Accounting for Wage and Employment Changes in the U.S. from 1968-2000: A Dynamic Model of Labor Market Equilibrium

Donghoon Lee
New York University

and

Kenneth I. Wolpin
University of Pennsylvania

September 2005,
revised, January 2006

I. Introduction:

In this paper, we present a unified treatment of and explanation for the evolution of wages and employment in the U.S. over the last 30 years. Specifically, we account for the pattern of changes in wage inequality, for the increased relative wage and employment of women, for the emergence of the college wage premium and for the shift in employment from the goods to the service-producing sector. The underlying theory we adopt is neoclassical, a two-sector competitive labor market economy in which the supply of and demand for labor of heterogeneous skill determines spot market skill-rental prices. The empirical approach is structural. The model embeds many of the features that have been posited in the literature to have contributed to the changing U.S. wage and employment structure including skill-biased technical change, capital-skill complementarity, changes in relative product-market prices, changes in the productivity of labor in home production and demographics such as changing cohort size and fertility.

Although changes in wages and employment have been well documented for much of the period covered in our analysis, it is useful to summarize the patterns in order to establish a common reference.[1] Tables 1 presents statistics on the distribution of (accepted) hourly wages over the period 1968-2000 based on March CPS data.[2] For ease of exposition, the annual figures are grouped into, and averaged over, six periods, 1968-1974, 1975-1979, 1980-1984, 1985-1989,1990-1994, 1995-2000. Table 1 highlights a number of trends: (1) Mean and median wages were relatively unchanged in the first three periods; between the 1968-1974 and 1980-1984 periods, the mean wage grew by about 4 percent and the median wage fell by about 2 percent.[3]

[1] See, for example, Katz and Autor (1999) and, more recently, Eckstein and Nagypal (2003) and Autor, Katz and Kearney (2004).

[2] An individual is defined as working in a calendar year if annual hours are at least 780. Wages, converted to1983 dollars using the GDP deflator, are for those age 16 to 64. Imputed wages are dropped, top-coded wages are set at twice the top-coded level and wages below 2 dollars are dropped. The self-employed are not included.

[3] Only accepted wages, wages for those that chose to work, are observed. The difference between accepted and offered wages is potentially important in understanding trends in observed wages (see e.g., Heckman and Sedlacek (1985)).

Mean and median wages grew slowly in the post 1980-1984 period; mean wages by 21.5 percent and median wages by 15 percent through the 1995-2000 period. (2) Wage growth has been uneven over different percentiles of the wage distribution. Wages below the median grew very little over the whole period, while they grew a great deal for those above the median, particularly those in the highest percentiles of the distribution. Specifically, up to the 1990-1994 period, workers in the 10th, and 25th percentiles experienced no wage growth, with some growth since then. However, between the 1968-1974 and 1995-2000 periods, the hourly wage of workers in the 75th percentile grew by 24 percent and those in the 90th percentile by 33 percent.[4] (3) Even those workers with the highest wages experienced little wage growth before the 1980-1984 period; for example, between 1968-1974 and 1980-1984, the growth in wages for workers in the 90th percentile of the wage distribution was only 8 percent.

Wage inequality not only has grown among all workers, but has also grown after accounting for wage differences that result from changes in schooling, age, gender and occupation-sector of employment. Table 2 reports the standard deviation of the log wage (in the first column) and the root mean square error from regressions of the log wage on alternative sets of regressors. The first set of regressors (1) includes schooling, age, age squared and gender, the second (2) adds dummies for six sector-occupations, and the following sets, (3) - (8), use the same regressors as (1) but condition on each occupation-sector in turn. Without controls, the standard deviation of the log wage increased from .542 in the 1968-1974 period to .642 in the 1995-2000 period. There is a drop in dispersion in all periods when controls are added, but the increase in dispersion over time remains. For example, in comparison, in specification (2) the root mean square error rises over time from .406 to .509. The specifications that condition on occupation-sector, and that control for the other regressors, indicate that increased wage dispersion is not confined to one sector or to one occupation, but is a more general phenomenon.

Given the pattern of increased wage inequality as seen in table 1, it should not be surprising that wages of more-schooled workers have grown faster than for those with less schooling. Table 3 documents this. The median hourly wage of high school graduates (12 years

[4] Hourly wages grew by 42 percent for the 95th percentile.

of schooling) was essentially flat over the entire period, falling until the 1980-1984 period (by 7 percent), and then rising essentially back to the level of the earliest period by 1995-2000. The median hourly wage of college graduates (16 years or greater), on the other hand, exhibited significant growth. Although, like the high school graduates, wages fell until 1980 (by 4 percent), they subsequently grew by about 25 percent from then until the 1995-2000 period. Given these patterns, the median wage of college graduates grew from being 52 percent higher than that of high school graduates in 1968-1974 to being 78 percent higher in 1995-2000. However, almost the entire increase occurred between 1980 and 1995; the "college premium" actually dropped slightly between 1968-1974 and 1975-1979 and has been essentially constant during the1990's.[5]

Although the pattern of wage change differed over time, with there being a significant trend break beginning in the 1980-1984 period, the proportion of the age 25 to 65 population who were college graduates grew steadily throughout. College graduates comprised only about 17 percent of that group in the 1968-1974 period, 24 percent by the 1980-84 period and 27 percent by 1995-2000.[6] While the potential supply of college graduates to the labor market was increasing relative to high school graduates, as seen in table 3, employment rates of each group grew similarly (from 70.0 to 78.8 percent for college graduates and from 58.2 to 65.7 for high school graduates). Overall, the number of employed college graduates for every 100 employed high school graduates grew from only 40 in the 1968-1974 to 84 in the 1995-2000 period.

Equally striking has been the very large increase over this period in female employment, both absolutely and relative to men, coupled with a substantial increase in the female-to-male wage ratio. These changes are shown in table 4. Although the median wage grew by only about 90 cents per hour for male workers over the 1968-1974 to1995-2000 period, the median wage for female workers grew by over 2 dollars an hour, leading to a 15 percentage point increase in the female-male median wage ratio (from .585 to .733). Over the same period, the male employment

---

[5] The pattern is similar for mean wages; the college premium grew from 62 percent to 93 percent.

[6] There has been a concomitant decline in the proportion of high school non-completers (less than 12 years).

rate remained roughly constant (although there was again a trend break before and after the 1980-1984 period, with the male employment rate declining and then rising), while the female employment rate rose by over 20 percentage points. Thus, in 1968-74, there were 55 working women for every 100 working men, while by 1995-2000, there were 82 working women for every 100 working men.[7]

Finally, while these major changes were occurring in the labor market, the production sector of the economy was also undergoing a dramatic shift. As has been going on for more than 50 years, the U.S. economy was continuing to shift its production from the goods-producing to the service-producing sector.[8] Table 5 highlights these changes.[9] Although the growth rate in the value of service-sector output relative to goods-sector output (in constant dollars) was monotonic, it accelerated after 1980. Between1968 and1980, the value of service-sector output in constant dollars grew by 1.26 percent per year more than the value of goods-sector output, while between 1981 and 2000 the differential growth rate was 2.51 percent per year. This increase in the differential rate of growth of the value of service-sector output between the 1968-1980 and 1981-2000 periods was mirrored by an even larger change in the relative rate of growth of capital allocated to the service sector. In the first period, the annual growth rate of capital was 0.67 percent less per year in the service sector, but 1.51 percent more in the second period. On the other hand, the relative rate of growth in service sector employment was slightly greater in the first period, 2.45 percent per year, than in the second, 2.09.

Given the differing occupational distribution among sectors, the shift towards service-sector production and employment went along with an increase in white-collar employment and a reduction in blue-collar employment economy-wide. Over the 1968-2000 period, the

---

[7] Recall that our definition of work includes what is considered part-time. The overall patterns would not be changed if we restricted attention to full-time work.

[8] See Fuchs (1968, 1980) and Lee and Wolpin (2004).

[9] The data in table 5 on output and capital come from the Bureau of Economic Analysis. The goods-producing sector consists of the agriculture, mining, construction and manufacturing industry categories, the service sector of the transportation and public utilities, trade, finance, insurance, real estate, private household service, miscellaneous service and public administration industry categories.

proportion of workers employed in white-collar occupations increased from 27 to 40 percent, the proportion in pink-collar occupations fell slightly, from 22 to 21 percent, and the proportion in blue-collar employment fell from 51 to 39 percent (Lee and Wolpin (2006)).

Our main conjecture is that these four phenomena, (i) increased wage inequality (overall and within groups), (ii) the rise in the college premium and relative increase in college graduates, (iii) the increase in the female-male wage ratio and in relative female employment, and (iv) the rise of the service sector, are inter-related, resulting from the same set of changes in underlying fundamentals. One piece of evidence consistent with this conjecture is the common trend break surrounding the 1980-1984 period that runs throughout the previous tabulations.

In considering these labor market trends, we build on an extremely large literature that, however, has mostly considered them as separate phenomena.[10] Murphy and Welch (1992) suggest that linking these phenomena (at least the first three) might prove useful in assessing candidate explanations, a suggestion we follow, perhaps more closely than they intended. Katz and Autor (1999) provide a comprehensive review.[11] As they point out, the primary framework for explaining these phenomena is based on standard demand and supply considerations. Among those considerations are:

Demand-Side Factors:

1. Factors that contribute to shifts towards increased employment in high skill industries - differential technological change across sectors.

2. Factors that contribute to skill upgrading within industries - skill biased

[10] The general rise in inequality and the increase in the college premium have often been linked (for example, Murphy and Welch (1992)), but not together with the rise in female-male wages and employment and the growth in the service sector. The rise in the service sector and in female employment have been linked (see Fuchs (1980)) and Welch(2000) argues that both the rise in wage inequality among men and the reduction in the gender wage gap are both the result of an increase in the price of (intellectual) skill.

[11] Among the papers surveyed by Katz and Autor are Bound and Johnson (1992), Gottschalk and Moffitt (1994), Juhn, Murphy and Pierce (1993), Katz and Murphy (1992), Krusell et. al. (2000) and Murphy and Welch (1992, 1993). More recent contributions include Baldwin and Cain (2000), Eckstein and Nagypal (2004), Hornstein et. al. (2004) and Welch (2000).

technological change within sectors and capital skill complementarity coupled with changes in the price of capital favoring capital-intensive sectors.

3. International trade changes - changes in product prices favoring skill-intensive sectors.

Supply-Side Factors:

1. Cohort size variation.

2. Factors that alter female labor supply given factor prices - fertility (if not a choice) or contraceptive costs, and changes in the value of home time or in social "norms" associated with female work.

3. Factors that alter educational investment behavior given factor prices.

4. Immigration.

Our approach differs from that found in the literature in at least two ways. First, we develop and estimate an explicit labor market equilibrium model.[12] Second, rather than rejecting a single explanation if it does not appear to be consistent with all facts (see, for example, Card and DiNardo (2002)), we quantitatively assess the relative importance of a number of explanations, some potentially countervailing, placed within the same framework.

The general features of the model we estimate are:[13] (i) There are two production sectors, goods and services. The aggregate production functions are CES with constant returns to scale in three skill types (white-, pink- and blue-collar occupations) and homogeneous capital. Capital and white-collar skill form a nested CES composite input. There is both time-varying neutral and non-neutral technological change and combined aggregate productivity and relative product price shocks. The relative goods-to-service product price is exogenous as is the price of capital.

---

[12] Our work is similar in that respect to Heckman, Lochner and Taber (1998).

[13] The model extends and builds on a long tradition of prior work. We extend Heckman and Sedlacek's (1985) static model of sectoral choice in the presence of skill heterogeneity to a dynamic choice setting, combining it with features in Willis and Rosen (1979) and Willis(1986), adopt the partial equilibrium dynamic schooling and occupational choice framework of Keane and Wolpin (1997), and extend the general equilibrium formulations of Lee (2001) and Heckman, Lochner and Taber (1998) to allow for sectoral choice and aggregate shocks. The model is essentially the same as that in Lee and Wolpin (2006).

(ii) Individuals age 16 to 65 choose among eight discrete alternatives at each age, working in any of the six sector-occupations, attending school or remaining in the home sector. An individual receives a stochastic wage offer from each sector-occupation in each period that is the product of a competitively determined sector-occupation-specific skill rental price and the individual's accumulated sector-occupation-specific skill. The latter depends on the individual's level of schooling in that period and the individual's accumulated work experience in each sector-occupation. There is an age-invariant non-pecuniary payoff to each sector-occupation and a stochastic consumption value of attending school and of remaining in the home sector. The latter depends on the number of pre-school children in the household and also is trended due to technological improvements in household production technology. Transiting between alternatives involves a cost. (iii) The population at any calendar time consists of overlapping generations of individuals of both sexes age 16 to 65 and is time-varying. The population consists of five types of individuals, where a type is distinguished by their endowment of each sector-occupation-specific skill and their consumption values of schooling and home.

To solve the model for the six equilibrium skill prices, which are determined by equating skill prices to their respective marginal revenue products evaluated at aggregate skill amounts, we adopt a forecasting rule, that is, a joint stochastic process, for skill prices, and develop an iterative algorithm to determine the parameters of the process.[14] We estimate the parameters of the model by matching data moments on employment, wages and school enrollment from the March supplements of the Current Population Surveys from 1968-2001, on sectoral output and capital from the Bureau of Economic Analysis and on employment transitions from the NLSY79. We present evidence on the fit of the model to salient pieces of the data.

We use the parameter estimates to simulate counterfactual experiments to quantitatively assess the relative importance of supply and demand factors. We find that there is no single explanation for all of the changes that have occurred. In some instances, technological change played the major role, sometimes Hicks-neutral and sometimes skill-biased change being of more central importance. In other instances, supply side factors played the more significant role.

---

[14] In Lee and Wolpin (2006), we provide evidence that this approximation is, by some metric, a reasonable approximation to the rational expectations equilibrium.

The next section presents the model, followed in section III by a discussion of the estimation method and in section IV by the results of the estimation and the model fit. Section V discusses the counterfactual experiments and evaluates the role of demand and supply factors in accounting for the four phenomena we study. Conclusions are provided in the last section.

