditions problem because of cohorts who reached age 16 in earlier years than 1968, we start the economy at 1865, where each cohort is given a distribution of schooling and work experiences in both occupations and a distribution of the number of preschool children.[22] Each person in each cohort alive in 1865 chooses the optimal career decision based on current and future skill prices. The aggregate skill supply in each occupation is calculated by summing individual skill supplies weighted by the cohort sizes (the 1800 cohort through the 1849 cohort) and skill prices are calculated from marginal products given the two aggregate skill supplies: the capital stock in 1865 and the output shares. In the next year (1866) the 1850 cohort enters the economy at the age of 16 with the initial schooling distribution obtained above and each cohort again solves their problem. The economy evolves until the year 2065. We record each year's skill prices for the two occupations to use for the next iteration and solve the model again from 1865 to 2065.

5.1. *Parameter Estimates.* This section reports the estimation results, provides an interpretation of the estimated parameters, and discusses the fit of the model.

The optimization problem describing career decisions pertains to that of a single individual. Individuals of different cohorts, because their lifetimes overlap in different calendar periods, face different skill rental price paths, different distributions of initial schooling, and different fertility processes. However, individuals within a cohort are ex ante identical (except for their actual initial schooling). Although the CPS data is not longitudinal, one of the moments used in the estimation—the one-period transition rate between white- and blue-collar employment—captures the degree to which there is some permanence in occupational decisions. As in most recent studies (e.g., Keane and Wolpin, 1997) that are based on longitudinal data, it has proven necessary to allow for additional heterogeneity in order to capture the degree to which there is permanence in these decisions. In implementing the model, it is assumed that in each cohort there are two types of people (for both men and women) treated as unobservable, who differ in their skill endowments, their consumption values of schooling and home, and their retirement rates.

Tables 4 through 7 report the parameter estimates. The estimation results indicate the existence of significant heterogeneity among the two types. For both males and females, one type is better at the white-collar occupation and the other type at the blue-collar occupation, indicating comparative advantage; that is, the

variance–covariance matrix is a scalar times the identity matrix and across groups of moments (e.g., between white-collar employment rate and earnings), we allow for heteroskedasticity and nonzero correlation. The error structure here, therefore, resembles that of the SUR model. We do not estimate the model by maximum likelihood using individual data in the CPS because of the difficulties that arise from the fact that the appropriate state variables, e.g., work experience, are not observed.

[22] We give the distribution of schooling and average work experiences and the distribution of preschool children for each age in 1940 to each cohort in 1865. The initial distributions of schooling and work experiences do not affect the career decisions in our estimation period at all. Instead, we could have given 0 years of schooling and 0 years of work experiences to each cohort and obtained the same career decision moments after 1968.

TABLE 4

ESTIMATION RESULTS—WORKING UTILITY

Parameter		White-Collar Skill	Blue-Collar Skill
Constant	Male I	12.22 (0.00099)	13.35 (0.00144)
	Male II	11.68 (0.00096)	13.50 (0.00096)
	Female I	11.77 (0.00098)	12.87 (0.00128)
	Female II	11.25 (0.00117)	12.95 (0.00098)
Education (E)		0.081 (0.000088)	0.054 (0.000099)
w.c. work experience (x_1)		0.093 (0.000095)	0.021 (0.000142)
w.c. work exp. square (x_1^2)		−0.0029 (0.0000046)	−0.0033 (0.000012)
b.c. work experience (x_2)		0.022 (0.000164)	0.096 (0.00010)
b.c. work exp. square (x_2^2)		−0.007 (0.000020)	−0.0027 (0.0000044)
Skill SD		0.49 (0.00069)	0.48 (0.00069)
Nonpecuniary	Male	736.8 (11.8)	
benefit	Female	−197.1 (9.5)	
Skill correlation (σ_{12})		0.031 (0.0013)	

NOTE: Standard errors are in parentheses. Blue-collar nonpecuniary benefit is normalized to be zero.

