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Skill-Biased Technical Change and the Cost of Higher Education

John Bailey Jones
Department of Economics
University at Albany - SUNY
jbjones@albany.edu

Fang Yang *
Department of Economics
University at Albany - SUNY
fyang@albany.edu

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Abstract

We document trends in higher education costs and tuition over the past 50 years. To explain these trends, we develop and simulate a general equilibrium model with skill- and sector-biased technical change. We assume that higher education suffers from Baumol's (1967) service sector disease, in that the quantity of labor and capital needed to educate a student is constant over time. Calibrating the model, we show that it can explain the rise in college costs between 1961 and 2009. We then use the model to perform a number of numerical experiments. We find, consistent with a number of studies, that changes in the tuition discount rate have little long-run effect on college attainment.

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1 Introduction

For most American families, the cost of a college education is a significant expense. College tuition has grown faster than inflation for decades. Attendance rates have slowed even as the college wage premium has soared (Goldin and Katz, 2008). Many observers fear that, in the words of a recent CNN headline (Censky, 2011), "surging college costs price out [the] middle class". In this paper, we develop a simple model that explains why college costs have risen so dramatically, and consider its implications.

We begin by documenting trends in higher education costs and tuition over the past 40 years. The data show that the total cost of educating a student has risen at roughly the same rate as per capita GDP. Since 1950, listed or "sticker price" tuition has grown more quickly than GDP, while tuition net of grant aid has risen at the same rate. To explain the cost trend, we develop and simulate a general equilibrium model with skill- and sector-biased technical change. In our model, higher education suffers from the service sector disease (Baumol and Bowen, 1966; Baumol, 1967). In particular, we assume that the quantity of skilled labor needed to produce a college degree is constant across time, even as it becomes more productive in other sectors. The data appear consistent with such an assumption. For example, in 1976 there were 16.6 students for each college faculty member; in 2009 the number had fallen only slightly to 16.0.[1] As potential college professors and administrators become more productive in other sectors, their wages, and the cost of college education, will rise. Our model successfully replicates the dramatic increase in higher education costs.

Our paper straddles two areas of research. The first is the industry-level analysis of higher education costs and tuition. There are a number of explanations for the increase in college costs and tuition: Archibald and Feldman (2011) provide a lucid review. One explanation is the service sector disease discussed above. An alternative explanation is that institutions of higher education have become increasingly inefficient. The inefficiencies arise from market power and public subsidies that allow colleges to pad their expenses (e.g., Bowen, 1980), or costly "arms races." Harris and Goldrick-Rab (2010) argue that because higher education practices are not objectively analyzed, significant inefficiencies almost surely exist. Other explanations focus on the tuition colleges charge, rather than the costs they incur. One such explanation is increased price discrimination. Many institutions, especially private ones, post a "sticker price" well in excess of the discounted tuition most students actually pay. Increasing the sticker price has allowed colleges to

[1] 2010 *Digest of Education Statistics*, Table 254. Ratios expressed in full-time equivalent terms.

offer a broader menu of net prices, increasing their ability to price discriminate. Although some students may face the full sticker price, the prices most students pay have risen more slowly. Yet another explanation is that decreased public funding has forced schools to raise tuition.

In their recent book, Archibald and Feldman (2011) conclude that the service sector disease plays a central role. They show that the cost trajectory of higher education is similar to that of other high-skill services, and that costs have risen rapidly at community colleges as well as at Ivy-league institutions. We show that in a general equilibrium model, this form of biased technical change generates an increase in college costs similar to those actually observed. We believe our model can make quantitative predictions of college tuition.

The second area of research consists of general equilibrium analyses of human capital accumulation and earnings dynamics. Ljungqvist (1993) argues that because the cost of providing education depends on the cost of skilled labor, education may be particularly expensive in countries where the current level of educational attainment is low. In contrast to Ljungqvist (1993), who uses theoretical arguments, most of this literature is quantitative. In an influential paper, Heckman, Lochner and Taber (1998a) show that sustained skill-biased technological change can explain the changes in education and earnings observed over the past few decades. Lee and Wolpin (2006, 2010) consider similar topics. Akyol and Athreya (2005) emphasize that investments in college are risky: drop-out rates are high. Gallipoli, Meghir and Violante (2010) analyze tuition schedules that vary with income and ability. Our contribution is to determine the cost of higher education within the model, allowing it to adjust to economic events.