II. Model:

To motivate the model specification, it is useful to summarize how demand and supply factors are incorporated into the model. As noted, the setup is that there are six skill types of labor, three within each of the two production sectors. The demand for skill types is determined by their respective marginal revenue products. Factor demand and product supply shift as there is technological change in each sector. The model allows for both sector-specific Hicks neutral and skill-biased technological change. Because there seems to have been a structural break in 1980, the model allows for the pace of skill-biased technological change to differ after 1980. Hicks-neutral technological change is estimated as a Solow-like residual and so may also exhibit a trend break. In addition, exogenous (by assumption) changes in the relative price of goods to services and in the rental price of capital directly affect product supplies and factor demands.[15] Periods of a rising relative price of services to goods would induce faster relative growth in service sector output and employment. A declining rental price of capital would increase the demand for capital relatively more in the capital intensive sector, as well as increasing the demand for complementary inputs, that is, for higher skill occupations if there is capital-skill complementarity (for which we allow). The model's estimates will determine the extent to which these demand-side factors are separately and jointly responsible for the labor market changes described above.

On the supply side, individuals choose among eight possible activities at each age, working in any of the six sector-occupations, attending school or remaining at home. The rate at which individuals accumulate sector-occupation specific skill depends on their initial endowments of each skill and on the history of their choices. For any given (birth) cohort, there

[15] We do not distinguish between relative product price changes and Hicks-neutral technological change. Throughout, when we refer to Hicks-neutral technological change, we mean its combination with product price changes.

is an age-dependent distribution of potential supplies of the six types of skill. In a stationary environment of constant cohort size, these potential supplies would not vary with calendar time. However, because of variations in cohort size, the environment we consider is not stationary in terms of the age distribution of the population; thus, the potential supply of sector-occupation skills varies with calendar time and may provide a part of the explanation for the observed labor market changes.[16] Changes in skill supply may also have accompanied the increase in female labor force participation as females are modeled as having potentially different skill endowments and preferences. Changes over time in female labor supply arise in the model because of changes in cohort-specific fertility rates (considered exogenous) and the effect that young children have on the value of female home time, and of changes in the marginal utility of home time caused by technological innovations in home production or in societal "norms." Finally, changes over time in school attainment at age 16 (initial schooling) may also have affected the skill distribution in ways that influenced the growth in the service sector. Again, the model's estimates will quantify the relative importance of supply factors in determining the growth in the service sector.

Additional model specification issues are addressed as the details of the model are presented.

Model Specification:

Technology:

We consider a two-sector economy, the goods-producing sector (G) and the service sector (R), each producing output (Y) using three skill categories of workers, white-, pink- and blue-
collar (W, P, B) and homogeneous capital (K). Each sector is also subject to an aggregate productivity shock (ζ). Skill units (S) of each worker category (occupation) employed in each sector are additive over workers in that occupation and sector. Specifically, production at time t, valued at the sector's period t real price (p), is given by the following nested CES function

[16] Further non-stationarity arises because of immigration which effectively increases the relative sizes of birth cohorts as cohorts age.

$$p_t^j Y_t^j = p_t^j \zeta_t^j F^j(S_t^{jW}, S_t^{jP}, S_t^{jB}, K_t^j)$$

(1)

$$= z_t^j\{\alpha_{1t}^j(S_t^{jP})^{\sigma^j} + \alpha_{2t}^j(S_t^{jB})^{\sigma^j} + (1-\alpha_{1t}^j-\alpha_{2t}^j)[\lambda_t^j(S_t^{jW})^{\nu^j} + (1-\lambda_t^j)(K_t^j)^{\nu^j}]^{\sigma^j/\nu^j}\}^{1/\sigma^j},\ j=G,R.$$

Production in each sector is subject to constant returns to scale. The elasticity of substitution between capital and white-collar skill is $1/(1-\nu^j)$ and that between the composite capital-white-collar skill input and the other skill categories $1/(1-\sigma^j)$. Hicks-neutral and factor-biased technological change are assumed to be time-varying.[17]

Sector-specific real productivity is subject to shocks, $z_t = p_t^j\,\zeta_t^j$, that, evaluated at constant dollars, are assumed to follow a joint first-order VAR process in growth rates. Specifically,

$$\text{(2a)}\quad \ln z_{t+1}^j - \ln z_t^j = \phi_0^j + \sum_{k=G,R} \phi_k^j(\ln z_t^k - \ln z_{t-1}^k) + \epsilon_{t+1}^j,\quad j=G,R,$$

where the innovations are joint normal with the elements of the variance-covariance matrix σ_{jk}^z, j,k=G,R. The time-varying factor shares, reflecting biased technological change, are assumed to be constant up to 1960 and then to follow separate linear trends until 1980 and then different linear trends thereafter. Specifically,

$$\alpha_{kt}^j = \alpha_{k0}^j \qquad \text{if } t<1960,$$

$$\text{(2b)}\qquad = \alpha_{k0}^j + \alpha_{k1}^j(t - 1960) \qquad \text{if } 1980 \geq t \geq 1960,$$

$$= [\alpha_{k0}^j + 20\alpha_{k1}^j] + \alpha_{k2}^j(t-1980) \quad \text{if } 2000 \geq t \geq 1980,\ j=G,R,\ k=1,2,3.$$

<u>Choice Set</u>:

At each age, from a = 16 to 65, an individual of type h who is alive at time t chooses

---

[17] The particular nesting assumption in (1) is similar to that in Krusell et. al. (2000) in which skilled labor (white-collar in our case) forms a composite input with capital. Although it is somewhat arbitrary to nest pink-collar with blue-collar skill rather than with white-collar skill, a rationale is that college graduation rates are much higher for those in white-collar than in pink-collar occupations; 56 percent of white-collar workers had college degrees in 2000, while that was true for only 20 percent of pink-collar workers. The difference was proportionately even greater in 1968, 41 percent versus 7 percent.

among eight mutually exclusive alternatives, each denoted by a dichotomous variable (d^{j}_{hat}) equal to one if alternative j is chosen and zero otherwise. Adopting the convention, which we continue throughout, that sector-occupation categories are ordered as {GW=1, GP=2, GB=3, RW=4, RP=5, RB=6}, the alternatives are: (1) work in the goods-sector white-collar occupation - d^{1}_{hat}, (2) work in the goods-sector pink-collar occupation - d^{2}_{hat}, (3) work in the goods-sector blue-collar occupation - d^{3}_{hat}, (4) work in the service-sector white-collar occupation - d^{4}_{hat}, (5) work in the service-sector pink-collar occupation - d^{5}_{hat} or (6) work in the service-sector blue-collar occupation - d^{6}_{hat}, (7) attend school - d^{7}_{hat}, (8) take leisure (neither work nor attend school) - d^{8}_{hat}. The population consists of H discrete types of individuals who permanently differ in preferences and skill endowments (unobserved by us, but known to the individual) as described below; the probability that an individual is of any given type is π_h. In what follows, we drop the h and t subscripts where the meaning is clear.

Preferences:

As previously noted, for tractability, we assume that the discrete time allocation decision is independent of the relative price of goods to services, that is, we assume a utility specification that enables us to ignore the consumption allocation decision. The flow utility at each age a for an individual of type h is given by

$$
\begin{aligned}
(3) \quad U^{h}_{a} = {} & \sum_{k=1}^{6} \gamma_k d^{k}_{a} + \gamma_{7h} d^{7}_{a} + \gamma_{8ht} d^{8}_{a} + \gamma_9 d^{8}_{a} d^{8}_{a-1} \\
& + \gamma_{10} d^{7}_{a}(1 - d^{7}_{a-1}) I(E_a < 12) + \gamma_{11} d^{7}_{a}(1 - d^{7}_{a-1}) I(E_a \geq 12) + u(c^{G}_{a}, c^{R}_{a}),
\end{aligned}
$$

where

$$
(3a) \quad \gamma_{7h} = \gamma^{c}_{12} \cdot \gamma_{70h} \cdot [\gamma_{71} I(\text{Male}=1) + \gamma_{72} I(\text{Male}=0)] \ ,
$$

$$
\begin{aligned}
\tilde{\gamma}_{8h} = {} & \gamma_{80h} [\gamma_{81} I(\text{Male}=1) + \gamma_{82} I(\text{Male}=0)] + \gamma_{83} n_{05,a} \\
& + \gamma_{84} E_a + \gamma_{85} I(E_a < 12) + \gamma_{86} I(E_a \geq 16)
\end{aligned}
$$

$$
\begin{aligned}
(3b) \quad \gamma_{8ht} & = \tilde{\gamma}_{8h} && \text{if } t < 1960 \ , \\
& = \tilde{\gamma}_{8h} + \gamma_{87}(t - 1960) && \text{if } 1980 \geq t \geq 1960 \ , \\
& = \tilde{\gamma}_{8h} + 20\gamma_{87} + \gamma_{88}(t - 1980)^{1} && \text{if } 2000 \geq t \geq 1980 \ ,
\end{aligned}
$$

and where γ_{12}^{c} , $\gamma_{83}-\gamma_{88}$ also differ by gender.[18] $u(c_a^R, c_a^G)$ is the separable consumption branch of the utility function.[19]

As seen from the form of (3), fitting the choice data required us to place additional structure on the utility function.[20] For example, the utility specification allows for differential non-pecuniary benefits associated with working in each sector-occupation, given by γ_k for k=1,...6, because wage differentials alone do not provide a good fit to the choice distribution. To capture the strong degree of persistence in the choice of the schooling and home alternatives, those choice-specific utilities are assumed to vary by an individual's time-invariant type, in addition to being subject to age-varying iid stochastic shocks, namely, $\gamma_{kha}=\gamma_{kh}+\epsilon_{ka}$, k=7, 8. To fit the fact that returning to school after a period of non-attendance is rare, the utility specification also includes a psychic cost of reentering high school, E_a less than 12, γ_{10}, and a

---

[18] γ_{12}^{c} is for cohort c, that is, those age 16 in year c and is piece-wise linear. Specifically,

$$\gamma_{12}^{c} = \gamma_{12}^{1920} \qquad \text{if } c \le 1920 \ ,$$

$$\gamma_{12}^{c} = \gamma_{12}^{1920}(1960-c)/40 + \gamma_{12}^{1960}(c-1920)/40 \qquad \text{if } 1960 \ge t \ge 1920 \ ,$$

$$\gamma_{12}^{c} = 1 \qquad \text{if } c = 1960 \ ,$$

$$\gamma_{12}^{c} = \gamma_{12}^{1960}(1980-c)/20 + \gamma_{12}^{1980}(c-1960)/20 \qquad \text{if } 1980 \ge t \ge 1960 \ ,$$

$$\gamma_{12}^{c} = \gamma_{12}^{1980}(2000-c)/20 + \gamma_{12}^{2000}(c-1980)/20 \qquad \text{if } 2000 \ge t \ge 1980 \ ,$$

[19] Alternative formulations of u with the property that the labor allocation decision is independent of the relative price of goods to services are that u is linear, or quasi-linear, and additively separable in goods and services consumption, $u(c_a^R, c_a^G) = c_a^R + g(c_a^G)$, or that u is Cobb-Douglas. A simpler alternative is to invoke the Hicks composite commodity theorem together with additive linearity of the utility function in the composite consumption good. However, relative prices have not been constant over the period.

[20] The exact structure we adopt for the utility function, and for the other structural relationships that are described below, is similar to that in Keane and Wolpin (1997) and in Lee and Wolpin (2006). As in those papers, the final forms are, in part, the result of structural modifications made during estimation by assessing within-sample fit.

separate cost for reentering college, E_a at least 12, γ_{11}. Particularly because females are less likely to work when there are young children in the household, the utility associated with being at home is allowed to depend on the number of children under the age of six ($n_{05,a}$) and, to better fit persistence in the home alternative, on whether the individual was at home in the previous period, γ_9. Finally, to allow for changes in supply side determinants of employment not captured by changes in fertility, namely changes in home productivity and in social "norms," the value of leisure is allowed to depend on calendar time (with a potential trend break in 1980); similarly, to account for supply side changes in schooling due, say, to changes in college tuition costs and access to junior colleges, the value of attending school is allowed to change with cohort (with potential trend breaks in 1960 and 1980). Preference shocks are joint normal with elements of the variance-covariance matrix given by σ^{ϵ}_{jk}, j, k=7, 8.

Constraints:

The individual faces the following budget constraint:

$$(4) \quad \sum_{j=G,R} p_t^j c_a^j = \sum_{k=1}^{6} w_{at}^k d_a^k - [\beta_1 I(E_a \geq 12) + \beta_2 I(E_a \geq 14) + \beta_3 I(E_a \geq 16)]\, d_a^7 - \sum_{k=1}^{8} \sum_{j=1}^{6} \delta_{jk} d_a^j d_{a-1}^k,$$

where w_{at}^k is the real wage (earnings) an individual of age a receives from working in sector-occupation k at time t, β_1 is the cost of the first two years of college attendance, β_2 the additional cost of the second two years and β_3 the additional cost of graduate school attendance. To flexibly fit the one-period transition patterns into sector-occupation- specific employment, we include parameters in (4), the δ_{jk}'s, that reflect a direct cost of switching from any of the eight alternatives to any of the six employment alternatives. These mobility parameters depend on gender.[21]

An individual receives a wage offer in each period from each sector and in each occupation. We adopt a Ben-Porath - Griliches specification of the wage function.[22] Each sector-

[21] The budget constraint does not allow for savings. To close the equilibrium model, payments from the return on capital in any year are assumed to be independent of all choices.