TABLE 5

ESTIMATION RESULTS—SCHOOLING UTILITY

Parameter		Male	Female
Constant	Type I	18,606.9 (11.4)	14,523.3 (11.5)
	Type II	10,145.4 (15.1)	8445.1 (19.0)
College tuition		7908.1 (8.6)	
Graduate school tuition		26.090.8 (43.0)	
Reentry cost		34,449.4 (47.3)	28,083.5 (67.8)
Age 16–17		9274.3 (21.4)	4276.9 (19.2)
Schooling shock SD		6422.8 (12.8)	5741.3 (11.8)

white-collar skill constant (the age 16 endowment) is higher for type I's than for type II's, but the blue-collar endowment is lower for type I's than for type II's. There are also differences among the types in the utilities attached to the nonwork alternatives. Type I's (both sexes) have a substantially higher consumption value for school attendance and also a higher home value. In addition, type Is are more

TABLE 6

ESTIMATION RESULTS—STAYING HOME UTILITY

Parameter		Male	Female
Constant	Type I	13,002.7 (13.1)	11,546.5 (7.9)
	Type II	8157.8 (13.3)	8031.4 (9.9)
Preschool children (NC)		61.5 (17.0)	3406.5 (12.5)
Staying home shock SD		9554.9 (14.2)	3657.4 (9.4)

TABLE 7
ESTIMATION RESULTS—DISCOUNT FACTOR, RETIREMENT RATE, AND TYPE PROPORTION

Parameter		Male	Female
Discount factor		0.93 (0.00010)	0.95 (0.000107)
Retirement rate	Type I	0.077 (0.00059)	0.21 (0.00041)
	Type II	0.14 (0.00044)	0.22 (0.00058)
Type I proportion		0.47 (0.00051)	0.69 (0.00096)

NOTE: Retirement rate is the constant retirement rate between ages 60 and 64.

likely than type II's to retire at age 65, rather than at an age between 60 and 64, than are type II's.

The education effect on skill, assumed to be the same for men and women, indicates that white-collar skill (and, thus, earnings) increase by 7.9% for each additional year of education and blue-collar skill by 4.8%. Also assumed to be the same for men and women, the first year of work experience increases skill by 9.4% both for the white-collar occupation and for the blue-collar occupation. Peak earnings is reached at 16.2 (18.4) years of white- (blue-) collar work experience. The first year of white-collar (blue-collar) work experience increases blue-collar (white-collar) skill by 2.1% (2.2%).

Insted of using actual data on post-secondary tuition costs, both the cost of college and of graduate school are estimated as parameters.[23] However, these increasing costs do not accurately reflect the accessibility to post-secondary education through increased access to 2-year colleges and to subsidized loans and other forms of financial aid. The cost of attending college (tuition plus other school-related expenditures) is estimated to be $7,465 and graduate school tuition, $25,799.[24]

School attendance, as noted, is heavily concentrated between the ages of 16 and 25. Although the finite horizon by itself leads to a declining attendance pattern with age (as in Ben-Porath, 1967), with i.i.d. shocks to the consumption value of schooling, the model generates too many transitions in and out of school. Introducing a school reentry cost, reflecting the increased cost of schooling associated with the depreciation of knowledge that occurs while not attending school, significantly improves the fit to the school attendance pattern. The reentry cost is estimated to be quite large, about $34,000 for men and $28,000 for women.[25] The sex difference reflects the fact that reentry does occur more frequently for women. The utility

[23] Crude data that average college tuition costs over college attendees show that real tuition costs have increased over the 1968–1993 period. (Source: U.S. Department of Education, "Digest for Education Statistics," National Center for Education Statistics, Office of Educational Research and Improvement, 1997.)

[24] In Keane and Wolpin (1997) the estimated cost of attending college is $4,168 and the estimated additional cost of attending graduate school is $7030 (in 1987 dollars). The estimated amounts in this article are also in 1987 dollars.

[25] Keane and Wolpin's (1997) estimate based on NLSY79 data for men is $20,030 to reenter high school and $8,709 to reenter college.