The paper most similar to ours is Castro and Coen-Pirani (2011), who also allow the cost of college to be a direct function of the wage for skilled labor. The two papers differ along a number of modelling dimensions,[2] and more important, in emphasis: we focus on college costs, while Castro and Coen-Pirani focus on educational attainment.

In addition to explaining the cost trends, our model allows us to assess the effect of higher tuition on college attainment. The model suggests that the long-term effects of changing tuition subsidies are small. Increasing the tuition discount rate by 1% increases enrollment by only 0.08%. Although many micro-level estimates, such as Dynarski (2003), suggest a much higher elasticity, our findings are consistent with the structural literature. As Heckman, Lochner and Taber (1998b) emphasize, once the price of skilled labor is

[2] Most notably, our model includes physical capital, while Castro and Coen-Pirani use a richer model of human capital.

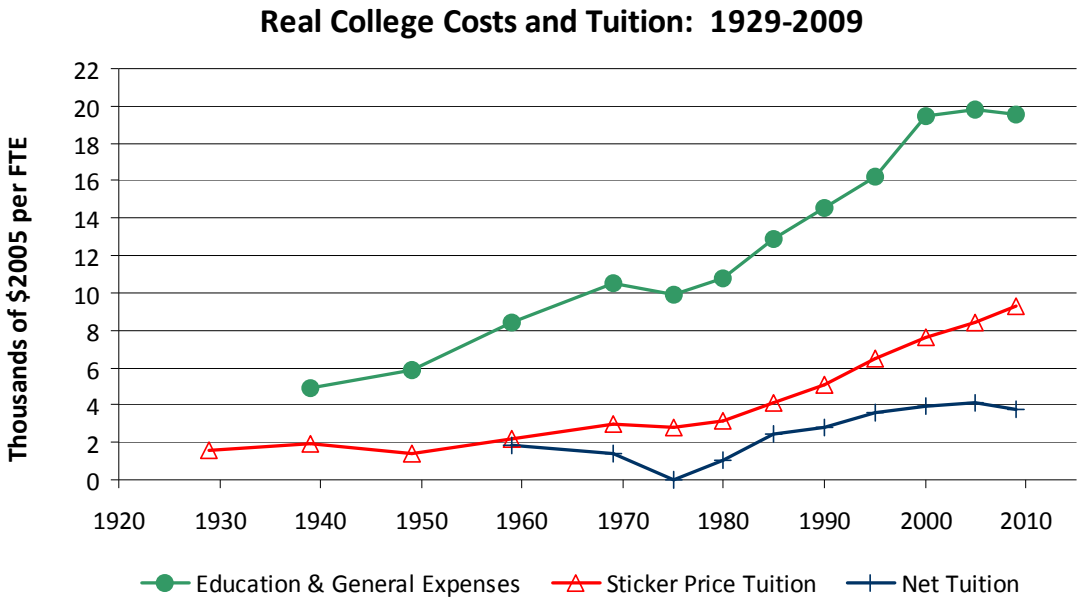

Figure 1

allowed to adjust in general equilibrium, the effects of policy changes are often muted.

The rest of the paper is organized as follows. In Section 2, we summarize historical patterns of higher education costs and pricing. In Section 3, we describe our model. In Section 4 we discuss how we calibrate the model. In Section 5, we use the model to perform a few policy experiments. In Section 6 we discuss some extensions to the model and conclude.

2 Higher Education Data

In this section, we present data related to higher education: costs, prices, enrollment, and returns. We use these data to motivate the structure of our model, and as calibration targets for our quantitative exercises.

2.1 Expenditures and Tuition

In considering "college costs", it is useful to distinguish between three distinct objects: (1) expenditures, the costs incurred in educating students; (2) the listed or "sticker" price for tuition; and (3) the net tuition students pay after receiving financial aid.