[22] See Ben-Porath (1967), Griliches (1977) and also Willis (1986).

occupation-specific wage offer is the product of a sector-occupation-specific competitively determined skill rental prices (r) and the amount of sector-occupation-specific skill units possessed by the individual (s). There is a production function for each type of skill. Skill units are produced through formal education and through work experience (X) accumulated in each sector-occupation and are subject to idiosyncratic iid shocks. To improve the fit of wage profiles, a linear age effect is introduced upon reaching age 40. Specifically, a type-h individual's (log) wage offer at age a and calendar time t in the j-th sector-occupation combination is

$$\begin{aligned} \log\ w^j_{hat} &= \ln r^j_t + \ln s^j_{ha} \\ &= \ln r^j_t + \omega^j_{0h} + \omega^j_{11} E_a + \omega^j_{12} I(E_a<12) + \omega^j_{13} I(E_a \geq 16) \\ &\quad + (\sum_{k=1}^{6} \omega^{jk}_2 X^k_a)^{\omega^j_3} - \omega^j_4 I(a>40)(a-40) + \omega^j_5 I(\text{Male}=0) + \eta^j_{at}. \end{aligned} \tag{5}$$

Years of education evolves as $E_a = E_{a-1} + d^7_{a-1}$ and sector-occupation-specific work experience as $X^j_a = X^j_{a-1} + d^j_{a-1}$, j=1,..,6. Age 16 (initial) schooling is taken as given and initial experience is zero in all sector-occupations. The ω^j_{0h}'s are (unobserved) skill endowments at age 16 for an individual of type h and the η^j_a's are age- and time-varying shocks to skill (reflecting, for example, health shocks). The probability that an individual is of any type depends on initial schooling at age 16. To capture increases in wage inequality not accounted for elsewhere in the structure, the sector-occupation variances in skill shocks are allowed to depend on calendar time.[23] Skill endowments also vary by gender. In (5), sector-occupation-specific "composite" work experience is a sector-occupation-specific weighted sum of work experience across all sector-occupations. Thus, in addition to the direct mobility cost associated with switching employment to a different sector-occupation (the δ_{jk}'s in (4)), there is also a loss to the extent that the accumulated work experience in the origin sector produces less composite work

[23] Specifically, $\sigma^2_\eta = \sigma^2_{\eta,0} I(t \leq 1960) + (\frac{\sigma^2_{\eta,1} - \sigma^2_{\eta,0}}{40})(t-1960) I(t \geq 1960)$.

experience in the destination sector, that is, there is a loss of specific human capital.

The number of pre-school children, ages 0 to 5, assumed above to affect the value of leisure, is taken to be exogenous and can be any one of three values, 0, 1 or 2 or more. Transitions from one value to another are governed by a transition probability function that depends on the individual's age, sex, education and birth cohort.[24]

Market Clearing:

The economy consists of overlapping generations of individuals age 16 to 65. Each individual alive at t maximizes the remaining expected discounted present value of lifetime utility given their age, subject to (3) - (5), by choosing among the eight alternatives. Maximized expected lifetime utility of an individual who is age a at time t is given by

$$(6) \quad V_a(\Omega_{at}) = \max_{\{d^j_{at}\}} \sum_{\tau=a}^{A} E[\rho^{\tau-a} U_\tau | \Omega_{at}],$$

where ρ is the discount factor and Ω_{at} is the information set (or state space) at age a and time t. The terminal period, A, the retirement age, is probabilistic starting from age 56; the probability increases linearly until age 64, differs by gender, and is one at age 65.[25] The information set consists of current idiosyncratic shocks, years of education and work experience, current and past skill rental prices, current and past aggregate shocks, the current and past ages of pre-school children, as well as other information used to forecast future rental prices.

At any time t, agents in the economy form a common forecast of the distribution of future skill rental prices, and based on that forecast and each agent's current state, including the current set of skill rental prices, the alternative that is optimal is chosen. Aggregate skill supplied to each

---

[24] Note that fertility is determined by the current level of completed schooling which depends on prior choices. The fertility transition probabilities are the sample transition rates within the following categories: individual ages between 16 and 65 by sex by four education categories (completed schooling less than 12, exactly 12, 13 to 15, 16 and over) and by single years between 1901 and 2000. Before 1960, it is not conditioned on education. The transitions are based on decennial census data from 1910, 1940, 1950, 1960 and on CPS data from 1964 on.

[25] The retirement probability is parameterized as follow:
$P_{at} = (1/40)[A(t-1960) + B(2000-t)]$, where $B = \omega^1_{5,0} + \omega^1_{5,1}(65-a)$ and $A = \omega^2_{5,0} + \omega^2_{5,1}(65-a)$.

sector-occupation is the sum of the skill units of the individuals choosing that alternative. Letting N_{at} be the total number of individuals who are age a at time t, aggregate skill supplies are given by

$$(7) \quad S_t^j = \sum_{a=16}^{65} \sum_{n=1}^{N_{at}} s_{nat}^j \, d_{nat}^j (r_t^1,\ldots,r_t^6) \qquad j = 1,..,6,$$

where we highlight the dependence of current choices on the set of six skill rental prices. The aggregate supply of capital is perfectly elastic at the current rental price of capital and aggregate demand is equal to the sum of the demand in the two sectors, $\overline{K}_t = K_t^G + K_t^R$. Given the static nature of the demand side of the model, aggregate skill demand for each sector-occupation is determined by equating the marginal revenue product of aggregate skill for each sector-occupation to its current (equilibrium) skill rental price. The amount of capital used in each sector at time t is determined by equating the marginal revenue `product of capital in each sector at time t to the exogenous rental price of capital, r_t^K. Formally,

$$\frac{\partial p_t^G Y_t^G(S_t^1, S_t^2, S_t^3, K_t^G)}{\partial S_t^j} = r_t^j \qquad j = 1,2,3,$$

$$(8) \quad \frac{\partial p_t^R Y_t^R(S_t^4, S_t^5, S_t^6, K_t^R)}{\partial S_t^j} = r_t^j \qquad j = 4,5,6,$$

$$\frac{\partial p_t^G Y_t^G(S_t^1, S_t^2, S_t^3, K_t^G)}{\partial K_t^G} = \frac{\partial p_t^R Y_t^R(S_t^4, S_t^5, S_t^6, K_t^R)}{\partial K_t^R} = r_t^K$$

In a rational expectations equilibrium, current and past values of the aggregate shocks and of capital rental prices, which are common to all agents, as well as the idiosyncratic elements of the state space associated with the decision problem of each agent in the economy (age, schooling, work experience in each sector-occupation, preference and skill shocks) will determine equilibrium skill rental prices. Specifically, equilibrium skill rental prices equate aggregate skill supplies and demands in all sector-occupations. At each time t, the six excess demand functions satisfy

$$(9)\quad [S_t^j]_{Demand} - [S_t^j]_{Supply} = e_t^j(r_t^1, r_t^2, ..., r_t^6;\ \tilde{Z}_t,\ \tilde{r}_t^K\ \tilde{\Omega}_t,\ \Theta) = 0 \quad \text{for } j=1,..,6,$$

where $\tilde{Z}_t$ is the vector of current and past productivity shocks, $\tilde{r}_t^K$ is the vector of the current and past capital rental prices, $\tilde{\Omega}_t$ is the state space vector at time t over all agents in the economy and Θ is the set of model parameters. The system of excess demand functions (9) does not have an analytical form nor does the set of skill rental prices have an analytical solution. To solve the model, we adopt the following numerical solution algorithm.

We assume that the solution to (9) for the growth rate of equilibrium skill rental prices can be approximated by the following function:[26]

$$(10)\quad \begin{aligned} \ln r_{t+1}^j - \ln r_t^j = \eta_0^j + \sum_{k=1}^{6} \eta_k^j[\ln r_t^j - \ln r_{t-1}^j] + \eta_7^j[\ln z_{t+1}^G - \ln z_t^G] \\ + \eta_8^j[\ln z_{t+1}^R - \ln z_t^R]. \end{aligned}$$

Essentially, (10) assumes that the contemporaneous growth rate of sector-specific productivity shocks and a one-period lag in the growth rate of sector-occupation-specific equilibrium skill rental prices are sufficient to capture the histories of aggregate shocks and the state space distribution of the agents in the economy (the joint population distribution of schooling, sector-occupation-specific work experience, children under six).[27] Although in the solution algorithm

---

[26] The methodology of approximating a rational expectations equilibrium process combines ideas in Krusell and Smith (1998) and Altug and Miller (1998). Krusell and Smith use moments of the aggregate distribution of the state space elements in the forecasting rule as an approximation to the rational expectations equilibrium for which they solve, while Altug and Miller assume a Markov process for the forecasting rule of the equilibrium price in their model but do not explicitly solve the equilibrium.

[27] Note that, given this approximation, we are agnostic as to what individuals know about future technological change, that is about α_{k1}^j and α_{k2}^j, or about the values of other future exogenous variables (for example, the rental price of capital, relative product prices etc.). There is an additional approximation error. The environment is explicitly non-stationary, allowing for

described below we treat the parameters of (10) as unrestricted, they are in fact themselves functions of the underlying parameters of the model (Θ).[28]

In implementing the solution algorithm, we assume the economy begins in 1860 (t=1). We observe the age distribution of the population at that time. Although we do not have data on the state space of agents alive in 1860, nor on actual sectoral output and the rental price of capital which are needed for the algorithm, for the purpose of describing the algorithm we assume that we do.[29] It turns out that the solution of the model for the periods that the model is fit to actual data (1968-2000) is not sensitive to the assumptions we make.[30]

The solution algorithm is an extension of the method developed in Lee (2000). Given parameters for (1), (3), (4), (5), a discount factor ρ, and observed sequences of output in each sector and of the rental price of capital, the algorithm consists of the following steps:

1. Choose a set of parameters for the equilibrium rental price process (10) and for the aggregate shock process (2a).

2. Solve the optimization problem for each cohort that exists from t=1 through t=T. The

non-constancy in the growth of population (and the related time-varying fertility process for the number of children under (6)). Rational expectations would imply that the rental price processes given by (10) are also time-varying.

[28] This representation of the rental price process reduces the state space of the agents' optimization problem to only the one- and two-period lags in rental prices and the one-period lag in aggregate shocks.

[29] In solving the model, as described above, we assign arbitrary values for the state space to each person age 16 to 65 in 1860, zero work experience in each sector-occupation and 8 years of schooling. We also assume that the capital real rental price, cohort size, real output in the two sectors and the fertility process between 1860 and 1900 are the same as in 1900. Output by sector is available starting in 1947. We extrapolate sectoral output backwards from that point, assume that the real rental price of capital is constant between 1900 and 1925 (its first available year) and allow cohort size to change as it actually did after 1900.

[30] We assume that the equilibrium skill rental price process (10) governs the choices made by all individuals age16 to 65 through the year 2050. This assumption is necessary in order to solve the optimization problems for individuals age 16 to 65 as of the year 2000. Thus, we solve the optimization problem for the 65 year old in 2050, 64 and 65 year olds in 2049, etc. Between 1860 and 2000, the optimization problem is solved for the full age distribution of 16 to 65 year.

maximization problem can be cast as a finite horizon dynamic programming problem. The value function (6) can be written as the maximum over alternative-specific value functions, $V_a^j(\Omega_{at})$, i.e., the expected discounted value of alternative j, that satisfy the Bellman equation, namely

$$V_a(\Omega_{at}) = \max_j [V_a^j(\Omega_{at})]$$

$$(11) \quad V_a^j(\Omega_{at}) = U_a^j(\Omega_{at}) + \rho E(V(\Omega_{a+1,t+1} | d_{at}^j = 1, \Omega_{at}) \text{ for } a<65,$$

$$= U_a^j(\Omega_{at}) \qquad \text{for } a=65.$$

The solution of the optimization problem is in general not analytic. In solving the model numerically, the solution consists of the values of $EV(\Omega_{a+1,t+1} | d_{at}^j = 1, \Omega_{at})$ for all j and elements of Ω_{at}.[31] We refer to this function as Emax for convenience. As seen in (11), treating the Emax functions as known scalars for each value of the state space transforms the dynamic optimization problem into the more familiar static multinomial choice structure. The solution method proceeds by backwards recursion beginning with the last decision period.[32]

3. Guess an initial set of values for period one rental prices, say $(r_1^j)^0$, for j=1,..,6. Given the age distribution at t=1 and the distribution of state variables for each cohort alive at that time and between the ages of 16 and 65, simulate a sample of agents' chosen alternatives at t=1 by drawing from the distribution of the idiosyncratic shocks to preferences and skills. Using (7),

---

[31] The state space at age a and time t for each individual consists of all current and past values of the (six) skill rental prices and the sector-specific productivity shocks, education, accumulated work experience in each sector-occupation, the number of children under the age of 6 and the previous period's choice.

[32] To circumvent the "curse of dimensionality," we adopt an approximation method in which the Emax functions are expressed as a parametric function of the state variables using methods developed in Keane and Wolpin (1994, 1997). In particular, the Emax functions are calculated at a subset of the state points and their values are used to fit a linear-in-parameters regression approximation in the state variables. As in Keane and Wolpin, the multivariate integrations necessary to calculate the expected value of the maximum of the alternative-specific value functions at those state points are performed by Monte Carlo integration over the shocks. In this case, the integrations are performed both over idiosyncratic shocks and aggregate shocks.

calculate aggregate skill levels in each sector-occupation.

4. Given aggregate skill supplies, equate the marginal product of capital in each of the two sectors to the rental price of capital, which is data. Using these two equations and the two production functions (1) with actual output in the two sectors as the left-hand side quantity, solve the four equations for the optimal capital input in each sector and for the two aggregate shocks, say $(z_1^j)^1$. The marginal product of the aggregate skill quantities, evaluated at the levels calculated in step 3 and at the capital stocks and aggregate shocks calculated in step 4 will in general differ from the initial guesses.

5. Update the initial guesses for the skill rental prices to be equal to the marginal products of aggregate skill, say to $(r_1^j)^1$. Repeat steps 3 and 4, using $(r_1^j)^1$ as the guess in step 3, until the sequence of skill rental prices and aggregate shocks converge, say to $(r_1^j)^*$ and $(z_1^j)^*$.

6. Guess an initial set of values for period two rental prices, say $(r_2^j)^0 = (r_1^j)^*$, for j=1,..,6. Repeat 3 and 4 for t = 2 to obtain $(r_2^j)^*$ and $(z_2^j)^*$.

7. Repeat step 6 for t = 3,.....,T.

8. Using the calculated series of equilibrium skill rental prices and aggregate shocks, estimate (2), the VAR governing aggregate shocks, and (10), the process governing the equilibrium skill rental prices.

9. Using these estimates, repeat 2-8 until the series of skill rental prices and aggregate shocks converge.

III. Estimation Method:

The solution of the model serves as input into the estimation procedure. Estimation is by simulated method of moments (SMM). Specifically, a weighted average distance between sample moments and simulated moments is minimized with respect to the model's parameters.[33] The weights are the inverses of the estimated variances of the moments. The procedure requires a choice of moments.

The data moments come from the several sources used in the previous tables. The March Current Population Surveys (CPS) over the period 1968-2001 and the National Longitudinal

[33] We describe the weighting procedure in Appendix A.

