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INTERSECTORAL LABOR MOBILITY AND THE GROWTH OF THE SERVICE SECTOR

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One of the most striking changes in the U.S. economy over the past 50 years has been the growth in the service sector. Between 1950 and 2000, service-sector employment grew from 57 to 75 percent of total employment. However, over this time, the real hourly wage in the service sector grew only slightly faster than in the goods sector. In this paper, we assess whether or not the essential constancy of the relative wage implies that individuals face small costs of switching sectors, and we quantify the relative importance of labor supply and demand factors in the growth of the service sector. We specify and estimate a two-sector labor market equilibrium model that allows us to address these empirical issues in a unified framework. Our estimates imply that there are large mobility costs: output in both sectors would have been double their current levels if these mobility costs had been zero. In addition, we find that demand-side factors, that is, technological change and movements in product and capital prices, were responsible for the growth of the service sector.

KEYWORDS: Labor mobility, service-sector growth, labor market equilibrium.

1. INTRODUCTION

ONE OF THE MOST STRIKING CHANGES in the U.S. economy over the past 50 years has been the growth in the service sector. In 1950, 57 percent of workers were employed in the service sector; by 1970 that figure had risen to 63 percent and by 2000 to 75 percent.[2] While relative service-sector employment was increasing over this period, the relative wage of service workers to goods workers remained roughly constant; while service sector employment grew by 2.2 percent per year faster than employment in the goods sector between 1968 and 2000, the real hourly wage in the service sector grew only by 0.23 percent more per year over the same period. Moreover, the real wage was not simply constant over this period. Between 1968 and 1974, the average real wage economywide grew on average by 1.7 percent per year, was essentially constant between 1974 and 1991, and then again grew, by 2.4 percent per year, between 1991 and 2000. Given the massive change in the sectoral allocation of labor and the rather small change in the relative wage, one might conclude that there are not significant frictions in the U.S. labor market with regard to adjustments to long-run shifts in economic fundamentals.

In this paper, we address several empirical issues. First, we assess whether or not the constancy of the relative wage implies that individuals face small direct

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[2]This increase of about 25 percentage points is of a similar magnitude as was the fall in agricultural sector employment over the previous 50 years, between 1900 and 1950.

psychic or monetary costs of switching sectors. We compare the evolution of the U.S. economy to economies where direct mobility costs are zero and, alternatively, where they are prohibitive. Second, we assess whether relative wage constancy implies that work experience is highly substitutable between sectors. Again, we compare the evolution of the U.S. economy to economies where all sector-specific work experience is general and, alternatively, where it is entirely specific. A by-product of the analysis of these issues is that we also provide an explanation for the observed persistence in intersectoral wage differentials. Finally, we assess the causes of the growth of the service sector, parceling out the factors responsible into those that originate in labor supply shifts and those in labor demand shifts.

The persistence of intersectoral wage differentials has been well documented and studied.[3] One strand of the literature is devoted to testing alternative explanations. Some explanations, for example, those related to unobserved differential labor quality and nonpecuniary attributes of employment, fall within the competitive wage-determination paradigm. Others, for example, segmented labor markets or efficiency wages, rely on noncompetitive models. Another strand of the literature is concerned with evaluating the extent to which relative wages respond to short-run sectoral variations in demand.[4] Direct mobility costs and specific human capital have been proposed as impediments to frictionless responses to short-run relative labor demand shocks.

The literature on assessing the ease with which the sectoral allocation of labor responds to long-run changes in market fundamentals is sparse. Weinberg (2001) finds that the postdisplacement wage of displaced workers is positively related to the predisplacement sector's lagged employment growth up to 10 years before, from which he concludes that adjustments to labor demand are slow. Weinberg also concludes that because within-sector wage changes are not related to employment changes, which are assumed (after adjustments for endogeneity) to proxy changes in labor's marginal product, the labor market does not conform to a competitive spot-market model.

Explanations offered for the shift toward service-sector production can be classified into those related to changes in final demand, to changes in technology, and to changes in labor supply. The first of these explanations is that as real incomes rise, the demand for services rises faster than that for goods (Caves (1980)). Fuchs (1980), however, argues that the income elasticity of demand for services is not likely to be significantly larger than that for goods and Summers (1985) provides evidence that the income elasticity for services is around unity.

[3]There is a long list of papers, including Dickens and Katz (1987), Krueger and Summers (1988), Gibbons and Katz (1992), Helwege (1992), and Keane (1993).

[4]See, for example, Lilien (1982), Loungani and Rogerson (1989), Jovanovic and Moffitt (1990), and Keane (1993).

The second explanation, most notably associated with Fuchs (1968, 1980), is that labor productivity has increased faster in the goods sector than in the service sector. However, as Fuchs (1980) notes, the difference in the growth of output per worker is overstated, because there has been faster growth in capital per worker in the goods sector. In a recent paper, Ngai and Pissarides (2004) derive sufficient conditions for a multisector growth model with differential Total Factor Productivity growth to lead to a balanced growth path and calibrate the model to the U.S. economy. They show that the model can fit the observed changes in employment shares among the agricultural, manufacturing, and service sectors reasonably well. A third explanation is that the growth in the service sector is the consequence of the increase in female labor force participation (Fuchs (1980)).

In this paper, we specify and estimate a two-sector labor market equilibrium model that allows us to address these empirical issues in a unified coherent framework. The model assumes a spot-market equilibrium for labor. It builds on a long tradition of prior work.[5] We extend Heckman and Sedlacek's (1985) static model of sectoral choice in the presence of skill heterogeneity to a dynamic choice setting, incorporate many features of Rogerson's (1987) model of sectoral reallocation in the presence of productivity shocks and mobility costs, adopt the partial equilibrium dynamic schooling and occupational choice framework of Keane and Wolpin (1997), and extend the general equilibrium formulations of Lee (2005) and Heckman, Lochner, and Taber (1998) to allow for sectoral choice and aggregate shocks.[6] We embed both supply and demand explanations for relative service-sector growth.

The general features of the model are the following: (i) The aggregate production functions for the goods and service sector are Constant Elasticity of Substitution (CES) with constant returns to scale in three skill types (white-, pink-, and blue-collar occupations) and capital.[7] Capital and white-collar skill form a nested CES composite input. There are both time-varying neutral and nonneutral technological change, and combined aggregate productivity and relative product price shocks. The relative goods-to-service product price and the price of capital are taken as exogenous to the U.S. economy. (ii) Individuals age 16–65 choose among eight discrete alternatives at each age, working in any of the six sector–occupations, attending school, or remaining in the

[5]Early relevant work includes Roy (1951), Ben-Porath (1967), and Willis and Rosen (1979).

[6]Although we incorporate all of the features of Lee (2005), there are additional features of the Heckman, Lochner, and Taber formulation that we omit; the reverse is also true. The most important differences are that Heckman, Lochner, and Taber allow for decisions about savings and time spent on human capital investment on the job. We model schooling as a sequential decision, allow for idiosyncratic and aggregate shocks, for unobserved heterogeneity in skill endowments and in preferences.

[7]White-collar occupations include professional, technical, and managerial categories; pink-collar occupations include clerical, secretarial, and sales categories; and blue-collar occupations include craftsmen, operatives, and laborers. Heckman, Lochner, and Taber assume that skill types correspond to schooling levels.

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 nonpecuniary 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 preschool children in the household.[8] Transiting between alternatives involves a mobility cost. (iii) The population at any calendar time consists of overlapping generations of individuals of both sexes age 16–65 and is time-varying. The population consists of four 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. The probability that an individual is of a given type depends on the individual's sex and on the level of schooling completed at age 16 (initial schooling). The proportion of types in the population, therefore, varies over time as the initial schooling distribution changes.

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 and capital, 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. The joint skill rental price process is expectations consistent. We provide evidence that this approximation is, by some metric, a reasonable approximation to the rational expectations equilibrium.

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 (CPSs) from 1968 to 2001 on sectoral output and capital from the Bureau of Economic Analysis and on employment transitions from the NLSY79 (defined in footnote 12). We present evidence on the fit of the model to the data.

We use the parameter estimates to simulate counterfactual experiments to evaluate the issues presented above. In particular, we simulate economies in which mobility costs differ and in which the degree of specificity of work experience in the skill production functions differ. An important finding is that the existence of substantial between-sector mobility costs is not inconsistent with the constancy of relative wages. There are three reasons for this. First, as

[8]We do not allow for time-varying payoffs to remaining at home except through changes in fertility. Greenwood, Seshadri, and Yorukoglu (2005) argue from a calibrated growth model that a large part of the increased female participation between 1900 and 1980 was induced by the introduction of and improvements in labor-saving consumer durables, e.g., washing machines, dishwashers, frozen dinners, etc. Our empirical analysis is confined to the latter third of the century.

in Heckman and Sedlacek (1985), the existence of a home sector provides a source of flexibility in terms of entry into the sector in which there is increasing demand. Second, new entrant cohorts also add entry flexibility. Third, the mobility of capital acts to equilibrate skill marginal products over time. We also find that supply-side factors, namely changes in cohort size and fertility, by themselves are neutral with respect to relative sectoral growth. The growth in the service sector resulted almost entirely from demand-side factors associated with technological change and relative goods-to-service product price changes.

The paper is organized as follows. In the next section, we provide a brief descriptive history of the growth of the service sector. The model is presented in Section 2, along with the solution algorithm. The estimation method is presented in the next section and the results of the estimation are presented in Section 4. Our analyses of mobility costs, specific experience, and the causes of the growth of the service sector are presented in Section 5. We then summarize and conclude.

2. SERVICE-SECTOR GROWTH AND INTERSECTORAL MOBILITY: A BRIEF DESCRIPTIVE HISTORY

Changes over the last five to six decades in the service-sector shares of output, capital, employment, and earnings are shown in Table I. Between 1950 and 2000, the service-sector share of output grew by 21 percentage points, from 56.4 to 77.4 percent; the share of capital grew by 4 percentage points, from 79.5 to 83.4 percent; the share of employment grew by 18 percentage

TABLE I

SERVICE-SECTOR SHARES OF OUTPUT, CAPITAL, EMPLOYMENT, AND EARNINGS IN SELECTED YEARS

			Employment		Labor Earnings	
Year	Output	Capital	All	Annual Hours 780 or More	All	Annual Hours 780 or More
1940	NA	NA	48.1	48.2	56.8	57.1
1950	56.4	79.5	57.3	59.5	60.4	60.1
1960	61.9	79.6	57.2	55.9	53.1	53.0
1970	66.2	80.5	63.4	61.3	60.4	59.7
1975	67.4	80.6	66.6	65.4	63.6	63.4
1980	67.5	78.8	67.7	66.0	63.9	63.4
1985	71.2	79.9	70.3	68.9	67.0	66.7
1990	73.9	81.6	72.3	71.1	70.5	69.7
1995	75.8	82.6	74.3	73.1	72.5	72.2
2000	77.4	83.4	75.3	74.7	75.4	74.3

TABLE II

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
All occupations			
Employment	2.23	2.45	2.09
Hourly wage	0.23	−0.17	0.50
White collar			
Employment	1.69	1.31	1.94
Hourly wage	0.19	0.26	0.14
Pink collar			
Employment	2.20	2.07	2.28
Hourly wage	−0.10	0.09	−0.22
Blue collar			
Employment	1.95	2.13	1.83
Hourly wage	0.08	−0.07	0.17

[a]Sector-specific nominal outputs divided by the GDP deflator.

points, from 57.3 to 75.3 percent; and the share of labor earnings grew by 15 percentage points, from 60.4 to 75.4 percent of total labor earnings.[9]

Although the growth rate in service-sector output relative to goods-sector output (in constant dollars) was monotonic, it accelerated after 1980. As seen in Table II, between 1968 and 1980, 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.[10] This increase in the differential rate of growth of the value of service-sector output between the 1968–1980 and 1981–2000 periods was mir-

[9]All nominal figures were converted to 1983 dollars using the gross domestic product (GDP) deflator. The data on output and capital come from the Bureau of Economic Analysis. Data on employment and earnings before 1970 are from decennial U.S. Censuses, and those from 1970 on are from March CPSs. The goods-producing sector consists of the agriculture, mining, construction, and manufacturing industry categories; the service sector consists of the transportation and public utilities, trade, finance, insurance, real estate, private household service, miscellaneous service, and public administration industry categories. In what follows, we define an individual as employed if he or she worked at least 39 weeks a year and 20 hours per week. None of the employment patterns would be significantly altered if this restriction was dropped or if annual hours was the measure of employment.