The top line in Figure 1 shows real expenditures per full-time-equivalent (FTE) student

for the higher education sector, including 2-year, 4-year and graduate students. These data are drawn from the U.S. Department of Education's Digest of Education Statistics, and converted to 2005 dollars with the GDP deflator. The data are measured over academic years, July 1 - June 30, which we index by the initial calendar year.[3] We focus the subset of costs included in the education and general category. Among the costs excluded from this category are auxiliary operations such as dormitories.[4] Average expenditures have more than trebled over time, from under $5,000 in 1939 to almost $20,000 today. Perhaps the most notable feature of the series in that between 1969 and 1975 costs actually fell slightly, before returning to their upward trend. Archibald and Feldman (2011) stress that during this time period the U.S. was still in what Goldin and Margo (2005) call the "Great Compression", during which relative wages for educated workers fell.

Figure 1 shows sticker price tuition per FTE over the same time period. Consistent with the cost measures, we calculate sticker price tuition as tuition revenues divided by FTE, again using data from the Digest of Education Statistics.[5,6] After falling between 1939 and 1949, sticker price tuition has risen more rapidly than expenditures. Most college students, however, receive some form of grant aid, either from the institution itself, or some external source such as the Federal government. Using data from the College Board (2010), we calculate average student grant aid.[7] Subtracting aid from sticker price tuition yields net tuition. The bottom line in Figure 1 shows net tuition. Net tuition has grown more slowly over time than sticker prices, suggesting that the increase in sticker prices is at least partly intended to increase the scope for price discrimination. Net tutition was particularly low in the 1970s, when many veterans received assistance. A striking feature of sticker price and especially net tuition is that they are quite low relative to expenditures. Although state aid to public institutions has not increased over time (in real per FTE terms), it is still significant. Federal grants are also a major source of

[3] Constructing the full series requires several splices: prior to 1967, costs are measured on a per-fall-enrollee basis, and after 1995 the data definitions were modified.

[4] One quirk of education and general expenditures is that they include institutional "scholarships and fellowships": rather than being deducted from tuition revenue, institutional aid is treated as an expense. In the cost series shown in Figure 1 we deduct these expenses: the effects of this adjustment are discussed in the data appendix. The data also exclude interest expenditures, which are not considered operating expenses.

[5] The Digest of Education Statistics also includes undergraduate tuition indices, which begin in 1964-65. We compare the tuition measures in the data appendix.

[6] This series also requires splicing per-FTE and per-enrollee data.

[7] Our calculations omit tax benefits. In recent years, the Federal income tax credits for higher education have grown rapidly (College Board, 2010). Aid data for 1959 are found by extrapolating backward from 1963.

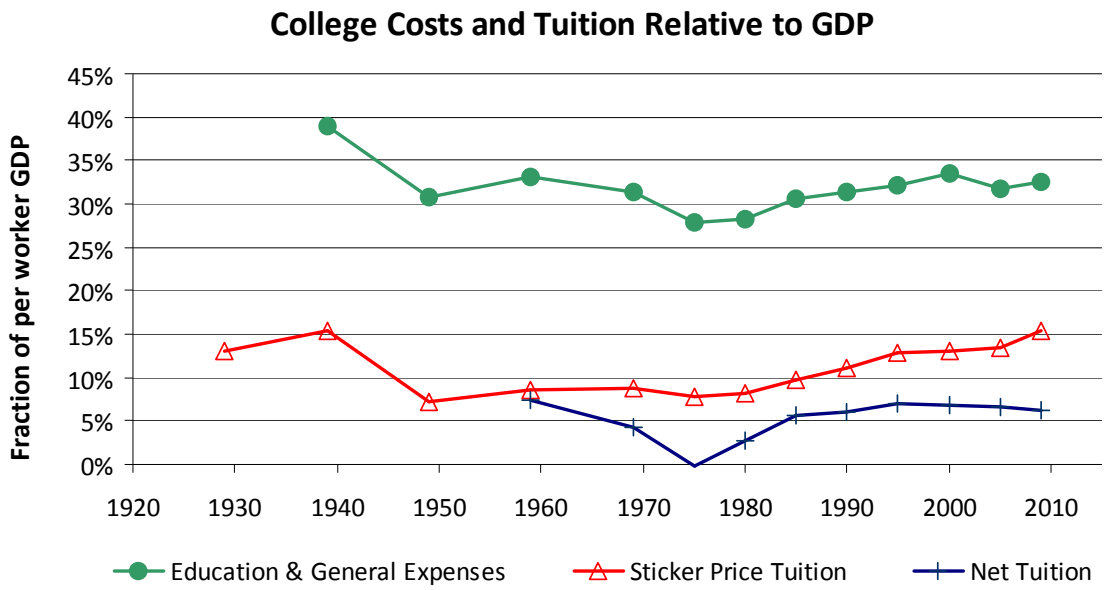

Figure 2

income, even at private institutions.