Surveys 1979 youth cohort (NLSY79) over the period 1979-1993 provide information on life cycle employment and schooling choices and on wages, various U.S. Censuses from 1910-1960 as well as the CPS provide information on the age 16 (initial) schooling distributions over time and on the preschool children process, and the Bureau of Economic Analysis provides data on sectoral capital stocks and on output from 1947-2000.[34, 35]

The simulated moments are generated for any given set of parameters and the derived series of equilibrium rental prices and aggregate shocks by simulating the behavior of samples of 800 individuals per cohort starting from cohorts that turned age 16 in 1919, and thus will be age 65 in 1968, and ending with cohorts that turned age 16 in 2000. Cross sectional simulated moments therefore contain 40,000 observations. Simulated moments weight each cohort by their representation in the population of 16 to 65 year olds.

The 33 years of CPS data span cohorts born as early as 1903 and as late as 1984 during some period of their lifetimes between the ages of 16 and 65. Although the CPS can be used to calculate the choice distributions for those cohorts and ages, being primarily a cross-sectional data set, it does not contain a history of employment choices that would enable the calculation of work experience.[36] The NLSY79 is a longitudinal data set surveying cohorts born from 1957-1964 annually from 1979 to the present. We use the NLSY79 data to calculate moments that represent or are conditioned on occupation- and sector-specific work experience.

---

[34] The aggregate capital stock is available from the same source starting in1929. The rental price of capital, to which the marginal product of capital in each sector is equated (see equation (8), is calculated from BEA data as the ratio of real capital income to the capital stock.

[35] Combining CPS data on wages and BEA data on capital and output without adjustment would lead to potential biases in the estimates of factor shares in GDP for two reasons. First, national income (NI) and GDP differ by the level of business taxes. To accommodate this difference, we deflate the previously defined “gross”skill rental price for each sector-occupation by the ratio of NI to GDP. This adjustment assumes that labor and capital share equally in taxes. Note that the marginal product of skill for each sector-occupation is still set equal to its “gross” rental price, although individuals only receive the net rental price as disposable income. Second, wages do not reflect total labor compensation. We augment CPS wages with BEA data on non-wage benefits in carrying out the estimation.

[36] We also use matched March CPS data in the estimation (see below).

In the model, sector-occupation-specific employment and schooling choices are mutually exclusive. In the estimation of the model, the decision period is assumed to be annual. To accommodate the fact that individuals do not necessarily engage in the same activity over an entire calendar year, the choice variables are defined according to the following hierarchical rule:

1. An individual is assigned to the school attendance alternative if they reported that schooling was their major activity during the survey week (CPS) or if they were attending school as of May 1 of the calendar year (NLSY79).

2. The work alternative is assigned to those not attending school who worked at least 39 weeks and at least 20 hours per week during the calendar year. When the individual is assigned to the work category, their industry and occupation is that of the job held during the year (CPS) or on the most recent job (NLSY79). The (hourly) wage is based on the same job assignment.

3. An individual who is neither attending school nor at work is assigned to the home category.

The data moments actually employed in estimation together with the data source are as follows:

1. <u>Career Decisions</u>:

CPS Data:

a. The proportion of individuals choosing each of the eight alternatives by year (1968-2000), age (16-65) and sex.

b. The proportion of individuals choosing each of the eight alternatives by year, sex and schooling level (four categories: high school dropout, high school graduate, some college, college graduate).

c. The proportion of individuals choosing each of the eight alternatives by year, sex, and by whether a preschool child is present.

NLSY79 Data:

a. The proportion of individuals choosing each of the eight alternatives by age (16-30), sex and initial schooling level at age 16 (<=9, >9).[37]

b. The proportion of individuals choosing each of the six work alternatives by experience (0, 1, 2, 3, 4+), sector-occupation and sex.[38]

2. Wages:

CPS Data:

a. The mean, median, and 10th and 90th percentiles of the log hourly real wage by the six sector-occupation categories, year and sex.[39]

b. The mean, median, and 10th and 90th percentiles of the log hourly real wage by highest grade completed, year and sex.

c. The mean log hourly real wage by year, age and sex.

d. The mean one-year difference in the log hourly real wage by current and one-year lagged sector-occupation and by sex.

e. The mean one-year difference in the log hourly real wage by age, current sector-occupation and sex.

NLSY79 Data:

a. The mean log hourly real wage by work experience (0, 1, 2, 3, 4+ years), sector-occupation and sex.[40]

3. Schooling:

CPS Data:

a. Distribution of highest grade completed by year, age and sex.

4. Career Transitions:

---

[37] 32 percent of the NLSY97 respondents (weighted) have completed less than 10 years of schooling at age 16.

[38] The sample is restricted to those respondents less than 18 years old in 1979, current age at least 18 and who are working.

[39] We also allow for log-normally distributed measurement error in the reported hourly wage rate.

[40] By assumption youths have zero work experience at age 16. We also assumed that youths who were age 17 or 18 in 1979 also had zero years of work experience.

CPS Data:

a. One-period joint transitions between the eight alternatives by year (1968-2000) and sex.[41]

b. One-period joint occupation, school and home transitions by age and sex.

c. One-period joint sectoral, school and home transitions by age and sex.

NLSY79 Data:

a. Distribution of years of work experience in each sector for individuals between the ages 29 to 31 and years 1990-1993.

b. Distribution of occupation-specific work experience for individuals between the ages 29 to 31 and years 1990-1993.

c. Distribution of the number of years of not working for individuals between the ages 29 to 31 and years 1990-1993, by sex.

5. Sector-specific capital : By year (1961-2000).

IV. Results:

Parameter Estimates

The parameter estimates and their standard errors are shown in appendix table A.1.[42, 43] A

---

[41] A number of years are missing because identifiers that match households between two years are not available. The missing transitions are between 1971 and 1972, 1972 and 1973, 1976 and 1977, 1985 and 1986, and 1995 and 1996.

[42] Heuristically, identification is achieved by a combination of functional form and distributional assumptions, along with exclusion restrictions. In terms of the latter, production function parameters are identified because current and past cohort sizes and rental prices of capital, assumed exogenous, are valid instruments for input levels. Identification of the wage offer parameters follows from standard selection correction arguments, namely from distributional assumptions and from the existence of variables that affect choices (variables in the utility function such as numbers of children) that are not in the wage offer function. Identification of utility function parameters follows from the existence of variables in the wage function that do not enter the utility function, for example, sector-specific work experience.

[43] We do not estimate the (subjective) discount factor, which, in prior partial equilibrium structural estimation problems, has proven difficult to pin down. It is instead fixed at .95, a 5 percent discount rate, which is close to the implied interest rate given that the rental price of capital (relative to the price of capital) in the data is .15 and given a 10 percent annual

number of normalizations are necessary because skill is not observable, but must be inferred from wages. As a result, the constant terms in the skill production functions cannot be disentangled from the level of skill rental prices (see (5)). The normalization we adopt is that the type-weighted average of skill endowments (in each sector-occupation skill production function) for males with initial schooling of less than 10 years is zero.[44] Thus, the levels of skill rental prices across occupation-sectors cannot be compared, although their changes over time are identified. For the same reason, aggregate levels of sector-occupation-specific skill are not comparable, which implies that the factor share parameters in the aggregate sector production functions ($\alpha^j_{1t}, \alpha^j_{2t}, \lambda^j_t$) are relative to these normalizations. The non-pecuniary benefit associated with white-collar employment in the goods sector is also normalized to zero (for both males and females). Thus, the non-pecuniary benefits of working in all other sector-occupations as well as the consumption values of schooling and home are relative to this normalization.

We discuss those parameters that are related specifically to the demand and supply factors discussed above.

1. Production function parameters:

We find there to be skill-biased technological change in both sectors.[45] In each sector, both the marginal product of the composite (white-collar-capital) input and the marginal product of the white-collar skill in the composite are increasing (the former because $\alpha^j_{21} + \alpha^j_{22} < 0$ and $\alpha^j_{11} + \alpha^j_{12} < 0$, and the latter because $\lambda^j_t > 0$). Hicks-neutral technological change (combined with product price changes) also exhibits a trend break around 1980, with the growth in value of service sector output (net of input changes) exceeding that of goods-sector output throughout the entire 1968-2000 period, although the growth was lower after 1980 than before. The elasticity of substitution between capital and white-collar skill (0.991 in the service sector and 1.13 in the goods sector) is less than that between the composite capital-white-collar skill and the pink- or

---

depreciation rate.

[44] We estimate the model with five types, having found improvements in fit over four or fewer types.

[45] This is consistent with the finding in Heckman, Lochner and Taber (1998), although their formulation of skill classes is by education rather than occupation.

blue-collar skill (1.35 in the service sector and 1.21 in the goods sector) in both sectors. Although it generally has been found in the literature, as here, that capital is more complementary to skilled labor than to unskilled labor, actual estimates of the substitution elasticity among occupations are extremely varied (Hamermesh, 1986).

2. Utility parameters:

The value of the home alternative is 23 percent higher for women than for men who have no children under the age of six, but is 3 time higher in the presence of a child under the age of 6. The value of home time increases for men between 1960 and 1980 and declines between 1980 and 2000. For women, the value of home time is decreasing throughout the period, at about the same amount per year before and after 1980.

3. Skill production functions:

Within each sector, schooling generally increases white-collar skill the most in both sectors. Composite work experience increases each sector-occupation specific skill at a decreasing rate. The standard deviation of the skill shock is increasing over time for each sector-occupation, though at different rates.

Model Fit: Figures 1-12 consider the model's ability to match the facts presented in tables 1-5. Corresponding to table1, the first two figures show the fit of the model to the overall wage distribution. The model captures the level and the relative constancy of the mean and median wage up to 1980, the rise in the mean and median from 1981 to 1994, and their faster rise from 1994 to 2000 (figure 1). The model also mimics the increase in wage dispersion as measured by the log of percentile ratios (figure 2), but, as seen in figure 3, the model understates the overall dispersion (noc-act vs. noc-pred) as measured by the standard deviation of the log wage as well as its increase. However, as also shown in figure 3, the fit to the residual dispersion based on the log wage regression (2) in table 2 (c-act vs. c-pred), although still understating the level, actually slightly overstates the increase. Thus, the model does capture both the increase in overall and residual wage inequality reasonably well.

As figure 4 shows, the model also captures the level and pattern of wages across schooling groups (see table 3). The model fits the slight U-shape for high school graduates, except for overstating the increase after 1994 a bit. The fit is slightly less good for college graduates, understating, in particular, the decline up to 1980. The overall increase in employment rates for both schooling groups is, as seen in figure 5, also captured well, although it is a few percentage points too high for high school graduates up to 1980. Figure 6 shows the fit of the ratio of college graduates to high school graduates. The model does well in capturing the overall increase, but not the more rapid increase since 1994.

Figure 7 graphs the actual and predicted college graduate to high school graduate wage ratio (the college wage premium) and their relative employment (the ratio of employed college graduates to employed high school graduates). The model does not capture the decline in the premium up to 1980 (table 3). The ensuing increase is captured quite well, except that the flattening out that occurred after 1994 is predicted to be at too low a level. The increase in the relative employment ratio, as seen in the right-hand side of figure 7, which, as noted is driven by the increase in the number of college graduates relative to high school graduates is predicted well by the model.

Differences between actual and predicted median wages of males and of females are small, as seen in figure 8, being only about 1 percent on average. Similarly, the model closely parallels the changes in employment rates for males and females, capturing the u-shape for the former and the steady rise for the latter (figure 9). As seen in figure 10, the actual and predicted median wage of females relative to males is closely matched, although the model predicts a slight increase in the ratio between 1968 and 1980, when it was instead essentially constant. The overall rise in the female-male employment ratio is matched well, except that the model overstates the attenuation in the increase that occurred starting in the mid 1980's. Finally, as seen in figures 11 and 12, the model also mimics the sector-specific changes in median wages, the declining service-sector share of capital before 1980 and increase thereafter, and the steady rise in the service sector share of employment over the entire 1968-200 period.

V. Discussion:

Accounting for Wage and Employment Changes:

To quantitatively assess the relative importance of demand and supply factors in accounting for wage and employment changes over the 1968-2000 period, we perform the following thought experiment. Suppose the world had stopped changing after 1960 in terms of demand and supply factors - that is, there was no further Hicks-neutral or skill-biased technological change, no further changes in fertility rates, in the value of leisure, in the rental price of capital or in the variance in skill shocks.[46] Compared to that world (the 1960 base), how would the U.S. labor market have evolved under alternative scenarios in which some of these factors changed as they did in actuality and others did not change, and how would those new worlds differ from what actually happened (as predicted by our model).

We consider eight counterfactual scenarios relative to the 1960 base: (1) cohort sizes and the fertility transition process change; (2) the value of leisure changes; (3) both (1) and (2); (4) the variance in sector-occupation skill shocks change; (5) the rental price of capital changes; (6) there is both Hicks-neutral (coupled with product price) change and skill-biased technological change; (7) there is only Hicks-neutral technological change (output in the two sectors are set at the levels in (6)); (8) there is only skill-biased technological change (output follows a balanced growth path and GDP in each year is set at the levels as in (6)). Tables 6-11 shows the results of these counterfactual experiments for equilibrium outcomes over the 1968-2000 period related to the previously documented changes in wage inequality, the college premium, female-to-male relative wages and employment and service-to-goods sector relative employment.[47]

The first column, the 1960 base, serves as the norm for the counterfactual experiments. For most of the outcomes, fixing fundamentals (technology, preferences, etc.) at their1960 values yields something close to stationarity - thus, dividing the simulated outcome in each period by the 1968-1974 outcome would give a value of 1.0 in each period, as in the tables.[48] All

---

[46] Because the fertility rate was higher in 1960 than subsequently, the population growth rate is faster in the 1960 baseline economy than in actuality.

[47] All counterfactual experiments and the 1960 base resolve for the equilibrium skill rental price process.

[48] The lack of stationarity arises for the following reason. In the 1960 base, the simulated state variables differ for each cohort in 1960 because the model is non-stationary. As we simulate forward one year, the 65 year olds are replaced with the 64 year olds (and a cohort of 16 year olds, with the same state variable distribution as the 16 year olds in 1960, is added). The 64 year olds have a different state variable distribution, for example, of schooling and work experience, than did the 65 year olds and so the population distribution of state variables that governs the equilibrium changes. Stationarity would be achieved after 50 years. Because we

of the counterfactual experiments as well as the baseline simulation of the economy at the estimated parameters (column 2) are normalized to 1.0 in the 1968-1974 period. Thus, all comparisons are with respect to percentage changes since the 1968-1974 period.