[10]However, this pattern resulted from relative prices changes. Over the entire period, the growth of service-sector output in physical units, that is, defined as nominal output divided by its sector-specific price, exceeded the same measure of growth of goods-sector output by 1.62 percentage points. Moreover, the relative service-to-goods sector output in this measure grew faster in the first period than in the second, by 2.91 vs. 0.79 percentage points.

rored 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 in the service sector, but 1.51 percent per year 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.

In light of the large shift in employment toward the service sector, sectoral relative wages would seem to have been remarkably stable over time. Table II also reports sectoral differences in the annual changes in employment and hourly wages overall and by occupation. For the entire 1968–2000 period, service-sector employment grew 2.23 percent per year faster than did goods-sector employment, while the average hourly wage grew only by 0.23 percent faster. For the first subperiod, these figures were 2.45 and −0.17 percent, and for the second, 2.09 and 0.50 percent. As the table also shows, the same pattern holds within occupations. Indeed, within occupations the differential percentage changes in relative wages tend to be much smaller than for all occupations together.

Although relative wage changes are small in comparison to changes in relative employment, relative wages were not entirely flat over the period. Although the relative average hourly wage was essentially flat between 1968 and 1984 (0.96 in 1968 and 0.94 in 1984), there has been a more noticeable rising trend in the relative hourly wage since then. The relative service-to-goods sector hourly wage rose from 0.94 in 1984 to 1.04 in 2000.

The occupational structure of the service and goods sectors as well as their workforce compositions have differed substantially throughout the 33-year period, although similar changes have occurred in the two sectors over time. As shown in Table III, the service sector was fairly evenly split among white-, pink-, and blue-collar workers in the earlier period. The goods sector, on the other hand, was over 70 percent blue collar in the earlier period. Both sectors have become significantly more white-collar intensive over time. The proportion of service-sector workers in white-collar occupations increased from 0.35 in 1968 to 0.41 in 2000 and the proportion of goods-sector workers in white-collar occupations increased from 0.17 in 1968 to 0.23 in 2000. Consistent with the occupational distributions, service-sector workers have completed a little over one more year of education on average than have goods-sector workers, a differential that has not changed much over time while education levels have increased overall by about a year. The service sector has historically been more female intensive than the goods sector, and has remained so. Indeed, the service sector is now majority female, having increased from 43 percent of the workforce in 1968 to 53 percent in 2000. The proportion of workers in the goods sector who are female also increased over the period, from about a fifth of the workforce in 1968 to a quarter in 2000.

The shift toward the service sector has involved both an increase in the proportion of new labor market entrants working in the service sector and an increase in the proportion of workers employed in the service sector as entrant

TABLE III

WORKFORCE COMPOSITION AND WAGES BY SECTOR

	1968–1980			1981–2000		
	Employment (Percent in Sector)	Mean Highest Grade Completed	Mean Hourly Wage	Employment (Percent in Sector)	Mean Highest Grade Completed	Mean Hourly Wage
Service sector						
All workers	100.0	12.6	10.09	100.0	13.6	11.91
Female	45.3	12.4	8.01	51.3	13.5	10.32
White collar	12.7	14.5	10.09	20.4	14.9	12.96
Pink collar	20.7	12.3	7.49	19.5	13.0	8.87
Blue collar	11.9	10.6	6.60	11.4	11.9	7.90
Male	54.7	12.7	11.84	48.7	13.7	13.63
White collar	22.3	14.5	14.57	20.9	15.3	17.69
Pink collar	9.5	12.9	11.46	8.2	13.8	12.67
Blue collar	22.9	10.9	9.58	19.6	12.1	9.87
Goods sector						
All workers	100.0	11.2	10.45	100.0	12.5	11.80
Female	22.4	11.1	6.92	25.3	12.4	9.12
White collar	1.6	13.3	9.79	5.3	14.4	13.32
Pink collar	6.7	12.3	7.57	7.3	12.9	9.24
Blue collar	13.7	10.2	6.21	12.6	11.3	7.21
Male	77.6	11.3	11.48	74.7	12.5	12.75
White collar	15.1	14.0	16.13	17.4	14.7	19.04
Pink collar	4.8	12.6	11.71	4.2	13.5	13.48
Blue collar	57.8	10.5	10.18	53.1	11.9	10.52

TABLE IV

SERVICE-SECTOR EMPLOYMENT SHARES BY AGE AND YEAR

Age	1968–1974	1975–1981	1982–1988	1989–1995	1996–2000
18–24	0.628	0.662	0.704	0.749	0.764
25–31	0.597	0.662	0.684	0.715	0.741
32–38	0.598	0.649	0.699	0.710	0.722
39–45	0.609	0.649	0.691	0.731	0.725
46–52	0.608	0.646	0.679	0.726	0.747
53–59	0.615	0.634	0.675	0.716	0.738
60+	0.650	0.671	0.701	0.741	0.754

cohorts age. Table IV shows the proportion of workers employed in the service sector for five 6-year intervals from 1968 to 2000 and for six 6-year age intervals (plus an open-ended interval of age 60 and over). As seen, the proportion of new entrants, those age 18–24, who worked in the service sector increased from an average of 0.63 over the 1968–1974 period to 0.76 over the period 1996–2000, although the increase has slowed over the last two periods.[11] In terms of changes within cohorts, those who entered the market in the period 1968–1974 increased their service-sector employment from 0.63 (at ages 18–24) to 0.75 at ages 46–52. This life cycle pattern appears to hold through the 1975–1981 entrant cohort. For the 1982–1988 entrant cohort, however, the proportion of workers employed in the service sector rose more slowly across the first three age categories and for the 1989–1995 cohort actually declined over the first two age categories, an indication, perhaps, that relative service-sector employment growth may be waning.

Table IV provides information only about net flows with age and calendar time. Table V, which uses data from the NLSY79, shows gross flows between sectors as well as the extent to which the choice of sector depends on previous employment choices, separately by sex.[12] As seen, for the entire sample, of those males (females) who worked in the service sector in year $t-1$, 85 (94) percent of those who continued to work in year t remained in the service sector. Of those males (females) for whom year $t-1$ was their first year working in the service sector, 76 (89) percent of workers in year t remained in the service sector, while for those who had 10–15 years of service-sector work experience, 97 (98) percent of workers remained in the service sector. Consistent with the relative growth in service-sector employment, those who worked in the goods sector at year $t-1$, at all levels of goods-sector experience, are less

[11]The increase was similar for males and females: for males the increase was from 0.52 to 0.66 and for females, from 0.78 to 0.89 (tables available on request).

[12]The NLSY79 (the 1979 cohort of the National Longitudinal Surveys of Labor Market Experience) follows a national random sample of individuals plus an oversample by race of about 12,000 individuals from the 1957–1964 birth cohorts. The figures in the table use weights to take into account the oversampling and clustered sample design.

TABLE V

SECTOR-SPECIFIC WORK EXPERIENCE AND EMPLOYMENT[a]

Sector-Specific Work Experience	Proportion of Workers Employed in Service Sector						Proportion of Workers Employed in Goods Sector					
	Worked in Services Previous Period		Worked in Goods Previous Period		At Home Previous Period		Worked in Goods Previous Period		Worked in Services Previous Period		At Home Previous Period	
	M	F	M	F	M	F	M	F	M	F	M	F
0	—	—	0.14	0.19	0.58	0.80	—	—	0.10	0.05	0.33	0.13
1	0.76	0.89	0.18	0.24	0.54	0.83	0.67	0.60	0.20	0.12	0.46	0.23
2	0.82	0.92	0.29	0.27	0.53	0.82	0.79	0.71	0.24	0.12	0.64	0.48
3–5	0.87	0.94	0.25	0.33	0.66	0.88	0.84	0.82	0.29	0.22	0.66	0.48
6–9	0.93	0.96	0.37	0.42	0.73	0.92	0.91	0.93	0.31	0.32	0.90	NA
10–15	0.97	0.98	NA	NA	NA	NA	0.92	NA	NA	NA	NA	NA
All	0.85	0.94	0.19	0.22	0.58	0.83	0.81	0.75	0.15	0.06	0.42	0.17

[a]NLSY79: restricted to respondents age less than 18 in 1979 and age 18 and above between 1980 and 1993. NA denotes fewer than 25 observations.

likely among those who work at year t to remain in the goods sector. Overall, 81 percent of males and 75 percent of females are stayers. Both the overall difference and the difference by the level of goods-sector experience are larger for females than for males, although by the time an individual has accumulated between 10 and 15 years of goods-sector experience, similar to the service sector, 92 percent of the males and at least 93 percent of females choose to remain working in the goods sector.

Not having worked in a sector at year $t-1$ significantly reduces the propensity, among those who work, to work in that sector at year t, at all levels of sector-specific experience. For example, only 37 percent of males with between 6 and 9 years of service-sector experience remained in that sector at year t if they worked in the goods sector in year $t-1$. Similarly, only 31 percent of males with between 6 and 9 years of goods-sector experience remained in that sector at year t if they worked in the service sector in year $t-1$. The figures are similar for females. The table also confirms that, as in the CPS data, women entrants or reentrants to employment are more likely to choose the service sector. For example, of those women with no previous experience in the service sector who chose to work at t, having been at home at $t-1$, 80 percent chose the service sector. The comparable figure for men was 58 percent. Likewise, of those men with no previous experience in the goods sector who chose to work at t, having been at home at $t-1$, 33 percent chose the goods sector, while the comparable figure for women was 13 percent.

3. MODEL

3.1. *Preliminaries*

Our goal is to design and estimate an equilibrium model of the labor market that is capable of reproducing the facts presented above and that, more specifically, enables a quantitative assessment of the relative importance of demand and supply factors in the growth of the service sector. The development of the model is necessarily constrained by a trade-off between complexity and computational tractability. The existence of such a trade-off requires that modeling choices be made at quite fundamental levels.