Figure 2 shows the same costs and tuition as fractions of per capita GDP, which is constructed from the national accounts and Census data.[8] These data show that, with the exception of 1939, education and general expenditures have stayed between 27 and 34 percent of per capita GDP. This is consistent with the hypothesis that higher education has enjoyed few productivity gains over the past few decades. After falling dramatically between 1929 and 1949, sticker price tuition has grown faster than GDP, while net tuition has grown at the same rate. The net tuition ratio, being a function of averages, need not imply that higher education is as "affordable" today as it was in the past. Median income has grown far more slowly than per capita GDP, and tuition varies widely across students (Leonhardt, 2009).

The data in Figures 1 and 2 are averages taken across both public and private institutions, with the latter including for-profit institutions as well as traditional non-profit schools. These averages also combine data for 2-year and 4-year institutions. Figure 3 shows disaggregated expenditure data, expressed as a fraction of GDP. Perhaps the most notable feature of the data is the steady rise in expenditures at private not-for-

[8] Consistent with the model below, our measure of population consists of people aged 18-74. Calculating per capita GDP total population makes the series in Figure 2 more variable, but does not change their general properties. To be consistent with academic years, we use averages of consecutive calendar-year values.

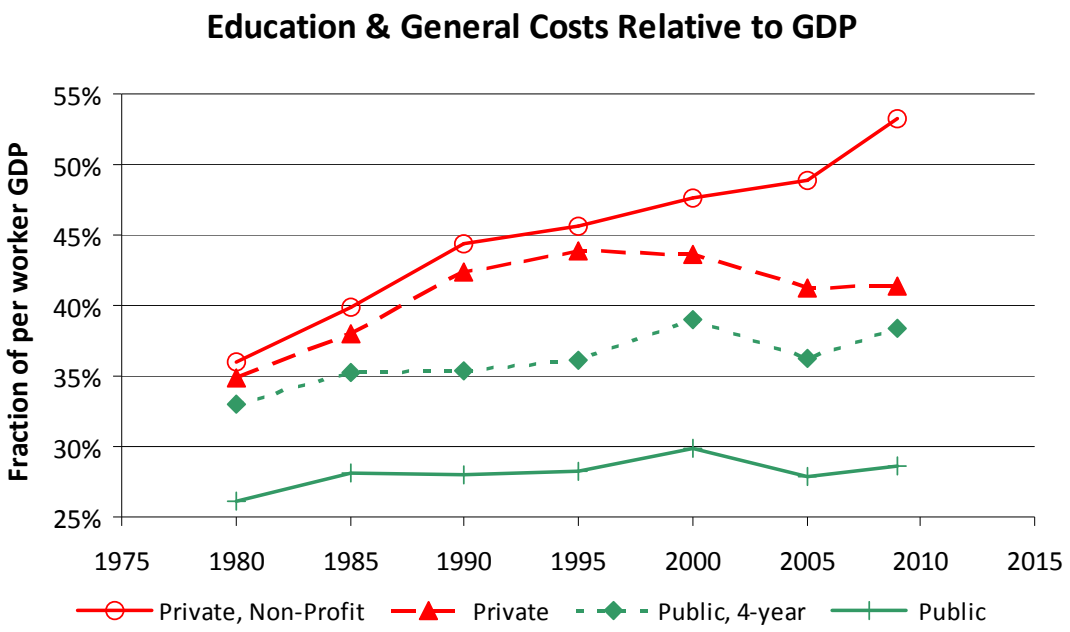

Figure 3

profit institutions. Such an increase is consistent with the argument that elite private institutions are engaging in expensive "arms races". Figure 3 also shows expenditures for all private institutions. In the recent decade for-profit institutions have grown rapidly, from 4 percent of private enrollment in 1980 to 33 percent in 2009. Because for-profit institutions tend to have lower costs, their growth has pulled down average expenditures in the private sector. Although separate cost data for 2-year and 4-year institutions are available only for public