TABLE 8
GOODNESS OF FIT: R^2 STATISTIC

Moment	Male	Female
White-collar employment rate	0.88	0.80
Blue-collar employment rate	0.89	0.85
School attendance rate	0.96	0.96
White-collar log labor earnings	0.82	0.69
Blue-collar log labor earnings	0.80	0.46

attached to remaining home increases by about $1,000 for men and $4,200 for women with each preschool child. The higher value for women helps explain the decrease in female labor force participation during the high fertility ages (around 25–30).[26] Finally, the discount factor is estimated to be almost the same for men and women, 0.93 and 0.95, respectively.

5.2. *Model Fit to Data.* Table 8 shows the goodness of fit of the estimated model in terms of R^2. This measure of fit demonstrates the degree to which the actual variation in the white-collar employment rate, the blue-collar employment rate, the school attendance rate, and the average log labor earnings, classified by cohort, age, sex, education level, and whether there is a preschool child, is explained by the model. This R^2 measure should be interpreted similarly to the same measure in a linear regression. The model captures the changes in career decisions and labor earnings over time and across cohorts reasonably well.[27]

This model is also able to generate one of the most prominent labor market changes in the United States since 1968: the changes in the college premium. Figure 8 shows that the actual and the predicted changes in college premium between 1968 and 1993 in the United States defined by the log wage difference between college graduates and high school graduates. It shows that the actual college premium was decreasing in the early 1970s but has persistently been increasing since 1975. This model successfully generates the changes in college premium since the 1970s in the United States both in terms of level and direction.

6. POLICY EXPERIMENT I: COHORT SIZE EFFECT

In this section, the effect of cohort size changes on career decisions and earnings over various cohorts is evaluated. The model is simulated under the baseline case in which cohort size hypothetically increases at a steady rate (see Figure 1) and the preschool children process is stationary. The result is compared to the actual data. The baseline, or cohort trend line, was constructed by removing the major cohort fluctuations: A straight line was fit between the 1910 and 2000 cohort sizes. The steady-state preschool children process was constructed by pooling the 1910

[26] Note that in addition to the reentry cost, there is additional positive utility of school attendance specific to ages 16 and 17.

[27] However, the fit of female labor earnings is not as good as in the other moments.

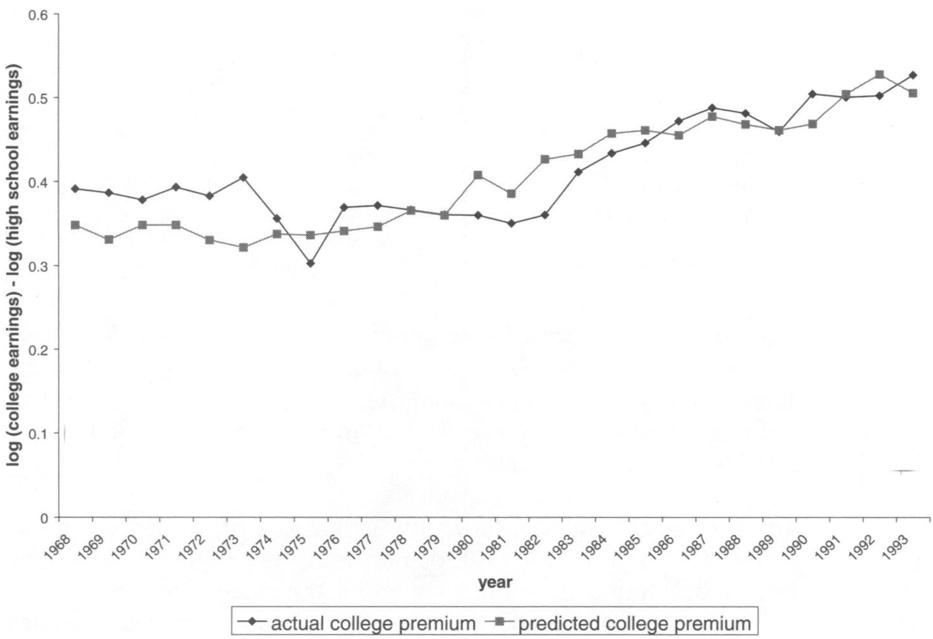

FIGURE 8

EXPLAINING CHANGES IN THE COLLEGE PREMIUM

through 1990 data sets and calculating the preschool children process conditioned on age and sex only.[28] Thus, the cohort constructed in this way maintains the stable trend from 1850. Relative to this trend line, actual cohort sizes reflect the periodic occurrences of baby booms and busts, e.g., the baby bust during WWII and the subsequent baby boom that peaked in the early 1960s.