Wage Inequality

Table 6 considers the determinants of the changes in overall wage inequality as measured by the log of the ratio of the 90th to the 10th percentile of the hourly wage. As seen in the baseline, between the 1968-1974 and 1994-2000 periods, this measure of inequality grew by 18 percent relative to the 1960 base.[49] The first three counterfactual experiments, changes in supply factors, that is, in cohort size, in fertility (that is, in the number of young children in the household) and in the value of home time, indicate that those changes by themselves (counterfactual (3)) would have led to a 7 percent reduction in wage inequality. The fourth counterfactual (4), that allows for increases in the variance in sector-occupation skill shocks, would account for 15 of the 18 percent increase if that were the only change, while the sixth counterfactual (6), which allows for both Hicks-neutral and skill-biased technological change, would have accounted for 14 of the 18 percent increase.[50] Of the two, (7) and (8) imply that it is skill-biased technological change that was most important in generating rising wage inequality. Changes in the capital rental price, as seen in counterfactual (5), had no effect on inequality.

Although, according to our estimates, technological change and increasing skill variance would each have been sufficient to cause almost the entire increase in overall inequality, technological change played a much smaller role in the increase in residual wage inequality. As seen in table 7, the entire 35 percent increase in residual inequality can be accounted for solely by increasing skill variance. Changes in technology, on the other hand, can account for only 5 of

---

divide all of the within-period outcomes of the baseline and the counterfactuals by the values obtained for the 1960 base for the same period, we set column 1 equal to 1.0 in all periods. Thus, the baseline and counterfactuals are net of 1960 base changes over time that arise because of the lack of stationarity.

[49] The actual growth was 14 percent, which is lower than the figure in the table because of the non-stationarity in the 1960 base.

[50] Clearly, these effects are not additive, as will be evident in later tables as well.

the 35 percent increase (experiment (6)).

The College Wage Premium and the Number of College Graduates

As seen in table 8, the growth in the college premium seems to have been solely a technology driven outcome. Neither supply side factors, increasing skill variance, nor changes in the capital rental price can account for any significant portion of the 28 percent increase that would have occurred if the world had been unchanged after 1960. Moreover, as seen in comparing experiments (7) and (8), skill-biased technological change was considerably more important than Hicks neutral change.

Table 9 reveals that changes in the educational attainment of the workforce, as measured by the ratio of the number of employed college graduates to the number of employed high school graduates, was also mostly a demand-driven phenomenon. Of the 233 percent increase that would have occurred, supply-side factors would have caused only an 8 percent increase. Technological innovation, on the other hand, by itself, would have accounted for a change of 149 percent, with both skill-biased technological change and Hicks-neutral change of similar consequence.

Female-Male Wages and Employment

As revealed in tables 10 and 11, a number of factors played a role in the increased relative wages and employment of women. Changes in the value of home time, by itself, would have accounted for 12 of the 24 percent increase in the female-to-male wage ratio and 24 of the 84 percent increase in the female-to-male employment ratio. All of the supply side factors taken together (experiment (3)) would have caused a 17 percent increase in relative wages and an 81 percent increase in relative employment. Dynamics are important here. The fall in women's value of leisure that was estimated in the model to have occurred induces women to invest more heavily in market skills, given that they anticipate spending a larger proportion of their lifetime in the labor market. Thus, they obtain more schooling and more work experience, both of which raise their wage absolutely and relative to men. Thus, unlike in a static model, an increase in the supply of women to the workforce can raise the relative wage of women. However, given that male and female skill within sector-occupations are perfect substitutes, male wages actually would have fallen because of the overall increase in labor supply.

Increases in sector-occupation skill shock variances and technological innovation would have each, by themselves, accounted for a significant part of the increase in relative wages, 14 and 13 percent of the 24 percent increase, respectively. They also would have played similar roles in accounting for the increased relative employment of women, respectively 25 and 24 percent of the 84 percent increase. Hicks-neutral and skill-biased technological change were about equally significant in accounting for these gender differences.

There are only two ways in which the female-male wage gap can change, given the model. One way is through differential changes in skill accumulation and the other is through selection into employment, and more specifically, into particular sector-occupations.
One can disentangle the two by looking at wage offers rather than accepted wages. A summary statistic for wage offers is the maximum offer over the six-sector-occupations. It turns out that the female-male (maximum) offered wage ratio, as estimated by the model, was .52 in the 1968-1974 period and rose to .65 in the 1995-2000 period, almost identical to the increase in accepted wages (see table 4).[51] Note, however, that because of work-occupation-sector selection, the gender gap is larger in offered wages than in accepted wages.

Service-Goods Sector Employment

Sectoral differences in Hicks-neutral technological change was the predominant factor in the relative growth in service sector employment, as seen in table 12 (experiment (7)), accounting for 73 of the 77 percent increase in the ratio of service-to-goods sector employment. Coupled with skill-biased technological change in the two sectors (experiment (8)), such change would account for (more than) the entire increase (experiment (6)). However, changes in the value of home time, which as seen would have induced women to enter the labor force, by itself, would also account for some of the sectoral employment change, 16 of the 77 percent increase.

VI. Conclusions:

The U.S. labor market looks very different today than it did 30 years ago. In this paper, we have shown that a competitive equilibrium model of the labor market can provide a coherent

[51] This finding is contrary to that of Mulligan and Rubinstein (2005) who argue from a standard static selection model that the closing of the gender wage gap is in no small part due to the changing composition of female workers.

explanation for the major labor market changes that occurred over that period. Based on estimates of the model structure, we performed simulations that compared today's world to what the world would have looked like if no fundamentals (technology, preferences and exogenous forcing variables) had changed since 1960. Based on this comparison, we quantitatively assessed the relative importance of demand and supply factors responsible for the differences that emerged.

The two-sector (services and goods) model that we postulated allowed for both sector-specific Hicks- neutral and skill-biased technological change. Our results demonstrated that they played different roles. Hicks-neutral technological change was especially important in accounting for the growth in service sector employment and skill-biased technological change was especially important in accounting for the increase in the college wage premium and the overall increase in wage inequality. However, the two played more equal roles in accounting for other phenomena, namely the increasingly more educated workforce, the narrowing of the gender wage gap and the increased feminization of the workforce. Supply side considerations, namely changes in fertility and in the value attached to home time, were of major significance in accounting for female-male wage and employment changes, were of less, but not negligible, importance in explaining the relative growth in service sector employment, but did not seem to be important in accounting for other changes. The labor market would have looked quite different than it does today, but in different ways, if either demand or supply-side factors had changed in isolation.

References:

Altug, S. and R. A. Miller. (1998): "The Effect of Work Experience on Female Wages and Labour Supply." Review of Economic Studies, 65, 45-85.

Autor D.H., L. F. Katz, and Kearney, M. (2004): "Trends in Wage Inequality: Re-Assessing the Revisionists." mimeo.

Baldwin, R. E. And G. Cain. (1997): "Shifts in Relative Wages: The Role of Trade, Technology and Factor Endowments," NBER working paper 5934.

Ben-Porath, Y. (1967): "The Production of Human Capital and the Life Cycle of Earnings." Journal of Political Economy, 75, 352-65.

Bound, J. and G. Johnson. (1992): "Changes in the Structure of Wagesin the 1980's: An Evaluation of Alternative Explanations." American Economic Review, 82, 371-92.

Card, D. and J.E. DiNardo. (2002): "Skill Biased Technological Change and Rising Wage Inequality: Some Problems and Puzzles." Journal of Labor Economics, 20,733-83.

Eckstein, Z. and Nagypal, E. (2004): "The Evolution of U.S. Earnings Inequality: 1961-2002." Federal Reserve Bank of Minneapolis Quarterly Review, 28, 10-29.

Fuchs, V. R. (1968): The Service Economy. New York: National Bureau of Economic Research.

__________. (1980): "Economic Growth and the Rise of the Service Sector." Working paper no. 486, National Bureau of Economic Research.

Gottschalk , P. and R. Moffitt. (1994): "The Growth of Earnings Instability in the U.S. Labor Market." Brookings Papers on Economic Activity 2, 217-72.

Griliches, Z. (1977): "Estimating the Returns to Schooling: Some Econometric Problems." Econometrica, 45, 1-22.

Hornstein, A., P. Krusell, and Violante, G.L. (2004): "The Effects of Technical Change on Labor Market Inequalities." mimeo.

Heckman, J. J., L. Lochner and C. Taber. (1998): "Explaining Rising Wage Inequality: Explorations with a Dynamic General Equilibrium Model of Labor Earnings with Heterogeneous Agents." Review of Economic Dynamics 1, 1-58.

__________ and G. Sedlacek. (1985): "Heterogeneity, Aggregation, and Market Wage Functions: An Empirical Model of Self-Selection in the Labor Market." Journal of

Political Economy 93, 1077-1125.

Juhn, C., K. M. Murphy and B. Pierce. (1993): “Wage Inequality and the Rise in Returns to Skill.” Journal of Political Economy, 101, 410-42.

Katz. L. F., and D. H. Autor. (1999): “Changes in the Eage Structure and Earnings Inequality.” In O. Ashenfelter and D. Card, eds. Handbook of Labor Economics, Vol. 3, 1463-1555, Amsterdam: North Holland.

__________ and K. M. Murphy. (1992): “Changes in Relative Wages, 1963-1987: Supply and Demand Factors.” Quarterly Journal of Economics, 107, 35-78.

Keane, M.P. and K. I. Wolpin. (1994): "The Solution and Estimation of Discrete Choice Dynamic Programming Models by Simulation and Interpolation: Monte CarloEvidence." Review of Economics and Statistics 76, 648-672.

__________ and K. I. Wolpin. (1997): “Career Decisions of Young Men.” Journal of Political Economy 105, 473-522.

Krusell, P. and A. A. Smith, Jr. (1998): “Income and Wealth Heterogeneity in the Macroeconomy.” Journal of Political Economy, 106, 867-896.

Krusell, P., L. E. Ohanian, V. Rios-Rull and G. L. Violante. (2000): “Capital-Skill Complementarity and Inequality: A Macroeconomic Analysis.” Econometrica 68, 1029-1054.

Lee, D. (2005): “An Estimable Dynamic General Equilibrium Model of School, Work and Occupational Choice.” International Economic Review, 46, 1-34.

__________ and K. I. Wolpin. Intersectoral Labor Mobility and the Growth of the Service Sector.” Econometrica., 74, 1-46.

Murphy, K. M. And F. Welch. (1992): The Structure of Wages.” Quarterly Journal of Economics 107, 285-326.

_______________. (1993): “Occupational Change and the Demand for Skill: 1940-1990” American Economic Review 83: 122-26.

Mulligan, C. And Y. Rubinstein. (2005): “Selection, Investment and Women’s Relative Wages Since 1975.” NBER working paper no. 11159.

Welch, F. (2000): "Growth in Women's Relative Wages and in Inequality among Men: One Phenomenon or Two." American Economic Review, 90, 444-449.

Willis, R. J. (1986): "Wage Determinants: A Survey and Reinterpretation of Human Capital Earnings Functions." in O. Ashenfelter and R. Layard (eds.) Handbook of Labor Economics Vol. 1: 525-602. Amsterdam: North Holland.

Willis, R. J. and S. Rosen. (1979): "Education and Self-Selection." Journal of Political Economy 87, S7-S36.

Appendix A

We provide details of the weighting procedure. The moments we use in estimation are aggregates of individual decisions and outcomes. For ease of presentation, consider the following set: (1) the proportion of men who work at each age from 16-65 at calendar time t; (2) the same as (1) for women; (3) the mean wage corresponding to the sample in (1); (4) the mean wage corresponding to the sample in (2). There are 50 moments, one for each age, in each of the four categories. We denote by k=1,..., 50 the kth moment and by j = 1,..,4, the jth category. Further, denote by N_{kj} the number of individuals that comprise the kth moment in the jth category, by n_j (=50) the number of moments in the jth category, and let x_{ikj} be the ith observation of the k-jth moment. The observations comprising each k-jth sample moment differ. For example, although the observations in the kth moment of j = 1 contain those in the corresponding kth moment of j=2, they are not identical because not all men work. And, the observations in the kth moment of j=1 and 3 (or 2 and 4) have no overlap because they are sex-specific.

Now, define the deviation of k-jth sample moment from the true moment as

$$\text{(A.1)} \quad \overline{m}_{kj}(\theta) = \frac{\sum_{i=1}^{N_{kl}} x_{ikj}}{N_{kj}} - \mu_{kj}(\theta)$$

and $\overline{m}(\theta)$ as the vector of the (50x4=200) values of $\overline{m}_{kj}(\theta)$, where θ is the parameter vector to be estimated. The objective function for estimating θ is

$$\text{(A.2)} \quad \min_{\theta} \overline{m}(\theta)' W \overline{m}(\theta),$$

where W is a weighting matrix. Note that at the true parameter values, the sample moments differ from the population moments only because of sampling error.

We make two assumptions in forming the weighting matrix (W):

(1) W is diagonal,

(2) $E[(\overline{m}_{kj} - \mu_{kj}(\theta))^2] = \frac{\sigma_j^2}{N_{jk}}$.

The first assumption, that the off-diagonal elements of W are zero, implies, for example, that repeated samples of the same size would not lead to a correlation between the proportion of men who work and the proportion of women who work at any k and k'. While such an assumption might not be violated for observations on unmarried men and women, it is unlikely to be true for married couples. Of course, our model implicitly treats all people as if they were unmarried. As a practical matter, because the observations differ across the moments, it is not possible to estimate the off-diagonal elements.

The second assumption is that the sampling variance is the same for all of the moments within a particular category. This assumption is clearly not true. For example, for given sample size, the sampling variance for the proportion working varies with the true probability of working. Although correct weights could be calculated, very low probability events, such as attending school at age 30, would receive very high weights. To avoid that, the weights we use are (weighted) averages of the inverse of the sampling variances over all of the moments within a category, the true weights under assumption 2

We use a two-step procedure for calculating the diagonal elements of W.

1. Set $\sigma_j^2 = 1$ and weight each sample moment by N_{kj}. Estimate θ according to (A.2).
2. Update σ_j^2 according to

$$\text{(A.3)} \quad \sigma_j^2 = \frac{1}{n_j} \sum_k N_{jk} [\overline{m}_{kj}(\hat{\theta})]^2,$$

where $\hat{\theta}$ is the first-stage estimate of θ. Weight each of the k moments in category j by $\frac{N_{kj}}{\sigma_j^2}$. Estimate θ according to (A.2).