The most fundamental decision concerns the modeling of markets. We begin with the assumption that factor and product markets are competitive. Within that paradigm, ideally we would like to model equilibrium in all markets simultaneously, that is, to solve jointly for equilibrium prices and quantities in factor and product markets. However, these markets differ in their openness and we want, for tractability, to avoid having to model international trade flows. Given that and modeling the labor market as closed, there are two alternatives: to assume that all other markets are either closed or that they are open. We adopt the latter approach because it is more tractable and because it is unclear a priori which assumption is a better approximation.[13] Thus, we assume that the real rental price of capital (and thus the real interest rate) and real product prices are exogenous, that is, they are set internationally and taken as given.

A second issue, closely connected to the first, is the choice of modeling the behavior of economic agents. On the production side, in terms of equilibrium determination, the main feature we want to capture is that both labor and capital are allocated efficiently between the two sectors. For that purpose, it is sufficient to specify production technologies in the two sectors at the aggregate, rather than the firm, level.[14] Given the questions we pose, the worker–consumer side is modeled at the microlevel as a dynamic optimization problem. However, for tractability, we do not model savings behavior and we assume that labor supply decisions are independent of relative product prices. This latter assumption avoids several complications. We do not have to specify a stochastic process for the evolution of the relative price of goods to services and, more importantly, we do not have to estimate the parameters of the consumption branch of the utility function.

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 because 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 (Table II), the model allows for the pace of skill-biased technological change to differ after 1980. 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. 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. The model's estimates will determine the extent to which the growth in the service sector resulted from technological change, and factor and product price changes.

[13]Assuming that markets are closed would add considerable complexity to the individual's optimization problem, for example, by having to solve also for life cycle savings, as well as requiring that we solve for additional equilibrium prices.

[14]We assume that capital can flow between sectors costlessly. Allowing for adjustment costs would greatly complicate the analysis as it would also make the production side of the model, which is now a static problem, dynamic. It is unclear how the demand for labor in general, and specifically by skill type, would be affected in both the short and long term, allowing for adjustment costs to capital.

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 specification of the choice model follows closely that of Keane and Wolpin (1997). 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 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 relative service-sector growth. Changes in skill supply may also have accompanied the increase in female labor force participation, because 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 fertility (considered exogenous) by cohort and the effect that children have on the value of female home time. 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.

3.2. *Model Specification*

3.2.1. *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 nested CES function

$$
\begin{aligned}
(1) \qquad p_t^j Y_t^j &= p_j^t \zeta_t^j F^j(S_t^{jW}, S_t^{jP}, S_t^{jB}, K_t^j) \\
&= z_t^j \big\{ \alpha_{1t}^j (S_t^{jP})^{\sigma^j} + \alpha_{2t}^j (S_t^{jB})^{\sigma^j} \\
&\qquad + (1 - \alpha_{1t}^j - \alpha_{2t}^j) \big[\lambda_t^j (S_t^{jW})^{\nu^j} + (1 - \lambda_t^j)(K_t^j)^{\nu^j} \big]^{\sigma^j/\nu^j} \big\}^{1/\sigma^j} \\
&\qquad\qquad (j = G, R).
\end{aligned}
$$

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 is $1/(1-\sigma^j)$. Hicks-neutral and factor-biased technological change are assumed to be time-varying.[15]

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

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

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, then to follow separate linear trends until 1980, and then different linear trends thereafter. Specifically,

$$\alpha_{kt}^j = \begin{cases} \alpha_{k0}^j & \text{if } t < 1960, \\ \alpha_{k0}^j + \alpha_{k1}^j (t - 1960) & \text{if } 1980 \geq t \geq 1960, \\ [\alpha_{k0}^j + 20\alpha_{k1}^j] + \alpha_{k2}^j (t - 1980) & \text{if } 2000 \geq t \geq 1980 \end{cases} \quad (j = G, R, k = 1, 2, 3). \tag{3}$$

3.2.2. *Choice Set*

At each age, from $a = 16$–65, an individual of type h who is alive at time t chooses among eight mutually exclusive alternatives, each denoted by a dichotomous variable (d_{hat}^j) equal to 1 if alternative j is chosen and 0 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 (i) work in the goods-sector white-collar occupation, d_{hat}^1; (ii) work in the goods-sector pink-collar occupation, d_{hat}^2; (iii) work in the goods-sector blue-collar occupation, d_{hat}^3; (iv) work in the service-sector white-collar occupation, d_{hat}^4; (v) work in the service-sector

[15]The particular nesting assumption in (1) is similar to that in Krusell, Ohanian, Rios-Rull, and Violante (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.

pink-collar occupation, d^5_{hat}; (vi) work in the service-sector blue-collar occupation, d^6_{hat}; (vii) attend school, d^7_{hat}; or (viii) 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 as described below. The probability that an individual is of any given type (π_h) depends on the individual's initial conditions, namely the level of schooling attained at age 16 and gender. In what follows, we drop the h and t subscripts when the meaning is clear.

3.2.3. *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

$$
\begin{aligned}
(4)\qquad U^h_a = {} & \sum_{k=1}^{6} \gamma_k d^k_a + \gamma_{7h} d^7_a + (\gamma_{80h} + \gamma_{81} n_{05,a}) d^8_a + \gamma_9 d^8_a d^8_{a-1} \\
& + \gamma_{10} d^7_a (1 - d^7_{a-1}) I(E_a < 12) \\
& + \gamma_{11} d^7_a (1 - d^7_{a-1}) I(E_a \geq 12) + u(c^G_a, c^R_a),
\end{aligned}
$$

where $u(c^R_a, c^G_a)$ is the separable consumption branch of the utility function.[16]

To fit the choice data requires additional structure on utility.[17] For example, the utility specification allows for differential nonpecuniary benefits associated with working in each sector–occupation, given by γ_k for $k = 1, \ldots, 6$, 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 independent and identically distributed (i.i.d.) stochastic shocks, namely, $\gamma_{kha} = \gamma_{kh} + \epsilon_{ka}$, $k = 7, 8$. To fit the fact that returning to school after a period of nonattendance is rare, the utility specification also includes a psychic

[16]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 quasilinear, and additively separable in goods and services consumption, that $u(c^R_a, c^G_a) = c^R_a + g(c^G_a)$, 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.

[17]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). As in that work, the final forms are, in part, the result of structural modifications made during estimation by assessing within-sample fit.

cost of reentering high school, E_a (completed years of schooling up to age a) less than 12, γ_{10}, and a separate cost for reentering college, E_a at least 12, γ_{11}.[18] 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. All parameters vary by the individual's gender. Preference shocks are joint normal with elements of the variance–covariance matrix given by σ^{ϵ}_{jk}, $j, k = 7, 8$.

3.2.4. *Constraints*

The individual faces the budget constraint

$$(5) \qquad \sum_{j=G,R} p^j_t c^j_a = \sum_{k=1}^{6} w^k_{at} d^k_a - [\beta_1 I(E_a \geq 12) + \beta_2 I(E_a \geq 16)]d^7_a - \sum_{k=1}^{8}\sum_{j=1}^{6} \delta_{jk} d^j_a d^k_{a-1},$$

where w^k_{at} 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 college attendance, and β_2 is the additional cost of graduate school attendance. To flexibly fit the one-period transition patterns into sector–occupation-specific employment, we include parameters in (5), the δ_{jk}'s, that reflect a direct cost of switching from any of the eight alternatives to any of the six employment alternatives.[19]

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.[20] Each sector–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 i.i.d.

[18]To estimate the model, we need to simulate the joint distribution of work experience and schooling as of 1968 (see below). To obtain a close fit to the distribution of schooling observed in 1968, the utility associated with attending school was, therefore, allowed to differ by cohort (c) in a piecewise linear manner. Specifically, $\gamma_{7h} = \gamma^1_{7h}$ if the individual is age 16 in 1960 or later, $\gamma_{7h} = \gamma^1_{7h}[(c - 1940)/20] + \gamma^2_{7h}[(1960 - c)/20]$ if the individual is age 16 between 1940 and 1959, $\gamma_{7h} = \gamma^2_{7h}[(c - 1900)/40] + \gamma^3_{7h}[(1940 - c)/40]$ if the individual is age 16 between 1900 and 1939, and $\gamma_{7h} = \gamma^3_{7h}$ if the individual is age 16 before 1900.

[19]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.

[20]See Griliches (1977) and also Willis (1986).

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 jth sector–occupation combination is

$$(6)\qquad \log w^j_{hat} = \log r^j_t + \log s^j_{ha} = \log r^j_t + \omega^j_{0h} + \omega^j_1 E_a + \left(\sum_{k=1}^{6} \omega^{jk}_2 X^k_a\right)^{\omega^j_3} - \omega^j_4 I(a > 40)(a-40) + \eta^j_a.$$

Years of education evolves as $E_a = E_{a-1} + d^7_{a-1}$ and sector–occupation-specific work experience evolves as $X^j_a = X^j_{a-1} + d^j_{a-1}$, $j = 1, \ldots, 6$. Age 16 (initial) schooling is taken as given and initial experience is zero in all sector–occupations. The ω^j_{0h}'s are (sector–occupation-specific) gender-specific skill endowments at age 16 for an individual of type h and the η^j_a's are age-varying shocks to skill (reflecting, for example, health shocks). In (6), 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 (5)), there is also a loss to the extent that the accumulated work experience in the origin sector produces less composite work experience in the destination sector, that is, there is a loss of specific human capital.

The number of preschool 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.[21]

The probability distribution of the H types is discrete: an individual's type probability depends on sex and initial (age 16) completed schooling, specifically whether the individual had completed 10 or more years; $\pi_h = \Pr(h = j \mid E_{16}, \text{sex})$ for $j = 1, \ldots, 4$. Type probabilities are time-varying to the extent that the initial schooling distribution has changed.

3.2.5. *Market Clearing*

The economy consists of overlapping generations of individuals age 16–65. Each individual alive at t maximizes the remaining expected discounted

[21]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, 13–15, and 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, and 1960, and on CPS data from 1964 on.

present value of lifetime utility given their age, subject to (4)–(6), by choosing among the eight alternatives. Maximized expected lifetime utility of an individual who is age a at time t is given by

$$V_a(\Omega_{at}) = \max_{\{d^j_{at}\}} \sum_{\tau=a}^{A} E[\rho^{\tau-a} U_\tau | \Omega_{at}], \tag{7}$$

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 61; the probability increases linearly until age 64 (ω_5 by each year) and is 1 at age 65. 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, and the current and past ages of preschool 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 sector–occupation is the sum of the skill units of the individuals who choose that alternative. Letting N_{at} be the total number of individuals who are age a at time t, aggregate skill supplies are given by

$$S^j_t = \sum_{a=16}^{65} \sum_{n=1}^{N_{at}} s^j_{nat} d^j_{nat}(r^1_t, \dots, r^6_t) \qquad (j = 1, \dots, 6), \tag{8}$$

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, $\overline{K}_t = K^G_t + K^R_t$. 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^K_t. Formally,

$$\frac{\partial p^G_t Y^G_t(S^1_t, S^2_t, S^3_t, K^G_t)}{\partial S^j_t} = r^j_t \qquad (j = 1, 2, 3), \tag{9}$$

$$\frac{\partial p^R_t Y^R_t(S^4_t, S^5_t, S^6_t, K^R_t)}{\partial S^j_t} = r^j_t \qquad (j = 4, 5, 6),$$

$$\frac{\partial p^G_t Y^G_t(S^1_t, S^2_t, S^3_t, K^G_t)}{\partial K^G_t} = \frac{\partial p^R_t Y^R_t(S^4_t, S^5_t, S^6_t, K^R_t)}{\partial K^R_t} = r^K_t.$$

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

$$(10)\qquad [S_t^j]_{\text{Demand}} - [S_t^j]_{\text{Supply}} = e_t^j(r_t^1, r_t^2, \ldots, r_t^6; \tilde{Z}_t, \tilde{r}_t^K, \tilde{\Omega}_t, \Theta) = 0 \qquad (j = 1, \ldots, 6),$$

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 (10) 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 (10) for the growth rate of equilibrium skill rental prices can be approximated by the function[22]

$$(11)\qquad \log r_{t+1}^j - \log r_t^j = \eta_0^j + \sum_{k=1}^{6} \eta_k^j [\log r_t^j - \log r_{t-1}^j] + \eta_7^j [\log z_{t+1}^G - \log z_t^G] + \eta_8^j [\log z_{t+1}^R - \log z_t^R].$$

Essentially, (11) 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 6).[23] Although in the solu-

[22]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.