As in the model, the aggregate capital stock is exogenous and assumed to be independent of cohort size. In theory, the aggregate capital stock is endogenously determined as the sum of individual savings and the capital stock should differ in equilibrium with cohort size. However, even though there were large changes in cohort size in the United States over the 20th century, the aggregate capital stock since 1945 looks linear and does not show much fluctuation. One interpretation is that capital accumulation is not very responsive to cohort size changes.

Figure 9 shows the predicted equilibrium log skill price over the period 1968 to 1993 based on actual cohort sizes. We see that the white-collar skill price has increased over time, whereas the blue-collar skill price has decreased since 1974,

[28] Notice that the actual preschool children process was conditioned also on year (cohort). I draw the same number of observations for each age from the 1910, 1940, 1950, and 1960 census data sets and 1970, 1980, and 1990 CPS data sets and pool them so that it represents the average family structure in the United States between 1910 and 2000 and construct the steady-state (average) preschool children process. Since we don't have data for 1920 and 1930, I substitute 1910 and 1940 data, respectively.

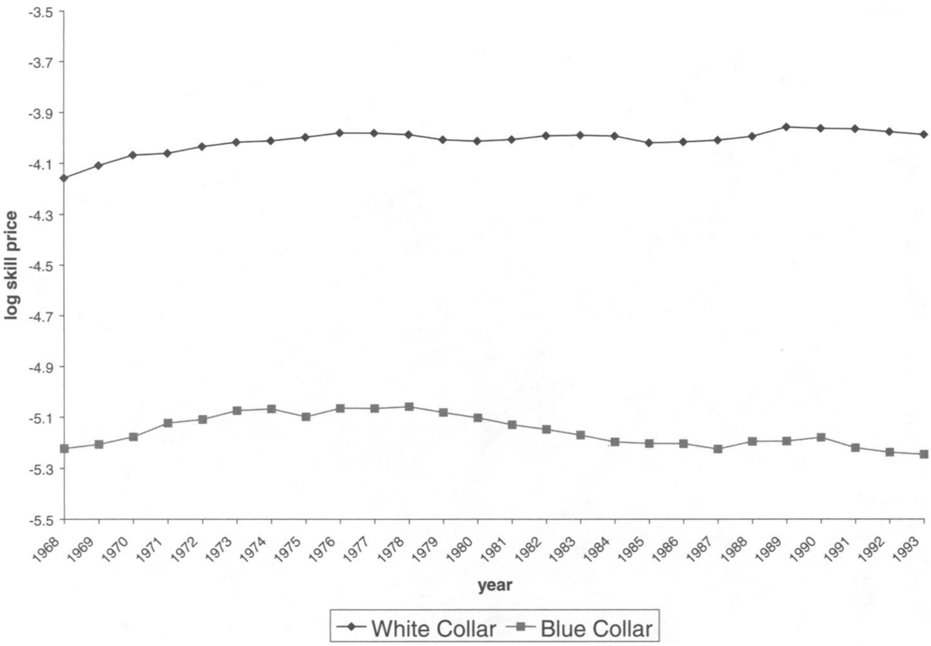

FIGURE 9

EQUILIBRIUM SKILL PRICE BY YEAR

which explains the earnings pattern by occupation during the period. Figure 10 shows the difference between the occupation-specific log skill prices based on actual cohort sizes and on the cohort trend line. The graph shows the skill price differences that arise between the actual cohort size and the hypothetical cohort size. As is apparent, skill prices based on actual cohort sizes are higher than those based on the cohort trend line until 1985. After 1985, however, this relationship is reversed. Skill prices that result from actual cohort sizes are lower than those from the cohort trend line because by 1985 most of the baby boom generation had entered the labor market and the economy was mainly dominated by them.