The variance-covariance matrix of the parameter estimates is given by $(G'W^{-1}G)^{-1}$ where G is the matrix of derivatives of the moments with respect to the parameters and W is the inverse of the variance-covariance matrix of the moments.

Table 1[a]
The Distribution of (Accepted) Hourly Wages: 1968-2000[a]

Period[b]	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	Mean
1968-74	4.10	5.72	8.40	11.65	15.88	9.60
1975-79	4.06	5.61	8.22	11.96	16.06	9.76
1980-84	3.98	5.57	8.21	12.17	16.61	9.99
1985-89	4.03	5.75	8.68	13.05	18.13	10.72
1990-94	4.02	5.75	8.89	13.40	19.04	11.17
1995-00	4.24	6.22	9.44	14.42	21.10	12.14

a. Real (1983) hourly wage rate.
b. Average of annual figures over the period.

Table 2
Residual Log Wage Dispersion (RMSE): 1968-2000

Period	No Regressors	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1968-1974	.542	.417	.406	.402	.344	.386	.450	.388	.406
1975-1979	.556	.439	.429	.427	.367	.407	.466	.411	.428
1980-1984	.575	.463	.451	.446	.398	.434	.481	.437	.446
1985-1989	.606	.493	.478	.458	.431	.452	.509	.466	.477
1990-1994	.626	.513	.495	.490	.461	.457	.530	.480	.487
1995-2000	.642	.527	.509	.500	.471	.472	.540	.497	.495

(1) Regressors: schooling, age, age square, gender.
(2) Regressors: schooling, age, age square, gender, occupation-sector dummies.
(3) – (8) Within each occupation-sector - regressors: schooling, age, age square, gender.

Table 3
Wages and Employment for College Graduates and for High School Graduates: 1968-2000

Period[b]	Median Wage[a] (1) College Graduate	(2) High Sch. Graduate	(1)/(2)	Employment Rate (1) College Graduate	(2) High Sch. Graduate	(1)/(2)	(1)/(2) x (#CG / #HS)[c]
1968-1974	12.01	7.92	1.52	.700	.582	1.20	.40
1975-1979	11.30	7.64	1.48	.718	.585	1.23	.51
1980-1984	11.48	7.38	1.56	.744	.591	1.26	.59
1985-1989	12.62	7.55	1.67	.772	.637	1.21	.66
1990-1994	13.17	7.49	1.76	.773	.630	1.23	.73
1995-2000	14.04	7.89	1.78	.788	.657	1.20	.84

a. Real (1983) hourly wage rate.
b. Average if annual figures over the period.
c. #CG = number of college graduates, #HS = number of high school graduates.

Table 4
Wages and Employment by Gender: 1968-2000

	Median Wage[a]			Employment Rate			
Period[b]	(1) Males	(2) Females	(2)/(1)	(1) Males	(2) Females	(2)/(1)	(2)/(1) x (#F / #M)[c]
1968-1974	10.02	5.86	.585	.721	.366	.508	.545
1975-1979	10.23	6.11	.597	.689	.399	.578	.613
1980-1984	10.31	6.37	.618	.668	.449	.673	.711
1985-1989	10.67	6.99	.655	.699	507	.725	.758
1990-1994	10.47	7.47	.714	.695	.540	.777	.803
1995-2000	10.93	8.01	.733	.728	.578	.794	.820

a. Real (1983) hourly wage rate.
b. Average if annual figures over the period.
c. #F = females, #M = males.

Table 5

Sectoral Differences in the Average Annual Percentage Change in Output, Capital, Employment and Hourly Wages

Service - Goods Growth Rate	1968-2000	1968-1980	1981-2000
Output (value in constant dollars)[a]	2.01	1.26	2.51
Capital	0.65	-0.67	1.51
Employment	2.23	2.45	2.09

a. Sector-specific nominal outputs divided by the gdp deflator.

Table 6
Accounting for the Increase in Wage Inequality: Log 90/10

Period	1960 Base	Base Line	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1968-1974	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1975-1979	1.00	0.99	1.00	1.01	1.02	1.03	1.00	1.01	1.01	1.01
1980-1984	1.00	1.06	1.00	1.01	1.01	1.06	1.00	1.03	1.01	1.03
1985-1989	1.00	1.10	0.99	1.00	0.98	1.08	0.99	1.08	1.03	1.07
1990-1994	1.00	1.14	0.99	0.98	0.96	1.12	0.98	1.11	1.03	1.10
1995-2000	1.00	1.18	0.98	0.95	0.93	1.15	0.98	1.14	1.05	1.14

(1) Actual change in cohort sizes and fertility process.
(2) Actual change in value of leisure.
(3) (1) + (2).
(4) Actual change in standard deviation of skill shock.
(5) Actual change in the rental price of capital.
(6) Actual Hicks-neutral and skill-biased technological change.
(7) Only Hicks-neutral technological change.
(8) Only skill-biased technological change.

Table 7
Accounting for the Increase in Wage Inequality: RMSE Log Wage Residual

Period	1960 Base	Base Line	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1968-1974	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1975-1979	1.00	1.08	1.00	1.01	1.01	1.08	1.00	1.00	1.00	1.00
1980-1984	1.00	1.14	1.00	1.01	1.01	1.15	1.00	1.00	1.00	1.01
1985-1989	1.00	1.20	1.00	1.02	1.02	1.22	0.98	1.01	1.01	1.01
1990-1994	1.00	1.27	1.00	1.03	1.03	1.29	0.98	1.02	1.01	1.01
1995-2000	1.00	1.35	1.00	1.03	1.03	1.36	0.98	1.05	1.02	1.04

(1) Actual change in cohort sizes and fertility process.
(2) Actual change in value of leisure.
(3) (1) + (2).
(4) Actual change in standard deviation of skill shock.
(5) Actual change in the rental price of capital.
(6) Actual Hicks-neutral and skill-biased technological change.
(7) Only Hicks-neutral technological change.
(8) Only skill-biased technological change.

Table 8
Accounting for the Increase in the College Premium

Period	1960 Base	Base Line	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1968-1974	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1975-1979	1.00	0.99	1.00	1.02	1.01	0.97	1.01	1.01	0.98	1.01
1980-1984	1.00	1.06	0.99	1.02	1.00	0.96	1.02	1.08	1.02	1.07
1985-1989	1.00	1.13	0.96	1.04	1.00	0.96	1.01	1.20	1.07	1.17
1990-1994	1.00	1.23	0.95	1.02	0.97	1.00	1.00	1.33	1.13	1.29
1995-2000	1.00	1.28	0.95	0.96	0.93	1.01	0.99	1.45	1.21	1.41

(1) Actual change in cohort sizes and fertility process.
(2) Actual change in value of leisure.
(3) (1) + (2).
(4) Actual change in standard deviation of skill shock.
(5) Actual change in the rental price of capital.
(6) Actual Hicks-neutral and skill-biased technological change.
(7) Only Hicks-neutral technological change.
(8) Only skill-biased technological change.

Table 9
Accounting for the Increase in the College/HS Employment Ratio

Period	1960 Base	Base Line	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1968-1974	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1975-1979	1.00	1.39	1.00	0.97	0.97	1.07	1.03	1.24	1.16	1.26
1980-1984	1.00	1.76	1.00	0.95	0.96	1.14	1.04	1.49	1.31	1.51
1985-1989	1.00	2.22	1.04	0.91	0.98	1.25	1.02	1.84	1.54	1.81
1990-1994	1.00	2.68	1.09	0.85	1.00	1.35	1.01	2.13	1.76	2.05
1995-2000	1.00	3.33	1.17	0.83	1.08	1.51	0.97	2.49	2.02	2.32

(1) Actual change in cohort sizes and fertility process.
(2) Actual change in value of leisure.
(3) (1) + (2).
(4) Actual change in standard deviation of skill shock.
(5) Actual change in the rental price of capital.
(6) Actual Hicks-neutral and skill-biased technological change.
(7) Only Hicks-neutral technological change.
(8) Only skill-biased technological change.

Table 10
Accounting for the Increase in the Female/Male Wage Ratio

Period	1960 Base	Base Line	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1968-1974	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1975-1979	1.00	1.03	1.00	1.01	1.01	1.02	1.01	1.01	0.99	1.01
1980-1984	1.00	1.07	1.01	1.03	1.04	1.05	1.03	1.03	1.00	1.02
1985-1989	1.00	1.13	1.02	1.07	1.09	1.08	1.02	1.07	1.01	1.03
1990-1994	1.00	1.20	1.02	1.10	1.13	1.11	1.02	1.11	1.04	1.06
1995-2000	1.00	1.24	1.04	1.12	1.17	1.14	0.99	1.13	1.07	1.08

(1) Actual change in cohort sizes and fertility process.
(2) Actual change in value of leisure.
(3) (1) + (2).
(4) Actual change in standard deviation of skill shock.
(5) Actual change in the rental price of capital.
(6) Actual Hicks-neutral and skill-biased technological change.
(7) Only Hicks-neutral technological change.
(8) Only skill-biased technological change.

Table 11
Accounting for the Increase in the Female/Male Employment Ratio

Period	1960 Base	Base Line	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1968-1974	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1975-1979	1.00	1.26	1.10	1.18	1.31	1.04	1.06	1.01	0.99	1.02
1980-1984	1.00	1.50	1.19	1.31	1.59	1.07	1.09	1.03	1.00	1.03
1985-1989	1.00	1.62	1.24	1.30	1.66	1.12	1.02	1.11	1.08	1.10
1990-1994	1.00	1.74	1.34	1.27	1.74	1.17	0.99	1.14	1.11	1.12
1995-2000	1.00	1.84	1.42	1.24	1.81	1.25	0.93	1.24	1.21	1.23

(1) Actual change in cohort sizes and fertility process.
(2) Actual change in value of leisure.
(3) (1) + (2).
(4) Actual change in standard deviation of skill shock.
(5) Actual change in the rental price of capital.
(6) Actual Hicks-neutral and skill-biased technological change.
(7) Only Hicks-neutral technological change.
(8) Only skill-biased technological change.

Table 12
Accounting for the Increase in the Service/Goods Employment Ratio

Period	1960 Base	Base Line	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1968-1974	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1975-1979	1.00	1.10	1.02	1.10	1.14	0.90	1.17	1.00	0.90	1.05
1980-1984	1.00	1.23	1.03	1.19	1.26	0.81	1.29	1.05	0.90	1.08
1985-1989	1.00	1.42	1.04	1.20	1.29	0.74	1.13	1.30	1.10	1.05
1990-1994	1.00	1.64	1.06	1.18	1.30	0.69	1.04	1.66	1.35	1.08
1995-2000	1.00	1.77	1.08	1.16	1.32	0.66	0.85	2.30	1.73	1.10

(1) Actual change in cohort sizes and fertility process.
(2) Actual change in value of leisure.
(3) (1) + (2).
(4) Actual change in standard deviation of skill shock.
(5) Actual change in the rental price of capital.
(6) Actual Hicks-neutral and skill-biased technological change.
(7) Only Hicks-neutral technological change.
(8) Only skill-biased technological change.

Table A.1

Parameter Estimates
(asymptotic standard errors in parentheses)

Production function (1)

	Services	Goods
σ	0.2614 (.0035)	0.1733 (.0021)
ν	-0.0094 (.0077)	0.1184 (.0032)
α_{10}	0.3091 (.0054)	0.0824 (.0025)
α_{11}	0.0006 (.0002)	-0.0011 (.0003)
α_{12}	-0.0024 (.0003)	0.0018 (.0005)
α_{20}	0.3443 (.0050)	0.5486 (.0115)
α_{21}	-0.0017 (.0002)	-0.0033 (.0003)
α_{22}	-0.0027 (.0003)	-0.0098 (.0005)
α_{30}	0.2535 (.0053)	0.2807 (.0068)
α_{31}	0.0022 (.0002)	0.0034 (.0003)
α_{32}	0.0048 (.0003)	0.0074 (.0005)

$\alpha_{3t} = (1 - \alpha_{1t} - \alpha_{2t}) \lambda_t$

Production Shocks (2)

	Service		Goods
ϕ_0	-0.0064		-0.0185
ϕ_G	-0.6877		-0.1573
ϕ_R	0.9243		0.2607
σ_{GG}		0.0007	
σ_{GR}		0.0004	
σ_{RR}		0.0005	

Table A.1
Parameter Estimates (continued)

Utility Parameters (3)

γ_{71}	4,761 (130)	γ_{81}	11,229 (218)
γ_{72}	10,230 (166)	γ_{82}	13,810 (136)
γ_{701}	0.66	γ_{801}	0.56
γ_{702}	0.79 (.020)	γ_{802}	1.25 (.009)
γ_{703}	1.82 (.021)	γ_{803}	0.96 (.015)
γ_{704}	1.74 (.019)	γ_{804}	1.50 (.011)
γ_{705}	0.83 (.021)	γ_{805}	0.81 (.011)

	male	female
γ_1	0	0
γ_2	-338 (54)	73 (44)
γ_3	669 (40)	535 (35)
γ_4	247 (43)	287 (37)
γ_5	153 (41)	146 (33)
γ_6	422 (41)	173 (36)
γ_{85}	-2,959 (247)	10,368 (175)
γ_{86}	436 (23)	252 (22)
γ_{87}	2,351 (181)	1,296 (99)
γ_{88}	8,231 (254)	3,526 (192)
γ_{89}	517.9 (9.8)	-17.2 (8.7)
$\gamma_{8,10}$	-242.9 (14.7)	-16.6 (11.0)
γ_9	8,556 (220)	7,087 (171)
γ_{10}	29,585 (715)	23,204 (516)
γ_{11}	33,139 (900)	24,594 (612)
$\sigma_{77}^{\varepsilon}$	11,878 (210)	11,709 (212)
$\sigma_{88}^{\varepsilon}$	17,611 (220)	10,353 (120)
γ_{12}^{1920}	0.50 (.032)	0.71 (.026)
γ_{12}^{1980}	1.16 (.034)	0.99 (.022)
γ_{12}^{2000}	0.69 (.042)	1.35 (.044)

Table A.1

Parameter Estimates (continued)

Budget Constraint (4)

β_1	14,494 (170)
β_2	12,194 (224)
β_3	4,087 (328)
δ_{jk} :	

To choice j			From choice k: 1	2	3	4	5	6	7	8
	male	1	0	11,561 (472)	3,943 (134)	607 (24)	12,168	4,551		
	male	2	9,484 (357)	0	15,924 (580)	10,091	607	16,531		
	male	3	1,541 (68)	2,190 (100)	0	2,148	2,797	607		
	male	4	12,123 (246)	24,383	17,305	0	12,259 (387)	5,181 (206)		
	male	5	18,253	12,123	31,475	6,130 (229)	0	19,351 (717)		
	male	6	13,177	14,184	12,123	1,053 (49)	2,061 (90)	0	25,673 (446)	16,094 (297)
	female	1	0	6,643 (297)	1,204 (55)	466 (21)	7,110	1,670		
	female	2	3,784 (158)	0	21,894 (1013)	4,250	466	22,360		
	female	3	521 (25)	1,308 (60)	0	988	1,774	466		
	female	4	5,859 (136)	9,530	6,627	0	3,671 (122)	768 (34)		
	female	5	9,423	5,859	11,146	3,564 (148)	0	5,287 (162)		
	female	6	6,062	6,784	5,859	203 (10)	925 (37)	0	12,498 (287)	6,528 (155)

Restrictions:
1. Cost of changing both sector and occupation is the sum of changing sectors with the same occupation and changing occupation within the sector.
2. Cost of moving from home or school to employment is independent of sector and occupation.