[23]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 nonstationary, allowing for nonconstancy 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 (11) are also time-varying.

tion algorithm described below we treat the parameters of (11) as unrestricted, they are in fact themselves functions of the underlying parameters of the model (Θ).[24]

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 or on actual sectoral output and the rental price of capital that are needed for the algorithm, for the purpose of describing the algorithm we assume that we do.[25] It turns out that the solution of the model for the periods that the model is fitted to actual data (1968–2000) is not sensitive to the assumptions we make.[26]

The solution algorithm is an extension of the method developed in Lee (2005). Given parameters for (1), (4), (5), and (6), 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 (11) and for the aggregate shock process (2).

2. Solve the optimization problem for each cohort that exists from $t = 1$ through $t = T$. The maximization problem can be cast as a finite horizon dynamic programming problem. The value function (7) 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

$$V_a(\Omega_{at}) = \max_j [V_a^j(\Omega_{at})], \tag{12}$$

$$V_a^j(\Omega_{at}) = \begin{cases} U_a^j(\Omega_{at}) + \rho EV(\Omega_{a+1,t+1} | d_{at}^j = 1, \Omega_{at}) & \text{for } a < 65, \\ U_a^j(\Omega_{at}) & \text{for } a = 65. \end{cases}$$

The solution of the optimization problem is in general not analytic. In solving the model numerically, the solution consists of the values of $EV(\Omega_{a+1,t+1}|$

[24]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.

[25]As noted, the model is solved as if the world began in 1860. In solving the model, as described above, we assign arbitrary values for the state space to each person age 16–65 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 backward 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.

[26]We assume that the equilibrium skill rental price process (11) governs the choices made by all individuals age 16–65 through the year 2050. This assumption is necessary to solve the optimization problems for individuals age 16–65 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 16–65 years.

$d^j_{at} = 1, \Omega_{at})$ for all j and elements of Ω_{at}.[27] We refer to this function as Emax for convenience. As seen in (12), 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 backward recursion, beginning with the last decision period.[28]

3. Guess an initial set of values for period one rental prices, say $(r^j_1)^0$, for $j = 1, \dots, 6$. 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 (8), 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 $(z^j_1)^1$. 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 $(r^j_1)^1$. Repeat steps 3 and 4, using $(r^j_1)^1$ as the guess in step 3, until the sequences of skill rental prices and aggregate shocks converge, say to $(r^j_1)^*$ and $(z^j_1)^*$.

6. Guess an initial set of values for period two rental prices, say $(r^j_2)^0 = (r^j_1)^*$, for $j = 1, \dots, 6$. Repeat steps 3 and 4 for $t = 2$ to obtain $(r^j_2)^*$ and $(z^j_2)^*$.

7. Repeat step 6 for $t = 3, \dots, T$.

8. Using the calculated series of equilibrium skill rental prices and aggregate shocks, estimate (2), the VAR that governs aggregate shocks, and (11), the process that governs the equilibrium skill rental prices.

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

[27]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.

[28]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 over both idiosyncratic shocks and aggregate shocks.

4. ESTIMATION METHOD

The solution of the model serves as input to 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. 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 over the period 1968–2001 and the National Longitudinal Surveys 1979 youth cohort over the period 1979–1993 provide information on life cycle employment and schooling choices, and on wages; various U.S. Censuses from 1910 to 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 (BEA) provides data on sectoral capital stocks and on output from 1947 to 2000.[29,30]

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 16–65-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.[31] The NLSY79 is a longitudinal data set that surveys cohorts born

[29]The aggregate capital stock is available from the same source starting in 1929. 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.

[30]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 three 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, total wage compensation derived from the CPS is less than that derived from the BEA. We follow exactly the same procedure as above using the CPS to BEA ratio of total wage compensation to deflate gross rental prices. Third, wages do not reflect total labor compensation. We augment CPS wages with BEA data on nonwage benefits in carrying out the estimation.

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

from 1957 to 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.

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:

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

(ii) 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, his or her 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.

(iii) 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:

- *Career Decisions*
  - I. 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 (1968–2000), sex, and schooling level (four categories: <12, $=12$, 13–15, 16+).
    - C. The proportion of individuals choosing each of the eight alternatives by year (1968–2000), sex, and by whether a preschool child is present.
  - II. 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 (<10, ≥ 10).[32]
    - B. The proportion of individuals choosing each of the six work alternatives by experience $(0, 1, 2, 3, 4+)$, sector–occupation, and sex.[33]

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

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

- *Wages*
  - I. CPS Data
    - A. The mean log hourly real wage by the six sector–occupation categories, year, and sex.
    - B. The mean log hourly real wage by highest grade completed (<12, =12, 13–15, 16+), year, and sex.
    - C. The mean log hourly real wage by year, age, and sex.
    - D. The mean 1-year difference in the log hourly real wage by current and 1-year lagged sector–occupation, and by sex.
    - E. The mean 1-year difference in the log hourly real wage by age, current sector–occupation, and sex.
    - F. The variance in the log hourly real wage by education, sex, and year.[34]
    - G. The variance in the log hourly real wage by sector–occupation, sex, and year.
  - II. NLSY79 Data
    - A. The mean log hourly real wage by work experience (0, 1, 2, 3, 4+ years), sector–occupation, and sex.[35]
- *Schooling*
  - I. CPS Data
    - A. Distribution of highest grade completed (<12, =12, 13–15, 16, >16) by year (1968–2000), age (16–65), and sex.
- *Career Transitions*
  - I. CPS Data
    - A. One-period joint transitions between the eight alternatives by year (1968–2000) and sex.[36]
    - 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.
  - II. NLSY79 Data
    - A. Distribution of years of work experience in each sector for individuals between the ages of 29 to 31 and the years 1990 to 1993.
    - B. Distribution of occupation-specific work experience for individuals between the ages of 29 to 31 and the years 1990 to 1993.
    - C. Distribution of the number of years of not working for individuals between the ages of 29 to 31 and the years 1990 to 1993, by sex.

[34]We also allow for lognormally distributed measurement error in the reported hourly wage rate.

[35]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.

[36]A number of years are missing because identifiers that match households between 2 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.

- *Sector-Specific Capital*: By year (1968–2000).

5. RESULTS

5.1. *Parameter Estimates*

The parameter estimates and their standard errors are shown in the Appendix.[37,38] A 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 (6)). The normalizations we adopt are that the constant term in each sector–occupation skill production function for type one males is set to zero.[39] 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 nonpecuniary benefit associated with white-collar employment in the goods sector is also normalized to zero (for both males and females). Thus, the nonpecuniary benefits of working in all other sector–occupations, as well as the consumption values of schooling and home, are relative to this normalization.

The parameters are categorized in the Appendix tables as they appear in the model section according to their equation number. We discuss those that are of particular interest.

[37]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 variance–covariance matrix of the moments. Off-diagonal elements are ignored. Identification of the model's parameters is implied by invertibility. 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.

[38]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 0.95, 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 0.15 and given a 10 percent annual depreciation rate.

[39]We estimate the model with four types, having found substantial improvements in fit over three or fewer types.

5.1.1. *Production Function Parameters*

The elasticity of substitution between capital and white-collar skill (0.98 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 blue-collar skill (1.34 in the service sector and 1.22 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)).

We find there to be skill-biased technological change in both sectors, although it takes a slightly different form in the two sectors.[40] In the goods sector, the marginal product of white-collar skill in the white-collar–capital skill composite is increasing (because λ_t^G is increasing) over time, while in the service sector, it is the marginal product of the composite skill that is increasing (because $\alpha_{1t}^R + \alpha_{2t}^R$ is decreasing).

5.1.2. *Utility Parameters*

The nonpecuniary benefits associated with working in the service sector are larger than in the goods sector for both men and women. The lowest nonpecuniary benefit for both sexes is goods-sector blue-collar employment and the largest is service-sector pink-collar employment for men and service-sector blue-collar employment for women. The consumption values of attending school and of being at home, although differing somewhat by type, are larger than the nonpecuniary benefits associated with work. The value of the home alternative is about the same for men and women who have no children under the age of 6, but the presence of a child under the age of 6 increases the value of being home by 10 times more for women than for men. The cost associated with returning to high school, having not attended in the previous year, exceeds its consumption value for both men and women and for all types. Returning to college eliminates the positive consumption value of attending for all but one type.

5.1.3. *Budget Constraint Parameters*

The estimated cost (tuition plus nontuition payments) of attending college is \$18,664 and that of attending graduate school, is \$30,004.[41] Mobility costs also tend to be significant. The cost of moving between sectors within the same occupation is estimated to be significantly larger than moving between occupations within the same sector. For example, for males the cost of moving from any occupation in the goods sector to the same occupation in the service sector is \$9,655, which is similar in magnitude for the reverse sector move (\$9,305). However, the cost of changing occupations within a sector ranges only between

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

[41]These are about \$27,000 and \$45,000 in 2000 dollars.

$3,000 and $7,000. Mobility costs for females are somewhat lower. The cost of changing sectors, but remaining in the same occupation, is about $7,000 and the cost of changing occupations within a sector ranges mostly between $1,000 and $5,000. There is a substantial fixed cost of entering employment, similar in magnitude for men and women, and ranging from $10,688 for women who enter employment from school to $15,528 for men who enter employment from home.

5.1.4. *Skill Production Functions*

The model treats all sector–occupation-specific skills as distinct. An alternative would be that occupation-specific skill is the identical skill in the two sectors. In that case, in a frictionless economy, occupation-specific skill rental prices would differ only because of differing nonpecuniary values attached to sector and, given their assumed constancy over time, the ratio of goods-to-service occupation-specific skill rental prices would not vary over time.