institutions, about 90 percent of 2-year students are in public colleges. Figure 3 reveals that once 2-year public institutions are excluded, public and private institutions have fairly similar levels of expenditure. Figure 3 also shows that the expenditures at 2-year public colleges follow a trajectory similar to that at 4-year public institutions; Archibald and Feldman (2011) view this as evidence against the arms race hypothesis.

Figure 4 displays disaggregated sticker price tuition. The distinction between non-profit and for-profit private institutions is more modest. Although for-profit institutions have lower costs, they rely more heavily on tuition revenue. Since 1992, the first year disaggregated revenue data are available, tuition for 4-year public institutions has risen relative to tuition for 2-year public institutions; we use the 1992 tuition ratio to infer 4-year tuition for earlier years.

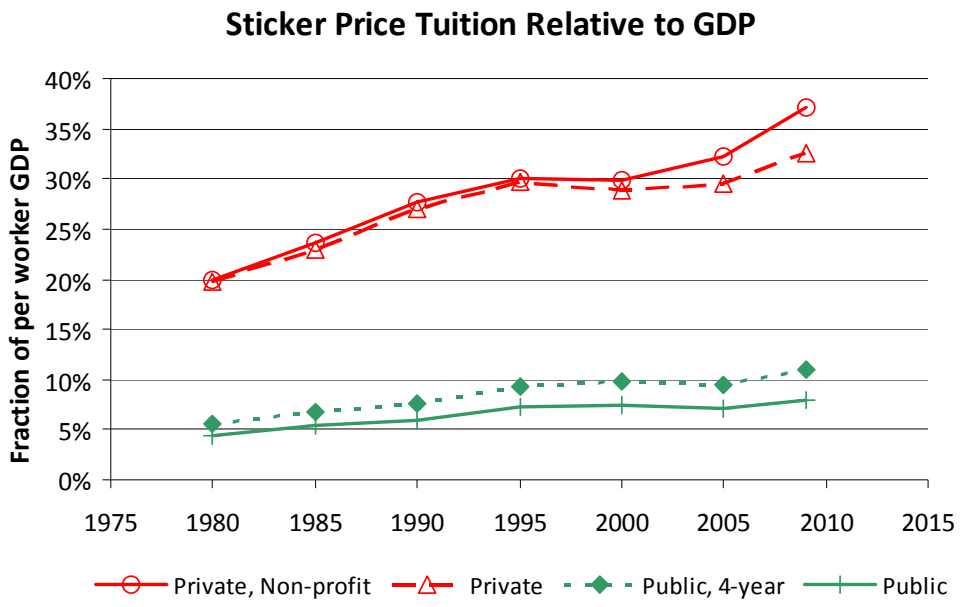

Figure 4

2.2 Staffing and Compensation

Table 1 shows staffing levels, measured as the ratio of students (in FTE) to employees (in FTE), as shown in the Digest of Education Statistics. Both overall and faculty staffing levels have remained roughly constant during the past three decades. The most notable change has been a reduction in non-professional staff in favor of non-faculty professionals. Assuming that worker quality has stayed constant as well, these constant staffing levels are consistent with our hypothesis that higher education has not enjoyed any efficiency gains.

Turning to costs per worker, data from the Digest of Education Statistics shows that faculty compensation has grown slowly. Figure 5 shows that salaries for full-time instructional faculty have in fact fallen relative to GDP. Controlling for faculty rank and including benefits (not rank-differentiated) does not change the trend. Figure 6 reveals ongoing changes in faculty composition. The fraction of instructional faculty that are full-time employees has fallen steadily, from 78% in 1970 to 51% in 2007. Figure 6 also shows that during the 1960s and 1970s, the share of faculty and students associated with 2-year colleges increased.