Table A.1
Parameter Estimates (continued)

Skill Production Functions (5)

		j = 1	2	3	4	5	6	π_h (E<=9)	π_h (E>9)
	ω_5	-0.587	-0.337	-0.403	-0.332	-0.271	-0.418		
		(.010)	(.009)	(.006)	(.006)	(.005)	(.006)		
	ω_{01}^j	-0.137	-0.960	-0.127	-0.375	-0.090	0.014	0.206	0.197
	ω_{02}^j	-0.192	-0.265	0.163	-0.060	-0.003	-0.070	0.338	0.322
		(.014)	(.042)	(.005)	(.011)	(.006)	(.007)	(.0071)	(.0074)
	ω_{03}^j	0.600	0.497	0.134	0.242	0.050	0.114	0.141	0.134
		(.012)	(.022)	(.012)	(.009)	(.013)	(.010)	(.0050)	(.0051)
	ω_{04}^j	-0.030	0.674	-0.224	0.246	-0.007	0.030	0.188	0.167
		(.018)	(.016)	(.014)	(.009)	(.012)	(.012)	(.0046)	(.0055)
	ω_{05}^j	0.110	0.710	-0.047	0.136	0.108	-0.005	0.126	0.181
		(.011)	(.016)	(.012)	(.009)	(.007)	(.012)	(.0058)	(.0051)
	ω_{11}^j	0.041	0.025	0.027	0.070	0.022	0.044		
		(.0005)	(.0006)	(.0007)	(.0010)	(.0006)	(.0007)		
	ω_{12}^j	-0.030	-0.254	-0.107	-0.810	-0.003	-0.019		
		(.012)	(.016)	(.008)	(.024)	(.009)	(.009)		
	ω_{13}^j	0.128	0.034	-0.288	0.043	0.161	0.115		
		(.008)	(.010)	(.022)	(.007)	(.009)	(.008)		
	ω_2^{jk}								
k	1	0.0698	0.0392	0.0209	0.0137				
		(.0017)	(.0015)	(.0007)	(.0004)	0.0077	0.0041		
	2		0.0227	0.0121					
		0	(.0007)	(.0004)	0	0.0045	0.0024		
	3			0.0289					
		0	0	(.0007)	0	0	0.0057		
	4	0.0117			0.0779	0.0287	0.0088		
		(.0003)	0.0043	0.0013	(.0016)	(.0008)	(.0004)		
	5					0.0310	0.0019		
		0	0.0047	0.0003	0	(.0007)	(.0001)		
	6						0.0540		
		0	0	0.0081	0	0	(.0012)		
	ω_3	0.446	0.567	0.465	0.461	0.490	0.486		
		(.013)	(.024)	(.013)	(.013)	(.015)	(.015)		
	ω_4	0.023	0.016	0.022	0.019	0.019	0.016		
		(.0007)	(.0006)	(.0006)	(.0005)	(.0006)	(.0006)		
	$\sigma_{\eta,0}$	0.231	0.171	0.213	0.138	0.169	0.270		
		(.008)	(.006)	(.006)	(.005)	(.005)	(.007)		
	$\sigma_{\eta,1}$	0.637	0.386	0.560	0.549	0.467	0.584		
		(.010)	(.010)	(.010)	(.009)	(.009)	(.010)		

Retirement process (6)

	$\omega^2_{5,0}$	$\omega^1_{5,0}$	$\omega^2_{5,1}$	$\omega^1_{5,1}$
male	0.163 (.007)	0.867 (.005)	0.110 (.004)	0.105 (.004)
female	0.921 (.003)	0.954 (.002)	0.193 (.007)	0.279 (.009)