A test of whether occupation-specific skills are distinct between sectors is whether the parameters of the occupation-specific skill production functions differ between sectors. The restrictions that would apply in that case are equality of schooling coefficients for the same occupation in the two sectors, and equality of the weights in composite experience for the same occupation in each sector.[42] Our estimates imply nonequivalence. For example, consider the skill production functions for white-collar skill in the two sectors. An additional year of schooling increases white-collar skill by 1.80 percent more in the service sector than in the goods sector. Moreover, the difference in the weights on occupation-specific work experience are large. In particular, the weights on white-collar goods-sector work experience in the goods- and service-sector composites are 0.058 and 0.015, the weights on pink-collar goods-sector work experience in the goods- and service-sector composites are 0.021 and 0.005, and the weights on blue-collar goods-sector work experience in the goods- and service-sector composites are 0.014 and 0.004.

Schooling increases white-collar skill the most in both sectors, followed by pink-collar and blue-collar skill. An additional year of schooling increases skill (and thus the wage) in the goods and service sector by 5.4 percent and 7.6 percent in white-collar occupations, by 4.6 and 4.7 percent in pink-collar occupations, and by 2.7 and 4.4 percent in blue-collar occupations.[43] Composite work experience increases each sector–occupation specific skill at a decreasing rate. As already noted, the weights in composite experience differ across

[42]Recall that composite work experience is $\sum_{k=1}^{6} \omega_2^{jk} X_a^k$. The parameters referred to in the text are the weights on sector–occupation work experience.

[43]Keane and Wolpin (1997), in a partial equilibrium model that does not distinguish among sectors or between white- and pink-collar occupations, estimates a white-collar schooling coefficient of 7.0 percent and a blue-collar coefficient of 2.4 percent.

sector–occupations, but, there are common patterns.[44] Own sector–occupation experience increases skill more than experience obtained in other sector–occupations. For example, for goods-sector white-collar skill, the weight on white-collar experience gained in the goods sector is 2.8 times larger than the weight on pink-collar experience gained in that sector and 4.1 times larger than the weight on blue-collar experience. For service-sector white-collar skill, the weight on white-collar experience gained in the service sector is 4.7 times larger than the weight on pink- collar experience gained in that sector and 8.0 times larger than the weight on blue-collar experience.

Experience obtained in a given occupation is more transferable between sectors than experience obtained in a different occupation. For example, in the case of service-sector white-collar skill, the weight on white-collar experience gained in the goods sector is 0.022, but the weights on pink- and blue-collar experience obtained in the goods sector are 0.005 and 0.003. However, experience gained in a given occupation is not uniformly more or less transferable between sectors than is experience gained in a different occupation within the same sector. For example, in the case of white-collar service-sector skill, white-collar experience gained in the goods sector has a higher weight (0.022) than does pink-collar experience gained in the service sector (0.017). However, this is not the case for white-collar goods-sector skill, where white-collar experience gained in the service sector has a lower weight (0.015) than does pink-collar experience gained in the goods sector (0.021) and essentially the same weight as blue-collar experience gained in the goods sector (0.014).

5.1.5. *Equilibrium Skill Rental Price Processes*

There are six equilibrium skill rental price processes. They are intended to be approximations of those that would be the outcome if agents had rational expectations. Although we cannot do a direct comparison of our approximation to rational expectations, as could Krusell and Smith (1998) in their model, one measure of the degree to which these approximations are close to their rational expectations counterparts is the adjusted R-squared of the regressions used in solving for them. The adjusted R-squared, based on the one-step-ahead forecast of the rental prices obtained in the last round of iterations of the solution algorithm using the parameter estimates from the skill rental price process estimated in the penultimate iteration round, are 0.98, 0.98, 0.87, 0.98, 0.98, and 0.92. Although these are high in some absolute sense, it is not clear how the predictions of the model, and the estimates that result, would differ from

[44]To conserve on parameters, the weights are restricted to be hierarchical: blue-collar experience may increase both the pink-collar and white-collar composite experience, but the latter two may not influence the blue-collar composite. Similarly, pink-collar experience may influence the white-collar composite, but white-collar experience may not influence the pink-collar composite.

the true rational expectations equilibrium.[45] One perhaps useful comparison is to the R-squared values based on the naive adaptive expectations forecasting rule that $r_{t+1} = r_t$. Those values are 0.72, 0.66, 0.73, 0.62, 0.59, and 0.46, which are considerably smaller than for the forecasting rule we adopt.

5.2. *Model Fit*

Tables VI and VII present evidence on how well the model is able to fit the data. Table VI compares the service-sector shares of capital, labor, and labor earnings over time in the actual data to that from the estimated model.[46] As seen, the fit for the service-sector share of capital is extremely good. The model captures the slight decline through the 1980–1984 period followed by the larger increase up to the 1995–2000 period. The fit for the employment share is also quite close, capturing well its increase over time. However, the relative service-to-goods sector hourly wage is understated throughout, although more seriously in the earliest period.[47] Except for that period, the ratio of the predicted to actual relative hourly wage ranges from 0.90 to 0.95.

Table VII compares the actual and predicted sectoral differences in annual growth rates in capital, employment, and wage, overall and by occupation,

TABLE VI

ACTUAL AND PREDICTED SERVICE-SECTOR SHARES OF CAPITAL AND EMPLOYMENT AND THE RELATIVE HOURLY WAGE

	Capital		Employment		Hourly Wage	
Year	Actual	Predicted	Actual	Predicted	Actual	Predicted
1968–1974	80.8	79.9	61.3	62.2	0.968	0.841
1975–1979	79.7	78.6	65.0	64.6	0.959	0.867
1980–1984	78.7	78.7	67.7	66.6	0.945	0.899
1985–1989	81.0	80.9	69.9	70.0	0.971	0.919
1990–1994	82.2	82.6	72.8	72.8	1.00	0.945
1995–2000	82.8	83.1	73.8	73.9	1.02	0.945

[45]It would be possible to improve on the approximations by adding additional state variables to the forecasting equation, for example, the capital rental price. The cost is that one would have to include those state variables in the state space of the individual's optimization problem and specify their equations of motion. The former increases computational time and the latter increases the number of parameters to be estimated.

[46]The figures based on the model are obtained from simulating the behavior of 800 persons per birth cohort. There are 50 birth cohorts in each cross section and thus each simulated cross section has 40,000 observations. The simulations start with the cohort that would be age 65 in 1968 (age 16 in 1918) and continues through the cohort that would be age 16 in 2000 (age 65 in 2050).

[47]Fitting wage statistics is perhaps the most difficult because we only observe wages for a sector–occupation when that alternative is selected. Not only are we fitting accepted wages by sector–occupation, the fit shown in Table VI is for the ratio of accepted wages. Exactly why we understate the service-to-goods sector mean wage ratio in the earlier periods is unclear.

TABLE VII

ACTUAL AND PREDICTED SECTORAL DIFFERENCES IN THE AVERAGE ANNUAL CHANGE IN CAPITAL, EMPLOYMENT, AND HOURLY WAGES

	1968–2000	
Service–Goods Growth Rate	Actual	Predicted
Capital	0.65	0.83
All occupations		
Employment	2.23	2.13
Hourly wage	0.23	0.51
White collar		
Employment	1.69	1.86
Hourly wage	0.19	0.17
Pink collar		
Employment	2.20	−0.14
Hourly wage	−0.10	−0.09
Blue collar		
Employment	1.95	1.63
Hourly wage	0.08	0.11

over the 1968–2000 period. The actual and predicted growth rate differentials for capital are quite close as are the overall employment and the hourly wage differentials. Within-occupation differentials for white- and blue-collar employment are also close, but the predicted differential for the pink-collar occupation is not. The pattern in the actual data that percentage changes in the hourly wage differential are small relative to those in the employment differential is also clear in the simulated data. Indeed, the predicted growth rate differentials in the hourly wage are quantitatively close to the actual differentials.

In the actual data, the observed increase in relative service-sector employment has occurred both through an increase in the proportion of new labor market entrants (those age 18–24) employed in the service sector and an increase in relative service-sector employment over the life cycle. A comparison of these actual patterns with those predicted by the model shows that the qualitative patterns are preserved and, except for understating the service sector share for the first two age groups in the 1968–1974 period, the quantitative estimates of the model are close.[48] In the data, the share of new workers (age 18–24) employed in the service sector rose by 13.6 percentage points from the periods 1968–1974 to 1996–2000 (from 0.628 to 0.764). The model predicts an increase over the same period of 8.6 percentage points (0.657 to 0.743). The actual and predicted increase for each of the following age groups are 14.4 vs. 8.9 for ages 25–31, 12.4 vs. 12.1 for ages 32–38, 11.6 vs. 15.5 for ages 39–45,

[48]The table that shows this comparison is available on request.

13.9 vs. 12.7 for ages 46–52, 12.3 vs. 12.9 for ages 53–59, and 10.4 vs. 6.9 for ages 60 and over. The model also captures the increase in service-sector employment over the life cycle quite well in most cases. For example, service-sector employment share for the cohort that was 18–24 years old in the period 1975–1981 increased by 6.3 percentage points from their entry to age 39–45 (from 0.662 to 0.725), while the model prediction is an increase of 7.0 percentage points (from 0.664 to 0.734).

The fit of the model with respect to the extent of state dependence in the choice of sector, in particular, one-period transition rates, is also matched quite well.[49] For example, among men who choose to work, the proportion choosing to work in the service sector is 0.85 for those who worked in the service sector the previous period, 0.19 for those who worked in the goods sector the previous period, and 0.58 for those who were not working the previous period. The corresponding predictions of the model are 0.93, 0.13, and 0.57. For females, the actual and predicted values are 0.94, 0.22, and 0.83 versus 0.96, 0.20, and 0.76. The fit of one-period transitions that are conditioned on work experience is less good, although the pattern that working in a sector conditional on the previous periods choice is increasing in that sectors experience is captured qualitatively, if not in all cases quantitatively, well.

6. DISCUSSION

6.1. *Mobility Costs and the Growth of the Service Sector*

As noted, mobility costs associated with switching sectors, according to the parameter estimates, are large. The cost of switching sectors can be as high as 75 percent of average annual earnings (over the 1968–2000 period). Nevertheless, as already seen, the model is able to fit the pattern in the data that relative average wages change very little over time while service-sector employment has expanded significantly. Constancy of the observed relative average wage does not preclude the existence of significant intersectoral mobility.

Table VIII compares the actual and predicted relative levels and rates of growth of sectoral output, capital, employment, and their service-sector shares, and shows the results of a number of counterfactual experiments that alter intersectoral mobility costs. All of the figures are normalized by the 1968 actual levels in the goods sector. Thus, in the first column of Table VIII, actual average goods-sector output (in constant dollars) was 18 percent higher during the period 1975–1979 than in 1968, service-sector output was 139 percent higher, and the service-sector share of output was 0.67. The second column shows the model predictions. They are exact for output, but this is artifactual because we use actual output to back out the output residuals (the z's in (1)) in our model solution algorithm. As already seen, the predictions are very close for the sector-specific levels and the service-sector shares of capital and em-

[49]The table that shows this comparison is available on request.