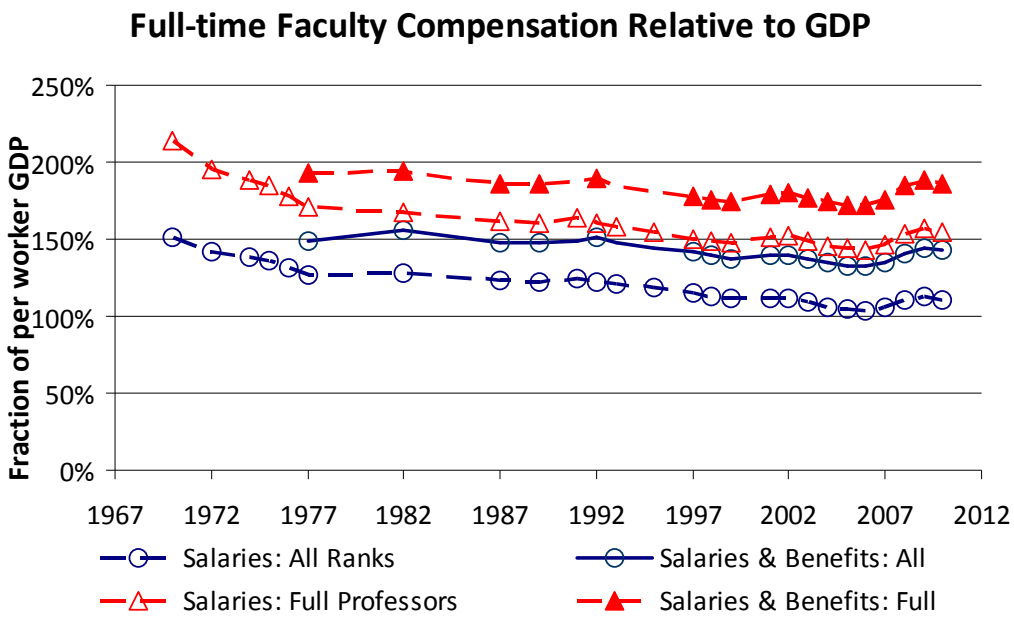

Figure 5

Table 1. Employees per Student			
	1976	1999	2009
All	0.185	0.209	0.186
Professional staff	0.102	0.134	0.132
Administrative	0.012	0.014	0.015
Faculty	0.060	0.067	0.062
Graduate assistants	0.010	0.009	0.009
Other professionals	0.020	0.043	0.046
Non-professional staff	0.084	0.075	0.054
Note: All quantities in FTE terms.			

While these trends have almost surely reduced the growth in college costs, interpreting them is difficult. The trends may well reflect a decline in the human capital embodied in college instructors. Alternatively, they may reflect idiosyncratic features in the specialized academic job market. Moreover, it is not clear whether reductions in human capital imply reductions in educational quality, as assumed by Castro and Coen-Pirani (2011), or simply reductions in costs. In the model below, our identifying assumption will be that providing a college education requires a fixed amount of skilled labor, with no changes in