Fig. 1: Actual and Predicted Wage Distribution Statistics
1968-2000

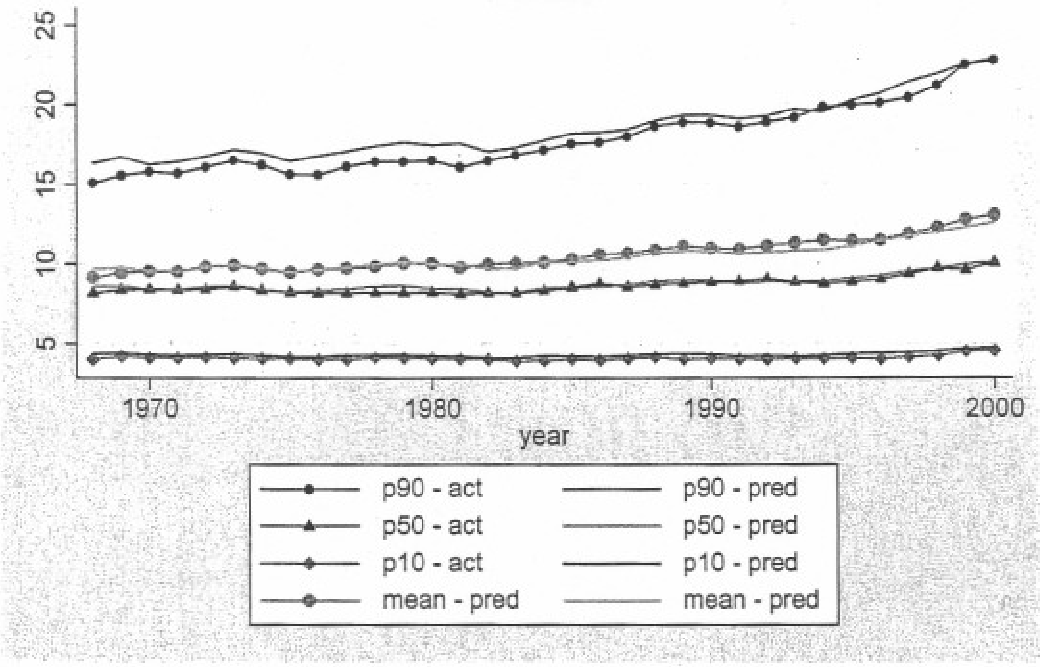

Fig. 2: Actual and Predicted Spread of the Wage Distribution
1968-2000

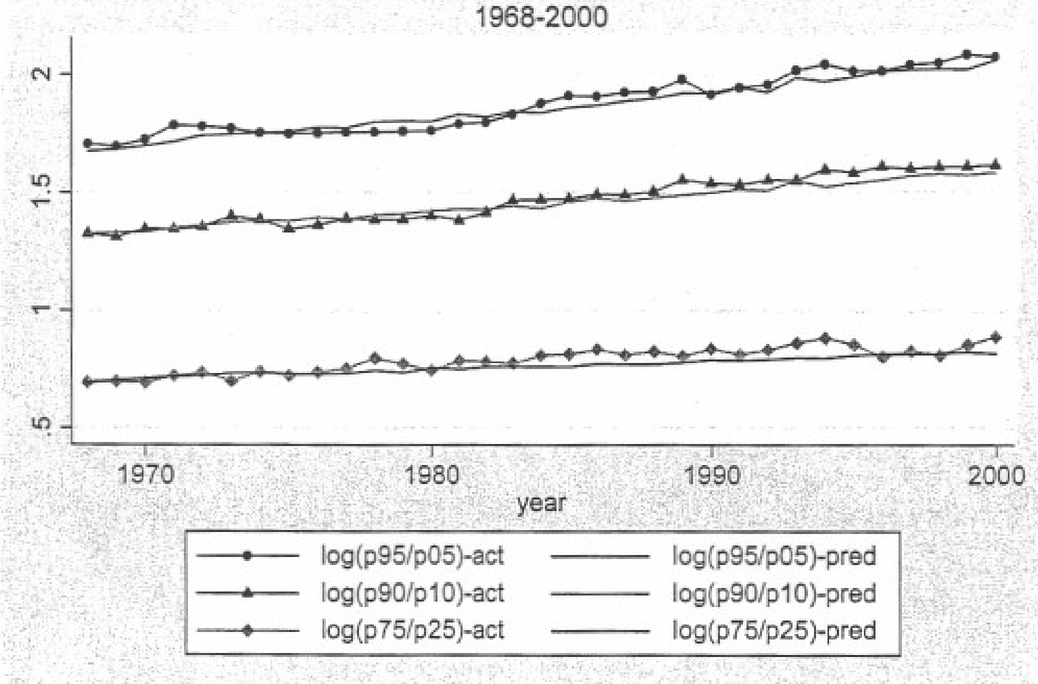

Fig. 3: SD Log Wage
1968-2000

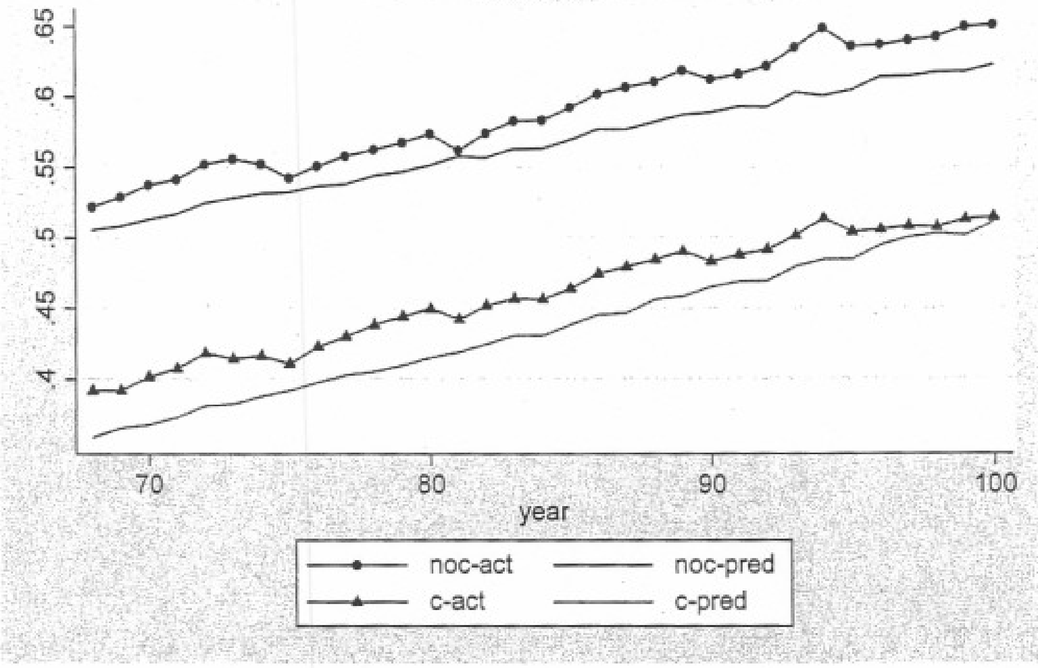

Fig. 4: Actual and Predicted Median Wages by Schooling
1968-2000

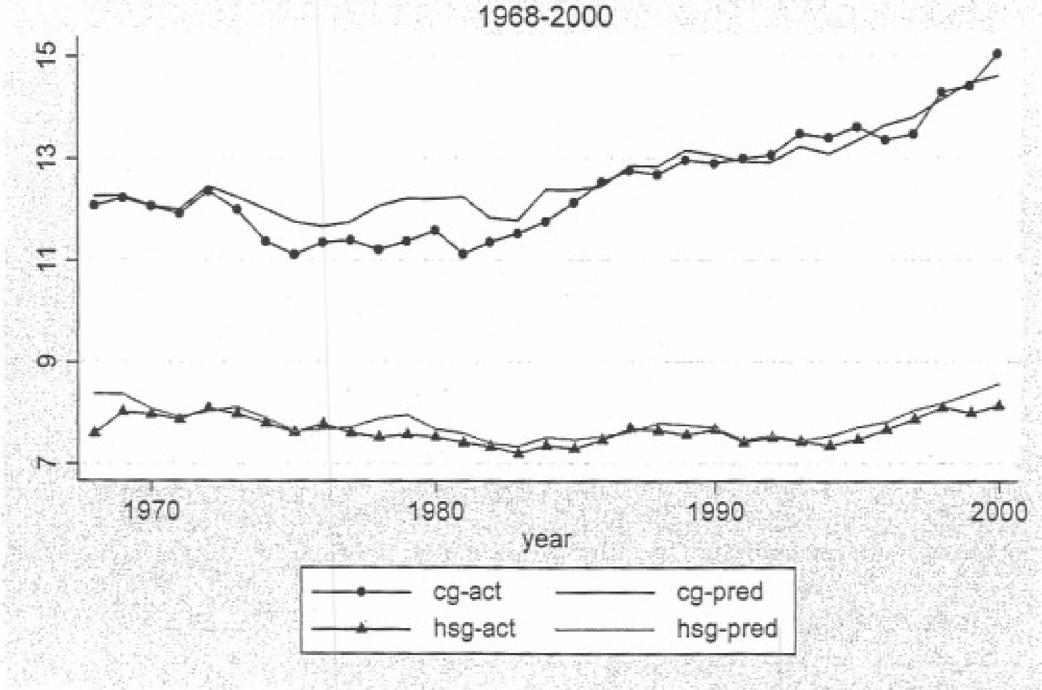

Fig. 5: Actual and Predicted Employment Rate by Schooling

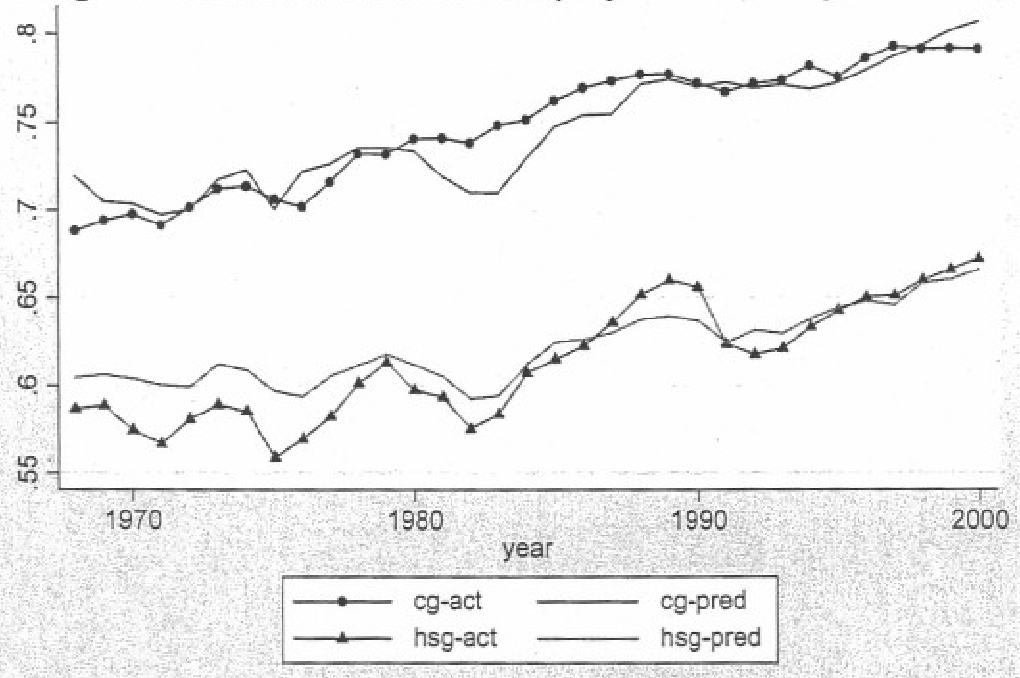

Fig. 6: Actual and Predicted College/HS Ratio
1968-2000

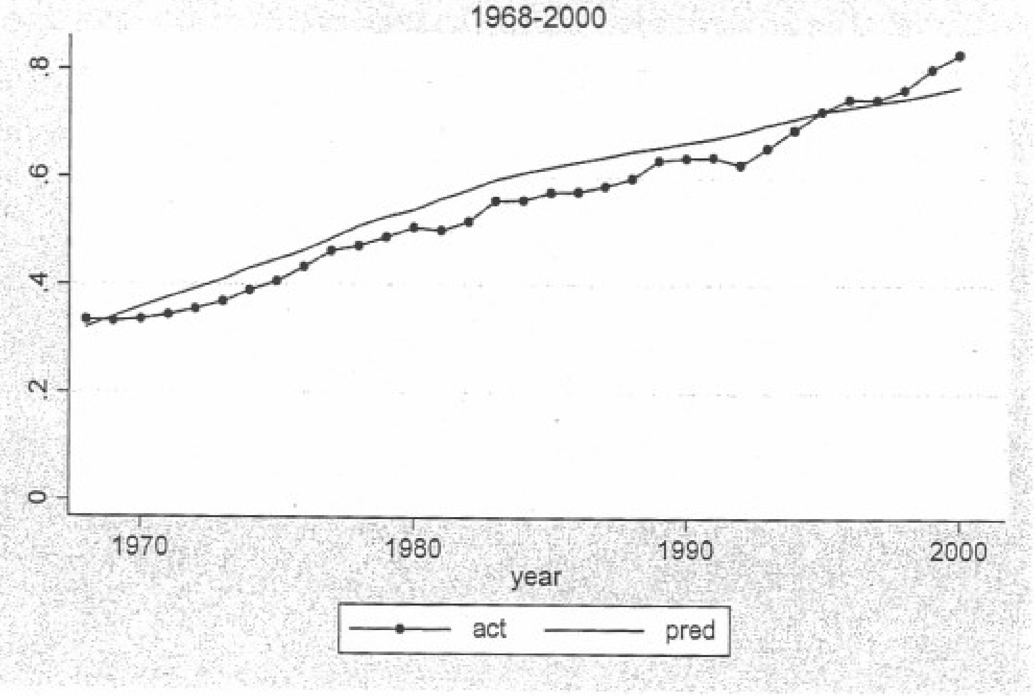

Fig. 7: Actual and Predicted College/HS (Median) Wage and Employment Ratio
1968-2000

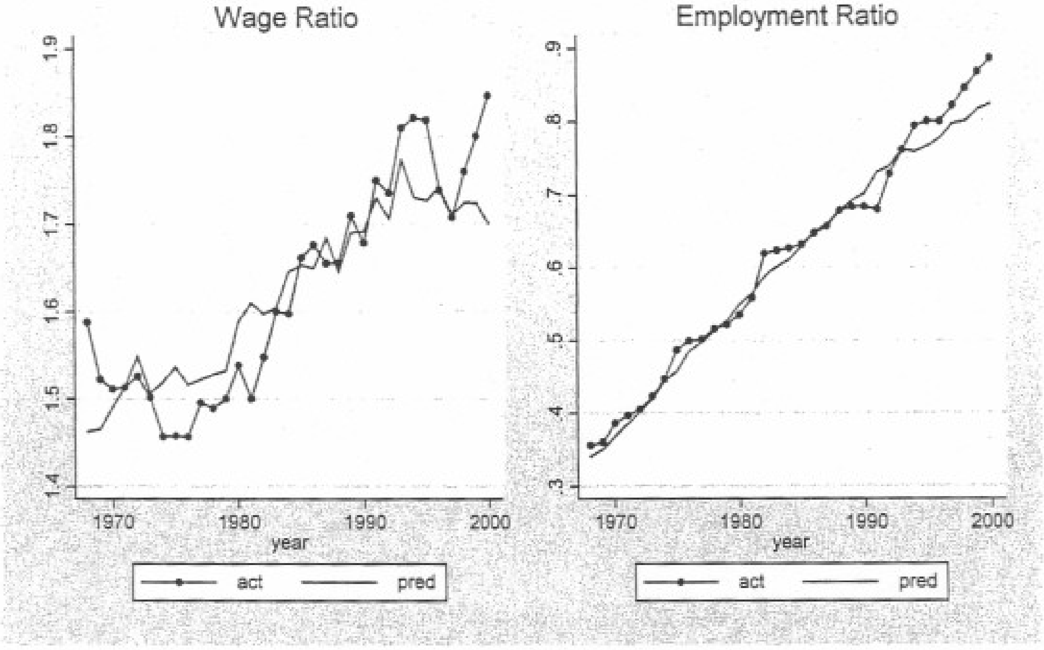

Fig. 8: Actual and Predicted Median Wages by Sex
1968-2000

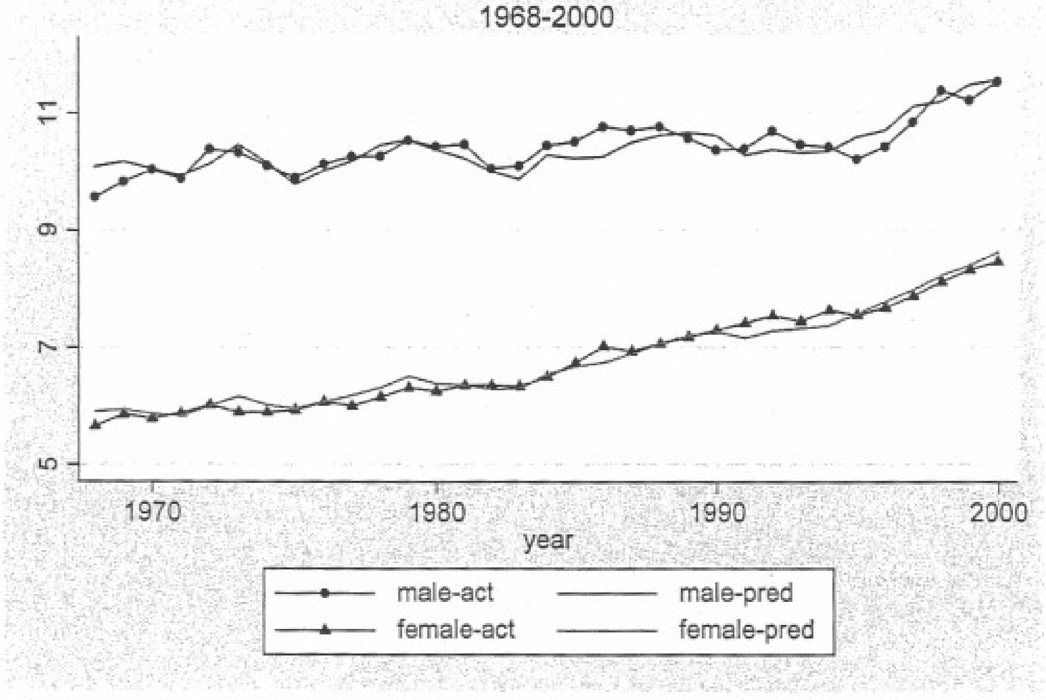

Fig. 9: Actual and Predicted Employment Rate by Sex

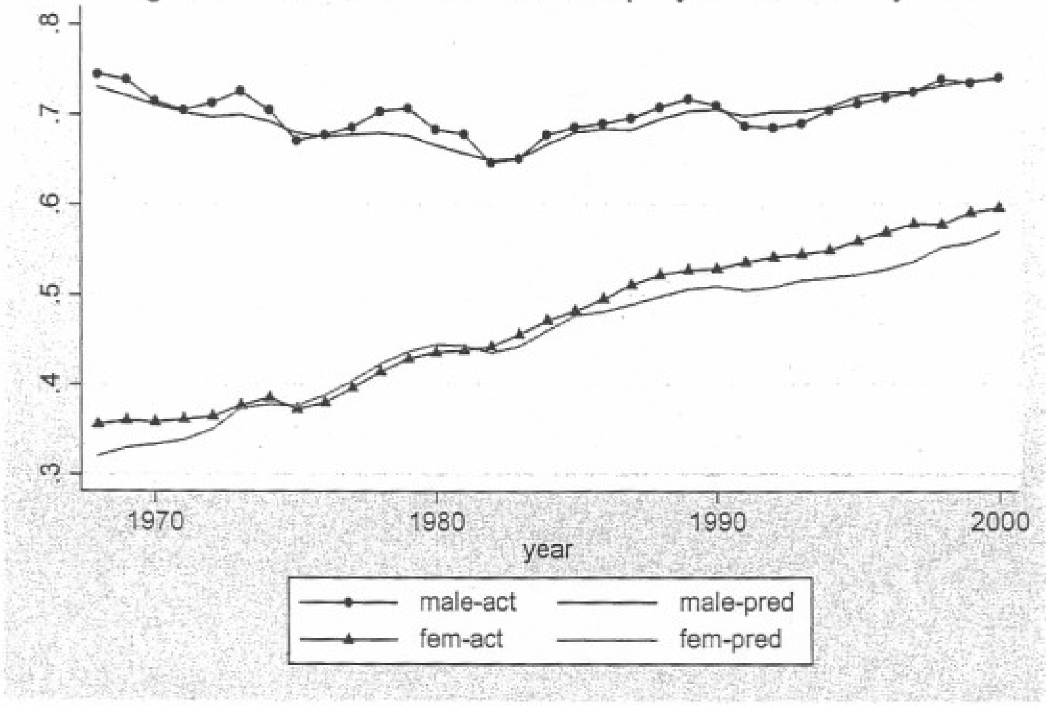

Fig. 10: Actual and Predicted Male-Female (Median) Wage and Employment Ratio

1968-2000

Fig. 11: Act. and Pred. Goods and Service Sector Wage and Employment Rate
1968-2000

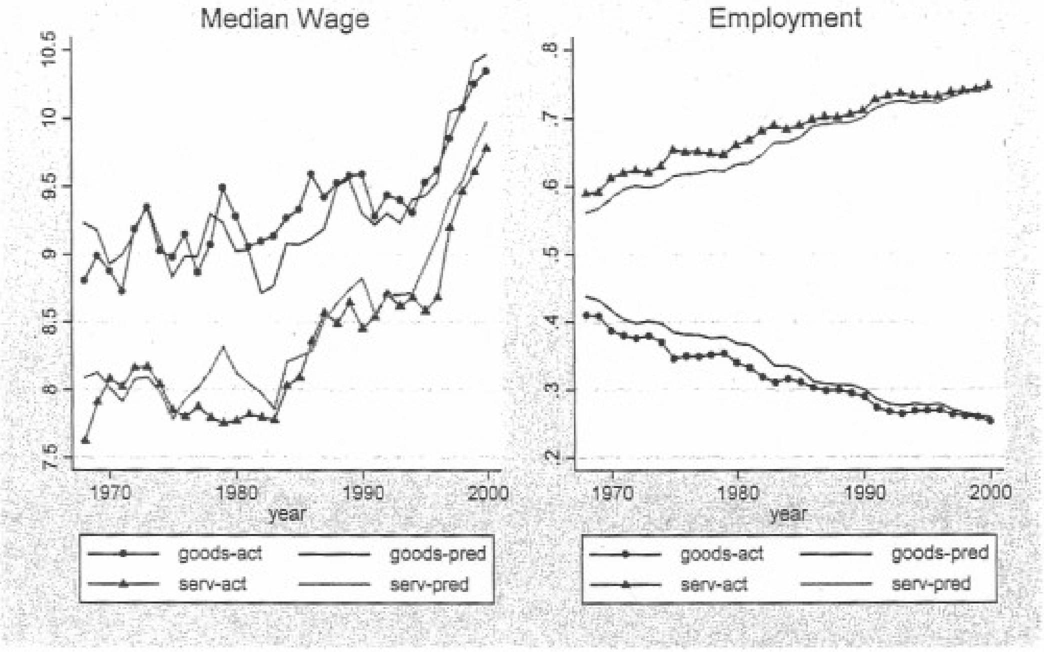

Fig. 12: Act. and Pred. Service/Goods Sector Capital Stock and Employment Ratio
1968-2000