TABLE VIII

THE EFFECT OF MOBILITY COSTS ON SECTORAL OUTPUT, CAPITAL, EMPLOYMENT, AND SERVICE-SECTOR SHARES

					Counterfactual Experiments[a]					
	Actual		Predicted		1		2		3	
Year	Goods	Services	Goods	Services	Goods	Services	Goods	Services	Goods	Services
					Output[b]					
1968–1974	1.03	1.98	1.03	1.98	0.31	1.10	0.33	1.17	1.68	6.51
Service share	0.66		0.66		0.78		0.78		0.80	
1975–1979	1.18	2.39	1.18	2.39	0.36	1.52	0.39	1.59	2.05	6.88
Service share	0.67		0.67		0.81		0.80		0.79	
1980–1984	1.26	2.80	1.26	2.80	0.39	1.93	0.41	2.01	2.35	7.64
Service share	0.69		0.69		0.83		0.83		0.76	
1985–1989	1.35	3.59	1.35	3.59	0.45	2.71	0.44	2.83	2.45	8.84
Service share	0.73		0.73		0.86		0.86		0.78	
1990–1994	1.38	4.20	1.38	4.20	0.49	3.28	0.46	3.39	2.62	10.34
Service share	0.75		0.75		0.87		0.88		0.80	
1995–2000	1.59	5.21	1.59	5.21	0.65	4.45	0.60	4.62	2.94	11.72
Service share	0.77		0.77		0.87		0.88		0.80	
					Capital[b]					
1968–1974	1.10	4.61	1.15	4.58	0.34	2.54	0.40	2.44	1.32	5.11
Service share	0.81		0.80		0.88		0.86		0.80	
1975–1979	1.36	5.34	1.37	5.02	0.41	3.17	0.47	3.07	2.05	6.88
Service share	0.80		0.79		0.89		0.87		0.77	
1980–1984	1.62	6.00	1.54	5.69	0.47	3.92	0.53	3.86	1.85	6.00
Service share	0.79		0.79		0.89		0.88		0.76	
1985–1989	1.63	6.97	1.57	6.67	0.52	5.02	0.56	4.93	1.93	6.95
Service share	0.81		0.81		0.91		0.90		0.78	
1990–1994	1.69	7.78	1.65	7.85	0.58	6.13	0.59	6.07	2.06	8.13
Service share	0.82		0.83		0.91		0.91		0.80	
1995–2000	1.85	8.93	1.84	9.03	0.74	7.69	0.69	7.66	2.31	9.21
Service share	0.83		0.83		0.91		0.92		0.80	
					Employment[b]					
1968–1974	0.99	1.58	0.89	1.47	0.30	0.97	0.33	1.02	1.01	1.60
Service share	0.61		0.62		0.76		0.75		0.61	
1975–1979	1.00	1.86	1.00	1.82	0.34	1.31	0.36	1.36	1.18	1.91
Service share	0.65		0.65		0.80		0.79		0.62	
1980–1984	1.04	2.18	1.09	2.18	0.37	1.66	0.39	1.73	1.31	2.24
Service share	0.68		0.67		0.82		0.82		0.63	
1985–1989	1.11	2.57	1.11	2.59	0.40	2.14	0.38	2.25	1.36	2.64
Service share	0.70		0.70		0.84		0.85		0.66	
1990–1994	1.07	2.87	1.09	2.91	0.41	2.44	0.39	2.54	1.36	2.93
Service share	0.73		0.73		0.86		0.87		0.68	
1995–2000	1.16	3.27	1.18	3.36	0.51	3.11	0.47	3.25	1.50	3.35
Service share	0.74		0.73		0.86		0.87		0.69	

[a]Counterfactual experiments: 1, no mobility between sectors; 2, no mobility between sectors except after intervening period of nonemployment; 3, zero cost of changing sectors.

[b]Normalized by 1968 goods-sector level.

ployment (except that employment is understated somewhat in the 1968–1974 period, although the predicted service-sector share is very close to the actual).

The first counterfactual (counterfactual experiment 1) raises intersectoral mobility costs to a level at which it is essentially never optimal to switch from the sector of the first employment spell. That is, in each period after the first working period, an individual's choice set is restricted to working in the sector first chosen or to the home sector.[50] Experiment 2 imposes a less, though still quite severe mobility restriction, namely that an individual may change sectors after first returning to the home sector for at least one period, but otherwise cannot move between sectors. Experiment 3 assumes that cross-sector mobility costs are zero. All of the exogenous variables and exogenous stochastic processes are unchanged in all of the experiments.[51]

These experiments all involve large changes in mobility costs and the effect of these changes on sectoral output and inputs are also large. In the most restrictive case, in which there is essentially no intersectoral mobility, output in the goods sector falls by 70 percent in the first period and never exceeds 65 percent of base year output in future periods. Service-sector output also falls in the base period, but proportionately less than goods-sector output. The service-sector share of aggregate output, therefore, increases considerably. In particular, the average service-sector share of output was 66 percent in the 1968–1974 period (both actual and predicted) and 77 percent in the 1995–2000 period (both actual and predicted). In the experiment, the share in the 1968–1974 period is 78 percent and in the 1995–2000 period is 87 percent. Capital behaves similarly, falling in both sectors, but proportionately more in the goods sector. The average service-sector share of capital in the 1968–1974 period, 80 percent, is 88 percent in the experiment. In the latest period, the comparable figures are 83 and 91 percent. Employment falls in both sectors as well, but again considerably more in the goods sector. The average service-sector share of employment in the first period is 76 percent under the experiment as compared to the model prediction of 62 percent; comparable figures for the later period are 86 and 73 percent.

There are two first-order effects of an increase in mobility costs. One is to alter the incentives for individuals to work relative to choosing the home sector. Clearly, the payoff to work declines because individuals cannot take advantage of idiosyncratic skill shocks that differentially affect their skill supply across sector–occupations or aggregate productivity shocks that differentially affect sector–occupation skill rental prices. The fraction of individuals working over all periods and ages falls from 57 to 38 percent due to the mobility restriction.

The second effect is to alter the relative payoff to working in the service versus the goods sector. The estimates of the goods- and service-sector pro-

[50] Although an individual may also return to school, that tends to be rare. As noted, reflecting that, estimated school reentry costs are large.

[51] However, the experiments involve resolving for the equilibrium skill rental price processes.

duction functions imply that the combination of Hicks-neutral technological change and changes in the relative service-to-goods prices (the z's) together with factor-biased technological change (the α's) imply an increased demand for inputs in the service sector relative to the goods sector.[52] With mobility cut off, as in experiment 1, equilibrium requires that new labor force entrants disproportionately enter the service sector. Indeed, among those new entrants choosing to work, between 84 and 89 percent chose the service sector over the 1968–2000 period, while the figure for the actual economy (as predicted by the model) is between 66 and 74 percent.[53]

The less severe restriction on mobility given by experiment 2 in Table VIII has only a slightly smaller quantitative effect on levels and service-sector shares than does experiment 1. Allowing for switching sector–occupation only after a period spent not working is almost as severe as not allowing for any switching at all. Experiment 3, that of reducing intersectoral mobility costs to zero, has large effects on output in both sectors. By the 1995–2000 period, output in both sectors is about as twice as high as with actual mobility costs, although the service-sector share of output is not much changed. Capital also flows into both sectors as does labor. With zero intersectoral mobility costs, goods-sector employment actually rises proportionately by slightly more than does service-sector employment, leading to a small decrease in the service-sector share. In terms of employment shares, the actual economy looks a lot closer to experiment 3, the zero mobility cost case, than to experiment 1, the infinite mobility cost case.

Table IX presents model predictions about annual percentage changes in skill rental prices within the 1968–1980 and 1981–2000 periods, and the effect of intersectoral mobility costs on those changes. As with actual hourly wages, the average annual change in skill rental prices tends to be small when compared to employment changes. In both periods and in each sector, skill prices, as predicted by the model, grew most in the white-collar occupation and least in the blue-collar occupation, where they actually declined or stagnated. The main result from the mobility cost experiments in Table IX, with few exceptions, is the invariance of skill rental prices to mobility costs. Even when intersectoral mobility costs are prohibitively large, as in experiment 1, the existence of a home sector, the flow of new labor market entrants, and the mobility of capital all serve to moderate the impact of aggregate shocks, changes in relative prices, and technological change on the relative prices of sector–occupation skill.

These experiments indicate that the observed growth in relative service-sector output and employment together with constant relative wages is not

[52]At the same input usage as in 1968, our estimates imply that service-sector output would have increased by 48 percent more than goods sector output by 2000.

[53]Table available on request.

TABLE IX

THE EFFECT OF MOBILITY COSTS ON SKILL RENTAL PRICES (ANNUAL PERCENTAGE CHANGES)

	1968–1980				1981–2000			
		Counterfactual Experiments[a]				Counterfactual Experiments[a]		
	Predicted	1	2	3	Predicted	1	2	3
Goods sector								
White collar	0.32	0.34	0.28	0.28	0.71	0.75	0.66	0.71
Pink collar	0.26	0.29	0.33	0.11	0.56	0.53	0.64	0.63
Blue collar	−0.20	−0.21	−0.06	−0.19	−0.42	0.02	−0.09	−0.45
Service sector								
White collar	0.62	0.29	0.43	0.51	0.46	0.49	0.45	0.54
Pink collar	0.43	0.47	0.55	0.39	0.29	0.28	0.26	0.36
Blue collar	−0.36	−0.34	−0.26	−0.31	0.07	0.22	0.17	0.07

[a] Experiment numbers are defined in Table VIII.

incompatible with substantial mobility costs. Indeed, as shown, mobility costs have a large impact on output in both sectors.

6.2. *Sector-Specific Work Experience and the Growth of the Service Sector*

Our estimates imply that work experience gained in one sector produces relatively more skill in that sector. All else the same, an individual's wage is higher if work experience is concentrated in the sector in which the individual is employed. Moving between sectors implies a lowered return to previous learning-by-doing investment. Sector-specific experience therefore acts like a barrier to mobility.

To see how the degree to which work experience is sector-specific affects the growth of the service sector and skill rental prices, we perform two counterfactual experiments. In one, we make all work experience general and in the other completely specific. The first experiment is implemented as follows. For each sector–occupation skill production function, we average the coefficients on white-collar goods-sector-specific work experience and white-collar service-sector-specific work experience, and similarly for pink- and blue-collar goods- and service-sector-specific work experience. In this way, it is irrelevant in which sector work experience was accumulated in terms of skill production. The second experiment is implemented by setting all cross-sector work experience coefficients to zero in each sector–occupation-specific skill production function.