The results of this comparison are as follows. First, the labor market was affected by the new baby bust generation born in the 1930s and 1940s. Skill prices were higher due to the decreased skill supply and this lower skill price resulted in the male baby bust cohorts working more, earning more, and also attending school more in order to take advantage of higher skill prices. Completed education and lifetime years of work experience were concomitantly also higher for this generation. Notice that the relative white/blue-collar skill price is essentially invariant to cohort size, probably due to the fact that type Is and IIs are fairly evenly represented in the population. The impact of increased skill prices on the female baby bust generation was, however, offset by the increase in fertility rates, since they were the mothers of the baby boom generation born in the 1950s and 1960s. As a result, the female baby bust generations chose to stay home more and,

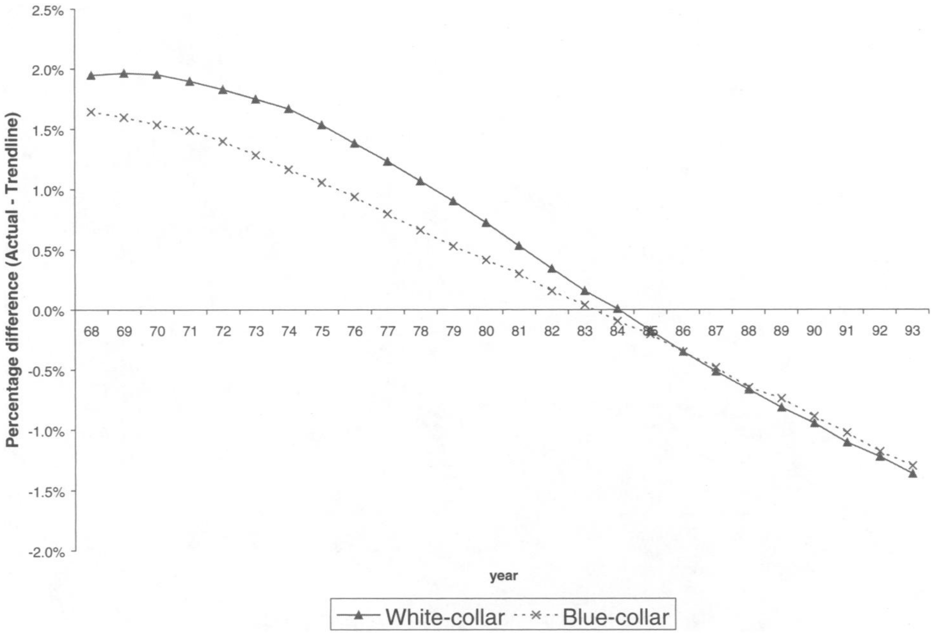

FIGURE 10

SKILL PRICE DIFFERENTIAL

consequently, attended school less and worked less in both occupations despite the increase in skill prices, whereas males from the baby bust generations were hardly affected by the increased fertility.

On the other hand, when the labor market was dominated by the baby boom generation, the opposite happened. Skill prices were lower in those periods and as a result, the male baby boom generation worked less, earned less, and attended school less compared to the cohort trend line. Completed education and the lifetime years of work experience were, therefore, lower for them. Because the baby boom generation had a lower fertility rate in the 1980s and 1990s, however, the effect of lower skill prices on female schooling and working decisions were offset to some degree by the decrease in fertility rates.

Figure 11 shows the difference in the college completion rate at age 30 between the actual cohort size and the cohort trend line. Males (females) from the baby bust generation completed college by as much as 0.3 (1.5) percentage points more (less) and males (females) from the baby boom generation completed college by as much as 1.0 (1.5) percentage points less relative to the cohort trend line. Figure 12 shows the difference in completed work experience at age 65 by cohort between the actual cohort and the cohort trend line. The male baby bust generation worked more compared to the cohort trend line in both occupations, whereas the baby boom generation worked less and the opposite holds for females due to fertility changes. In terms of total years of completed work experience (white-collar plus