The results of these counterfactual experiments are shown in Table X. The most notable attribute is the rather small effect of either experiment on service-sector shares. The degree of sectoral specificity of work experience does not appear to be an important determinant of the relative size or growth of the

TABLE X

THE EFFECT OF SECTOR-SPECIFIC EXPERIENCE ON SECTORAL OUTPUT CAPITAL, EMPLOYMENT, AND SERVICE-SECTOR SHARES

					Counterfactual Experiments[a]			
	Actual		Predicted		4		5	
Year	Goods	Services	Goods	Services	Goods	Services	Goods	Services
				Output[b]				
1968–1974	1.03	1.98	1.03	1.98	0.92	1.62	0.78	1.83
Service share	0.66		0.66		0.64		0.70	
1975–1979	1.18	2.39	1.18	2.39	1.11	1.95	0.89	2.28
Service share	0.67		0.67		0.64		0.72	
1980–1984	1.26	2.80	1.26	2.80	1.24	2.28	0.94	2.72
Service share	0.69		0.69		0.65		0.74	
1985–1989	1.35	3.59	1.35	3.59	1.39	2.94	1.00	3.55
Service share	0.73		0.73		0.68		0.78	
1990–1994	1.38	4.20	1.38	4.20	1.49	3.40	1.02	4.18
Service share	0.75		0.75		0.70		0.80	
1995–2000	1.59	5.21	1.59	5.21	1.91	4.15	1.21	5.25
Service share	0.77		0.77		0.68		0.81	
				Capital[b]				
1968–1974	1.10	4.61	1.15	2.54	1.03	3.74	0.87	4.22
Service share	0.81		0.80		0.78		0.83	
1975–1979	1.36	5.34	1.37	3.17	1.27	4.08	1.02	4.77
Service share	0.80		0.79		0.76		0.82	
1980–1984	1.62	6.00	1.54	3.92	1.50	4.62	1.14	5.52
Service share	0.79		0.79		0.75		0.83	
1985–1989	1.63	6.97	1.57	5.02	1.60	5.45	1.16	6.60
Service share	0.81		0.81		0.77		0.78	
1990–1994	1.69	7.78	1.65	6.13	1.77	6.36	1.22	7.81
Service share	0.82		0.83		0.78		0.80	
1995–2000	1.85	8.93	1.84	9.03	2.18	7.18	1.40	9.10
Service share	0.83		0.83		0.77		0.81	
				Employment[b]				
1968–1974	0.99	1.58	0.89	1.47	0.87	1.25	0.69	1.41
Service share	0.61		0.62		0.59		0.67	
1975–1979	1.00	1.86	1.00	1.82	1.02	1.55	0.76	1.80
Service share	0.65		0.65		0.60		0.70	
1980–1984	1.04	2.18	1.09	2.18	1.15	1.85	0.82	2.17
Service share	0.68		0.67		0.62		0.72	
1985–1989	1.11	2.57	1.11	2.59	1.22	2.23	0.83	2.63
Service share	0.70		0.70		0.65		0.76	
1990–1994	1.07	2.87	1.09	2.91	1.26	2.47	0.81	2.93
Service share	0.73		0.73		0.66		0.78	
1995–2000	1.16	3.27	1.18	3.36	1.51	2.82	0.92	3.44
Service share	0.74		0.73		0.65		0.79	

[a]Counterfactual experiments: 4, sector experience is general within occupations; 5, sector experience is specific.
[b]Normalized by 1968 goods-sector levels.

service sector. In addition, changes in relative skill rental prices are also not influenced by the degree of specificity.[54]

6.3. *The Growth of the Service Sector*

There are four exogenous factors in the model that can account for relative growth in the service sector: two on the supply side of the labor market and two on the demand side. Supply-side forces are changes in cohort size and changes in fertility that affect the number of young children in the household. Demand-side forces are technological change and changes in relative product prices and in the price of capital. Table XI compares the effect of six counterfactual experiments on output, capital, employment, and their service-sector shares to the model predictions. Table XII shows the effect on skill rental prices.

We begin with a baseline case (experiment 6) in which all of the four factors—cohort size, the fertility transition process, technological change, and prices—are set to their 1960 levels, that is, a no-growth economy in the long run.[55] The experiments relax these factors in turn. Experiment 7 allows for changing cohort size. Experiment 8 allows both for changing cohort size as in the previous experiment and for the fertility transition process with respect to the number of children under the age of 6 to change as it did after 1960. Experiment 9 allows for Hicks-neutral and skill-biased technological change as it is estimated to have occurred, and experiment 10 allows for changes in relative product prices and the price of capital as they actually occurred.[56] Experiment 11 simultaneously implements both of the previous two experiments. Experiments 8 and 11 taken together yield the first column predictions.

The baseline economy has a constant service-sector share of output, capital, and employment, all of which are close to the figures predicted by the model for the 1968–1974 period. Allowing for cohort size changes after 1960 (experiment 7) and for those changes combined with fertility change (experiment 8), while expanding the size of the economy, leaves service-sector shares of output, capital, and employment unchanged. By themselves, these supply-side factors cannot account for any part of the relative growth of the service sector.

Technological change and price changes that occurred after 1960 had opposite effects on sectoral growth—technological change (experiment 9) increased the service-sector share of output, capital, and employment through the 1968–1984 period and then reduced the share, while price changes (experiment 10) reduced the service-sector shares up to that point and then increased the share.[57] The combined effect (experiment 11) led to an increase in

[54]Table available on request.

[55]The aggregate shock in the z-process is fixed also at the 1960 value. For the economy to reach a steady state, all existing cohorts as of 1960 must die off.

[56]Thus, we assume that the aggregate shocks are those that occurred after 1960. This yields a particular realization for the economy.

[57]It is not clear that these separate effects are meaningful, because prices would be affected by technological change to the extent that the latter is somewhat global.

TABLE XI

THE EFFECT OF EXOGENOUS COHORT SIZE, FERTILITY, PRICES, AND TECHNICAL CHANGE ON SECTORAL OUTPUT, CAPITAL, EMPLOYMENT, AND SERVICE-SECTOR SHARES

	Predicted		Counterfactual Experiments[a]											
			6		7		8		9		10		11	
Year	Goods	Services	Goods	Services	Goods	Services	Goods	Services	Goods	Services	Goods	Services	Goods	Services
							Output[b]							
1968–1974	1.03	1.98	0.80	1.44	0.87	1.58	0.88	0.64	1.53	1.12	0.85	0.82	1.31	1.14
Service share	0.66		0.64		0.65		0.65		0.42		0.49		0.46	
1975–1979	1.18	2.39	0.83	1.55	0.99	1.83	1.03	1.97	1.05	1.92	1.34	0.56	1.47	1.37
Service share	0.67		0.65		0.65		0.66		0.64		0.29		0.48	
1980–1984	1.26	2.80	0.85	1.60	1.14	2.07	1.19	2.28	0.85	2.35	1.56	0.44	1.45	1.54
Service share	0.69		0.65		0.65		0.66		0.73		0.22		0.52	
1985–1989	1.35	3.59	0.89	1.68	1.30	2.36	1.37	2.67	1.41	2.49	1.11	0.60	1.37	1.90
Service share	0.73		0.65		0.65		0.66		0.64		0.35		0.58	
1990–1994	1.38	4.20	0.90	1.72	1.42	2.60	1.50	2.97	1.73	2.47	0.86	0.73	1.22	2.17
Service share	0.75		0.66		0.65		0.66		0.59		0.46		0.64	
1995–2000	1.59	5.21	0.97	1.79	1.65	2.95	1.75	3.41	2.58	2.73	0.63	0.79	1.15	2.63
Service share	0.77		0.65		0.64		0.66		0.51		0.56		0.69	
							Capital[b]							
1968–1974	0.15	4.58	0.80	3.64	0.87	3.98	0.88	4.12	1.62	2.38	0.91	2.15	1.48	2.58
Service share	0.80		0.82		0.82		0.82		0.59		0.70		0.64	
1975–1979	1.37	5.02	0.82	3.85	0.98	4.56	1.01	4.89	1.13	3.70	1.45	1.49	1.72	2.87
Service share	0.79		0.83		0.82		0.82		0.76		0.50		0.62	
1980–1984	1.54	5.69	0.83	3.94	1.11	5.08	1.15	5.60	0.85	2.35	1.71	1.16	1.79	3.15
Service share	0.79		0.83		0.82		0.83		0.82		0.41		0.64	

Continues

TABLE XI—*Continued*

	Predicted		Counterfactual Experiments[a] 6		7		8		9		10		11	
Year	Goods	Services	Goods	Services	Goods	Services	Goods	Services	Goods	Services	Goods	Services	Goods	Services
							Capital[b]							
1985–1989	1.57	6.67	0.87	4.13	1.27	5.79	1.33	6.54	1.65	4.72	1.08	1.41	1.61	3.56
Service share	0.81		0.83		0.82		0.83		0.74		0.57		0.69	
1990–1994	1.65	7.85	0.87	4.18	1.38	6.32	1.46	7.23	2.12	4.77	0.82	1.69	1.46	4.09
Service share	0.83		0.83		0.82		0.83		0.69		0.67		0.74	
1995–2000	1.84	9.03	0.95	4.38	1.60	7.22	1.71	8.34	3.36	5.51	0.54	1.63	1.32	4.61
Service share	0.83		0.82		0.82		0.83		0.62		0.75		0.78	
							Employment[b]							
1968–1974	0.89	1.47	0.73	1.06	0.81	1.18	0.83	1.24	1.40	0.84	0.84	0.72	1.09	0.87
Service share	0.62		0.59		0.60		0.60		0.40		0.46		0.44	
1975–1979	1.00	1.82	0.76	1.12	0.93	1.36	0.98	1.50	0.83	1.35	1.25	0.50	1.14	1.02
Service share	0.65		0.60		0.59		0.61		0.62		0.29		0.47	
1980–1984	1.09	2.18	0.77	1.15	1.06	1.53	1.13	1.74	0.65	1.68	1.47	0.37	1.13	1.14
Service share	0.67		0.60		0.59		0.61		0.72		0.20		0.50	
1985–1989	1.11	2.59	0.81	1.19	1.20	1.71	1.29	1.99	0.94	1.61	1.17	0.54	1.03	1.31
Service share	0.70		0.60		0.59		0.61		0.63		0.32		0.56	
1990–1994	1.09	2.91	0.81	1.21	1.30	1.85	1.40	2.17	1.15	1.49	0.91	0.69	0.90	1.45
Service share	0.73		0.60		0.59		0.61		0.56		0.43		0.62	
1995–2000	1.18	3.36	0.88	1.25	1.50	2.07	1.62	2.44	1.55	1.39	0.72	0.83	0.83	1.67
Service share	0.73		0.59		0.58		0.60		0.47		0.54		0.67	

[a]Counterfactual experiments: 6, steady state: cohort size, prices, fertility, and technology fixed at 1960 levels; 7, only cohort size not fixed; 8, cohort size and fertility not fixed; 9, technology not fixed; 10, prices not fixed; 11, technology and prices not fixed.

[b]Normalized by 1968 goods-sector levels.

TABLE XII

THE EFFECT OF EXOGENOUS COHORT SIZE, PRICES, TECHNICAL CHANGE, AND FERTILITY ON SKILL RENTAL PRICES (ANNUAL PERCENTAGE CHANGES)

	1968–1980							1981–2000						
		Counterfactual Experiments[a]							Counterfactual Experiments[a]					
	Predicted	6	7	8	9	10	11	Predicted	6	7	8	9	10	11
Goods sector														
White collar	0.32	−0.13	−0.11	−0.12	−0.14	0.85	0.80	0.71	−0.03	−0.08	−0.05	2.17	−1.72	0.49
Pink collar	0.26	−0.10	−0.10	−0.26	0.05	0.63	0.55	0.56	−0.05	−0.06	−0.02	1.92	−1.31	0.57
Blue collar	−0.20	−0.03	−0.04	−0.16	−0.14	1.36	0.43	−0.42	0.02	0.04	0.02	1.69	−2.11	−0.86
Service sector														
White collar	0.62	−0.20	−0.13	−0.14	1.84	−0.96	1.21	0.46	−0.12	−0.21	−0.21	0.68	−0.23	0.63
Pink collar	0.43	−0.14	−0.18	−0.02	1.63	−0.72	1.14	0.29	0.05	0.08	0.08	0.63	−0.18	0.38
Blue collar	−0.36	−0.07	−0.13	−0.13	0.45	−0.36	0.31	0.07	−0.01	0.05	0.06	0.54	−0.55	0.03

[a] Experiment numbers are defined in Table XI.

the service-sector share of output (employment) over the entire period from 0.46 (0.44) in 1968–1974 to 0.69 (0.67) in 1995–2000, a much larger percentage point increase than actually occurred. Given these results, it appears that the growth of the service sector occurred primarily because of demand-side changes.

Table XII shows the effects of these demand and supply factors on skill rental prices. As seen, white- and pink-collar skill rental prices were increasing between 1968 and 1980 in both sectors, while blue-collar skill rental prices were declining. As experiment 8 shows, factors that increased the supply of labor actually reversed the positive trend in white- and pink-collar skill rental prices and reduced the fall in blue-collar skill prices. A similar effect is observed for the 1981–2000 period, namely that supply-side factors made relative skill prices less trended. Demand-side factors, during the earlier period (experiment 11), led to a larger positive trend in skill rental prices in both sectors and in all occupations. During the later periods, these factors tended to make skill rental prices in the goods sector rise less rapidly (white collar) or fall more quickly (blue collar). At the same time, however, they tended to make rental prices rise more rapidly in the service sector.

7. CONCLUSIONS

We have developed and estimated a multisector multioccupation competitive equilibrium model of the U.S. labor market with both idiosyncratic shocks to preferences, and skill and aggregate production shocks. The model was intended to capture the major shift in the industrial structure of the U.S. economy toward the production of services rather than goods that has occurred over the last 50 years. Over that period of marked change, the hourly wage within the service sector remained roughly constant relative to the wage within the goods sector. Given this constancy, we considered the conjecture that labor was able to move easily between sectors at little or no economic cost. Using the estimates of our equilibrium model, we quantified the cost of sectoral mobility at the individual and aggregate levels. It turned out to be large in both cases. At the individual level, the estimated direct mobility cost (psychic and monetary) ranged generally between 50 and 75 percent of average annual earnings. At the aggregate level, our estimates implied that, based on a counterfactual experiment, output in both sectors would have been double their current levels if these mobility costs had been zero.

The rise in the service sector has been attributed to a number of possible supply and demand factors. We quantified the relative importance of these factors. Between 1968 and 2000, the service sector share of employment rose by 17 percentage points (from 0.58 to 0.75). Our counterfactual experiments indicated that if all else had remained the same at their 1960 levels except for supply-side factors, cohort size, and fertility, there would have been no change in the service-sector employment share over the period. On the other hand, had only demand factors, production technology, and product and capital prices changed since 1960, leaving the supply-side factors at their 1960 levels, the service-sector share of employment would have increased by 27 percentage points.

On a methodological note, analyzing the extent to which the quantitative assessments in this paper are affected by specific model features, ranging from market structure to functional form and error distribution assumptions, would require the reestimation of the model under alternative specifications. In making some choices, we have been guided by theory, by the previous empirical literature, and by inductive use of model fit, while in others the choice was based on tractability. Other researchers would perhaps have chosen differently. As tractability becomes less of an issue, due to advances in methods and computation, it will become easier to ascertain the robustness of our results to the many alternatives available.

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APPENDIX: PARAMETER ESTIMATES

In all appendix tables, the asymptotic standard errors are given in parentheses. Equation numbers in the titles refer to the text.

TABLE A.1

PRODUCTION FUNCTION (1)

	Service	Goods
σ	0.251 (0.0055)	0.182 (0.0035)
ν	−0.016 (0.0136)	0.118 (0.0112)
α_{10}	0.256 (0.0050)	0.042 (0.0024)
α_{11}	0.003 (0.0003)	0.001 (0.0002)
α_{12}	−0.002 (0.0002)	0.002 (0.0003)
α_{20}	0.449 (0.0055)	0.594 (0.0097)
α_{21}	−0.008 (0.0002)	−0.003 (0.0004)
α_{22}	−0.002 (0.0003)	−0.010 (0.0005)
α_{30}	0.213 (0.0045)	0.268 (0.0096)
α_{31}	0.007 (0.0004)	0.001 (0.0004)
α_{32}	0.004 (0.0003)	0.007 (0.0006)
$\alpha_{3t} = (1 - \alpha_{1t} - \alpha_{2t})\lambda_t$		

TABLE A.2

PRODUCTION SHOCKS (2)

	Service		Goods
ϕ_0	−0.0022 (0.0050)		−0.0155 (0.0055)
ϕ_G	−0.5274 (0.1917)		−0.4176 (0.2136)
ϕ_R	0.9424 (0.1654)		0.5192 (0.1842)
σ_{GG}		0.00061	
σ_{GR}		0.00040	
σ_{RR}		0.00055	

TABLE A.3

BUDGET CONSTRAINT[a] (4)

Tuition Cost $\beta_1 = 18{,}664$ (246)
$\beta_2 = 11{,}400$ (491)
Mobility Cost δ_{jk}

	From Choice k							
To Choice j	1	2	3	4	5	6	7	8
Male 1	0	7,238	6,375	9,655	16,893	16,030		
		(560)	(504)	(359)				
2	4,649	0	3,203	14,304	9,655	12,858		
	(405)		(270)					
3	3,692	4,868	0	13,347	14,523	9,655	12,191	15,528
	(314)	(432)					(315)	(315)
4	9,305	13,125	12,401	0	3,820	3,096		
	(316)				(287)	(228)		
5	13,655	9,305	14,631	4,350	0	5,326		
				(343)		(331)		
6	13,320	15,951	9,305	4,015	6,646	0		
				(250)	(484)			
Female 1	0	3,478	805	6,680	10,158	7,485	10,688	11,121
		(263)	(90)	(349)			(297)	(321)
2	1,861	0	4,701	8,541	6,680	11,381		
	(166)		(462)					
3	3,337	7,355	0	10,017	14,036	6,680		
	(374)	(631)						
4	7,249	8,299	9,048	0	1,049	1,799		
	(258)				(98)	(180)		
5	12,283	7,249	11,195	5,034	0	3,945		
				(290)		(284)		
6	11,413	9,658	7,249	4,164	2,409	0		
				(341)	(203)			

[a] Restrictions: The cost of changing both sector and occupation is the sum of changing sectors with the same occupation and changing occupation within the sector. The cost of moving from home or school to employment is independent of sector and occupation.

TABLE A.4

SKILL PRODUCTION FUNCTIONS (5) AND RETIREMENT PROCESS[a] (6)

	j						Type Probability		
							Initial Schooling <10	Initial Schooling ≥10	Retirement Probability ω_5
	1	2	3	4	5	6			
Male									
ω_{01}^j	0	0	0	0	0	0	0.04	0.07	0.122
ω_{02}^j	−0.38	−0.32	0.11	−0.28	−0.31	0.04	0.69	0.32	(0.008)
	(0.064)	(0.049)	(0.018)	(0.023)	(0.022)	(0.019)	(0.011)	(0.011)	
ω_{03}^j	0.06	0.29	0.10	−0.09	0.15	0.18	0.10	0.40	
	(0.030)	(0.026)	(0.022)	(0.024)	(0.018)	(0.020)	(0.005)	(0.012)	
ω_{04}^j	0.25	0.24	−0.06	0.22	−0.12	−0.46	0.17	0.21	
	(0.027)	(0.029)	(0.065)	(0.018)	(0.040)	(0.101)	(0.006)	(0.007)	
Female									
ω_{01}^j	−0.50	−0.14	−0.37	−0.27	−0.18	−0.40	0.19	0.12	0.113
	(0.019)	(0.019)	(0.010)	(0.011)	(0.013)	(0.011)			(0.010)
ω_{02}^j	−0.88	−0.46	−0.26	−0.55	−0.48	−0.36	0.63	0.32	
							(0.014)	(0.013)	
ω_{03}^j	−0.44	0.15	−0.27	−0.35	−0.03	−0.22	0.09	0.28	
							(0.007)	(0.011)	
ω_{04}^j	−0.25	0.10	−0.43	−0.05	−0.30	−0.86	0.10	0.28	
							(0.006)	(0.009)	
ω_1^j	0.054	0.046	0.027	0.076	0.047	0.044			
ω_2^{jk}	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)			
$k=1$	0.058	0	0	0.022	0	0			
	(0.004)			(0.001)					
2	0.021	0.028	0	0.005	0.007	0			
	(0.002)	(0.002)							
3	0.014	0.011	0.035	0.003	0.002	0.013			
	(0.001)	(0.001)	(0.001)						
4	0.015	0	0	0.080	0	0			
	(0.001)			(0.003)					
5	0.005	0.007	0	0.017	0.026	0			
				(0.001)	(0.001)				
6	0.004	0.003	0.009	0.010	0.009	0.046			
				(0.001)	(0.001)	(0.002)			
ω_3	0.35	0.44	0.63	0.44	0.47	0.55			
	(0.016)	(0.023)	(0.019)	(0.014)	(0.015)	(0.020)			
ω_4	0.015	0.018	0.018	0.018	0.015	0.012			
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)			
σ_η	0.38	0.32	0.32	0.44	0.36	0.38			
	(0.010)	(0.010)	(0.006)	(0.008)	(0.008)	(0.007)			

[a]Restriction: $\omega_{0h}^j - \omega_{01}^j$ is the same for males and females; $h = 2, 3, 4$ and $j = 1, 2, 3, 4, 5, 6$.

TABLE A.5

UTILITY PARAMETERS[a] (3)

	Male	Female
γ_1	0	0
γ_2	1,022 (115)	309 (92)
γ_3	−817 (94)	−303 (72)
γ_4	2,638 (128)	568 (89)
γ_5	3,881 (160)	1,997 (92)
γ_6	1,772 (118)	2,189 (108)
γ_{71}^1	9,503 (250)	11,276 (301)
γ_{72}^1	7,181 (224)	8,521
γ_{73}^1	7,365 (233)	8,740
γ_{74}^1	16,928 (466)	20,087
$\gamma_{7h}^2/\gamma_{7h}^1$	0.72 (0.034)	0.59 (0.030)
$\gamma_{7h}^3/\gamma_{7h}^1$	0.83 (0.081)	1.34 (0.121)
γ_{810}	14,950 (313)	12,590 (228)
γ_{820}	19,152 (243)	16,128
γ_{830}	22,043 (411)	18,562
γ_{840}	21,504 (509)	18,108
γ_{81}	942 (115)	10,259 (347)
γ_9	4,473 (172)	10,133 (311)
γ_{10}	26,987 (509)	27,540 (756)
γ_{11}	8,051 (273)	11,356 (442)
$\sigma_{77}^{\varepsilon}$	5,243 (182)	5,792 (220)
$\sigma_{88}^{\varepsilon}$	14,606 (266)	12,789 (227)

[a]Restriction: $\log(\gamma_{7h}) - \log(\gamma_{71})$ for males $= \log(\gamma_{7h}) - \log(\gamma_{71})$ for females; $\log(\gamma_{8h0}) - \log(\gamma_{810})$ for males $= \log(\gamma_{8h}) - \log(\gamma_{810})$ for females; $h = 2, 3, 4$.

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