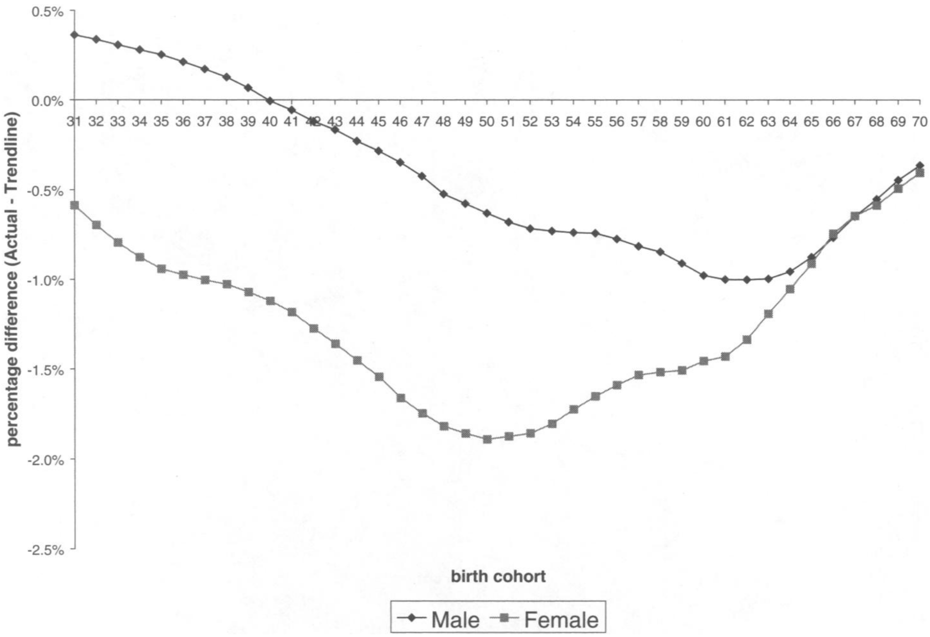

FIGURE 11

COLLEGE COMPLETION RATE DIFFERENCE BY COHORT

blue-collar), males (females) from the baby bust generation worked by as much as 0.1 (0.5) years more (less) and males (females) from the baby boom generation worked by as much as 0.1 (0.2) years less (more).

7. POLICY EXPERIMENT II: THE EFFECT OF A TUITION CHANGE

The evaluation of large-scale policy interventions based on partial equilibrium analyses may be misleading. In this section, the effect of a change in college tuition costs on the career decisions and labor earnings of the birth cohorts between 1958 and 1965 is evaluated under both partial and general equilibrium assumptions. The partial equilibrium effect of a tuition change alters career decisions assuming that skill prices do not change. The general equilibrium effect of a tuition change alters career decisions allowing skill prices to change. For example, the partial equilibrium effect of a tuition subsidy is to increase the incentive to obtain more schooling, and with this increased human capital, to work more over the lifetime; however, this increased schooling, and subsequent increased work experience, increases the aggregate skill supply, which has the effect of decreasing skill prices. Because of this feedback effect, the initial incentive to attend school will be reduced.

To assess the difference between partial and general equilibrium effects, the following three experiments are evaluated: (i) the effect of a $100 tuition increase

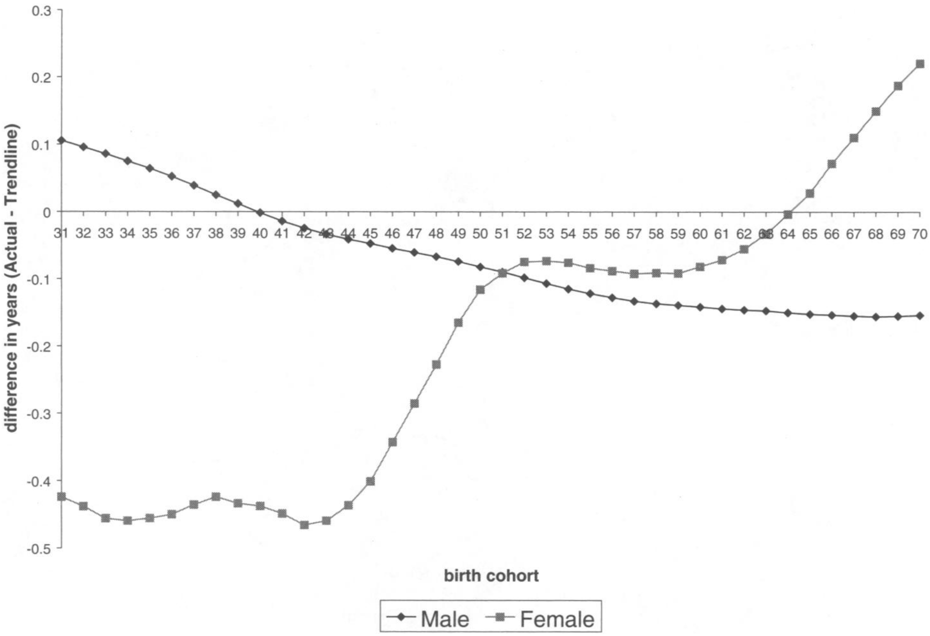

FIGURE 12

YEARS OF WORK DIFFERENCE BY COHORT

on the college enrollment rates between the ages of 18 and 19; (ii) the effect of a \$100 tuition increase on college enrollment rates between the ages of 18 and 24; (iii) the effect of a 50% tuition reduction on completed years of education by age 30.

The results of these experiments are given in Table 9. The partial equilibrium effect of a \$100 increase in college tuition is predicted to reduce the college enrollment rate for 18–19 year olds in these cohorts by 1.12% for males and 1.66% for females. Widening the age span to 18–24 leads to slightly larger reductions. These effects are consistent with what has been found in the literature (see Keane and Wolpin, 2001). The third experiment shows that the partial equilibrium effect of a 50% tuition subsidy would increase completed schooling by more than half a year for men and by almost a full year for women. In all of the experiments, the general equilibrium effect is smaller than the partial equilibrium effect as a result of skill price adjustments. However, the magnitude of differences between general and partial equilibrium effects is small, usually less than 10%.[29]

As discussed in the Introduction, Heckman et al. (1999) found the general equilibrium effect of a tuition subsidy to be close to zero, although partial equilibrium effects are of a similar magnitude as in Table 9. Although it is not possible to completely reconcile the results in their paper and those presented here given the

[29] As in the previous experiment, any effect of a tuition subsidy on the capital stock is ignored.

TABLE 9
TUITION SUBSIDY (INCREASE) EFFECT

Experiment	Sex	Predicted Value	PE Value	GE Value	PE Effect	GE Effect
1	Male	27.17%	26.86%	26.88%	−1.12%	−1.05%
	Female	27.46%	27.01%	27.05%	−1.66%	−1.52%
2	Male	17.78%	17.54%	17.55%	−1.34%	−1.27%
	Female	17.35%	17.01%	17.02%	−1.95%	−1.86%
3	Male	11.98	12.20	12.17	0.57	0.50
	Female	12.22	12.56	12.53	0.88	0.82

NOTE: PE effect = partial equilibrium effect. GE effect = general equilibrium effect. PE effect and GE effect in experiments 1 and 2 are in terms of percentage increase. Experiment 1: A $100 tuition increase (in 1995 dollars) on the college enrollment rate (ages 18 and 19). Experiment 2: A $100 tuition increase (in 1995 dollars) on the college enrollment rate (ages 18 through 24). Experiment 3: A 50% tuition reduction on completed years of education by age 30.

complexity of both models and the major modeling differences that exist, the following insights are potentially useful. Recall that in the present model, people have both white- and blue-collar skills at any point in time and can choose either occupation irrespective of their education level. A policy intervention, such as a tuition subsidy, that increases schooling will increase the aggregate skill supply more in the occupation whose skill production is most augmented by additional schooling, in this case in the white-collar occupation. However, because individuals are still subject to random shocks in both their amounts of white- and blue-collar skill, only a proportion of those who obtain more schooling and who previously chose the blue-collar occupation will now choose the white-collar occupation. Given that there is learning by doing, the initial occupation decision will have some permanence. The larger are the variances in skill shocks, the smaller will be the increase in the relative aggregate supply of white- to blue-collar skill and the smaller will be the fall in the relative white-collar skill rental price. In contrast, in the Heckman et al. (1999) framework, everyone who chooses additional schooling must enter the sector that uses (only) more educated labor. Thus, a given partial equilibrium increase in educated labor will translate into a similar magnitude increase in the aggregate supply of sector-specific skill.

The second feature that may be of particular significance in this regard is the treatment of individual heterogeneity. In the Heckman et al. paper, people are assumed to be identical after controlling for observable ability (measured by the AFQT score) and educational attainment. In the present model, heterogeneity is treated as unmeasured (as in Heckman and Singer, 1984) and arises in skill endowments and in consumption values of schooling and home. This unobservable heterogeneity captures differences in many dimensions: the quality of schooling, family background, innate abilities, etc. The degree of heterogeneity critically affects the extent to which the tuition subsidy affects the relative amounts of white- to blue-collar aggregate skill. Individuals who have relatively more blue-collar skill and who are induced to obtain more schooling by the subsidy will not necessarily enter the white-collar occupation, even though the additional schooling augmented their relative white- to blue-collar skill level. Some of the difference in the results could be due to the differential degrees of heterogeneity allowed for in the two papers.

8. POLICY EXPERIMENT III: EXPLAINING THE INCREASE IN FEMALE EMPLOYMENT

Perhaps, the most noticeable change in career paths between 1968 and 1993 is the increase in female employment, especially in white-collar occupations. During this period, overall female employment increased 39%, from 36.5% in 1968 to 50.8% in 1993. This increase in female employment is solely attributable to an increase in white-collar employment from 22% in 1968 to 37% in 1993. Female blue-collar employment was 14% both in 1968 and 1993. According to the model, the increase in female employment is potentially attributable to changes in all of the exogenous processes: aggregate technology, cohort size, the number of preschool children, the capital stock, and the initial schooling distribution at age 16. In this section, we evaluate the role that two of these factors played in the change in female employment over this period, the change in the number of preschool children, and the increase in the capital stock.

First, simulating the model under the assumption that the process generating the number of preschool children after 1960 was the same as that of 1960, it appears that female employment would have been 5% age points lower in the 1990s if the high fertility had persisted after 1960. Thus, the decrease in the fertility rate since 1960 captures about 36% of the increase in female employment. On the other hand, male earnings would have been 1% higher in the same period due to the decreased female skill supply. Although the change in fertility would account for a significant part of the employment increase, the increase in the capital stock by itself would have increased female employment even more. Based on a simulation where the capital stock is assumed to be constant after 1968, it is found that the actual increase in the capital stock captures about 77% of the increase in female employment.

9. CONCLUSION

In this article, a dynamic general equilibrium model of career decisions was estimated. The model was shown to provide a reasonable fit to data on the schooling, employment and occupational choices, and wages, of individuals represented in the Current Population Surveys from 1968 to 1993. The model was used to estimate the effects of cohort size on these decisions as well as to understand the changes that have occurred in these outcomes over cohorts and through time. The model was also used to assess the extent to which college tuition policy changes affect these behaviors and to compare the estimates that are obtained from a partial equilibrium with those obtained from a general equilibrium analysis. Finally, the model was used to assess the reasons behind the increase in female labor force participation over this period.

Based on the estimates of the model, the impact of cohort size on career decisions of each cohort was assessed. Compared to a baseline case in which cohort size increased at a steady (average) rate and the fertility process was stationary, the male baby bust generations are estimated to have completed college at a higher rate and worked more over the lifetime. In contrast, the males from the baby boom generations are estimated to have completed college at a lower rate and to have worked less over their lifetime. However, the impact of cohort size is found to differ across gender due to the differential impact of fertility on the value of home production.

With respect to the sensitivity of schooling decisions to changes in college tuition, the model predicts that a 1% increase in tuition would reduce college enrollment rates by 1.27% in partial equilibrium with fixed skill prices, consistent with previous estimates, and by 1.05% in the general equilibrium case where the skill prices are endogenous. Thus, for this policy experiment, the partial equilibrium analysis of schooling choice does not differ much from the general equilibrium analysis. Finally, with respect to the increase in female employment, it is found that by itself, 36% of female employment increase can be explained by the decrease in fertility over the period. As a comparison, 77% of female employment increase can be explained by the increase in capital stock over this period.

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