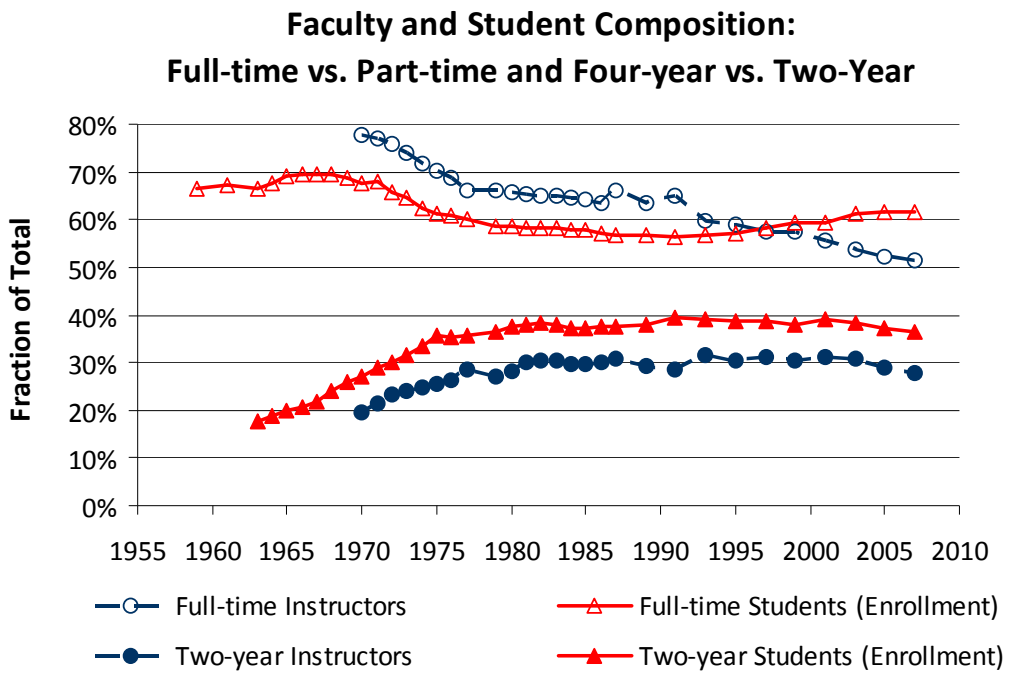

Figure 6

either efficiency or quality.

The reduction of non-professional staff in favor of non-faculty professionals has probably raised staffing costs. Unfortunately, the data do not provide compensation information for non-instructional employees.

2.3 Capital

The Digest of Education Statistics reports total physical plant in the higher education sector for selected years between 1899-1900 through 1994-95. Unfortunately, these data do not divide capital between "education and general uses", as opposed to auxiliary "current fund" uses such as dormitories.[9] Assuming capital is proportional to operating cost, Table 2 shows real, educational and general-related, physical plant per FTE. While it varies greatly from decade to decade, over the long-term physical plant is more or less constant. The data show that because capital use is constant, while real wages are rising, user costs (here calculated as 9 percent of plant) are a shrinking fraction of total expenditures.

[9] Another limitation of the Department of Education's capital data is that it capital is measured at book, or historical cost. We convert the book values into current cost values on the basis of the Bureau of Economic Analysis' fixed asset data for equipment and non-residential structures.

Table 2. Expenditures and Physical Plant			
	Education & General Expenditures*	Education & General Capital*	User Cost / E&G Expenses
1929-30	4.14	17.02	37.0%
1939-40	5.08	21.75	38.6%
1949-50	6.02	17.07	25.5%
1959-60	8.75	25.44	26.2%
1969-70	11.21	30.96	24.9%
1975-76	10.44	29.10	25.1%
1980-81	11.35	27.31	21.7%
1985-86	13.66	25.36	16.7%
1990-91	15.55	27.02	15.6%
* Measured in 1,000s of $2005 per FTE.			

2.4 College Attainment and Earnings

Moving to the demand side of the higher education market, Figure 7 presents college attainment by year of birth, using the IPUMS implementation of the Current Population Survey.[10] Because most people have completed their undergraduate studies by the time they reach 30, we measure each cohort's attainment as the average across ages 28-32. Figure 7 shows that college attainment rose rapidly among the cohorts born between 1935 and 1950; this in part reflects financial aid provided to Vietnam war veterans (Angrist and Chen, 2011). Attainment fell slightly among the cohorts born between 1950 and 1960, rose rapidly among the cohorts born between 1960 and 1970, and has risen slowly ever since.

Another piece of the puzzle is earnings. Figure 8 shows the college premium for earnings and wages, again calculated from IPUMS CPS data.[11] We calculate the premium as ratio of the mean earnings (wages) of people aged 30-74 with at least a Bachelor's degree to the mean earnings (wages) of people aged 30-74 whose highest degree is a high school diploma. Figure 8 shows that in 1961 (the March 1962 survey), men with a Bachelor's

[10] Assuming the attainment rates have a quadratic trend and an autoregressive residual, we use the data for 1936-1979 to project attainment for people born between 1980 and 1990.

[11] Our construction of these variables, and especially the top-coding adjustment for income, most closely follows the approach in Heathcote, Perri and Violante (2011). In calculating hours, we convert interval responses into numerical values with the approach described in Abraham, Spletzer and Stewart (1998).

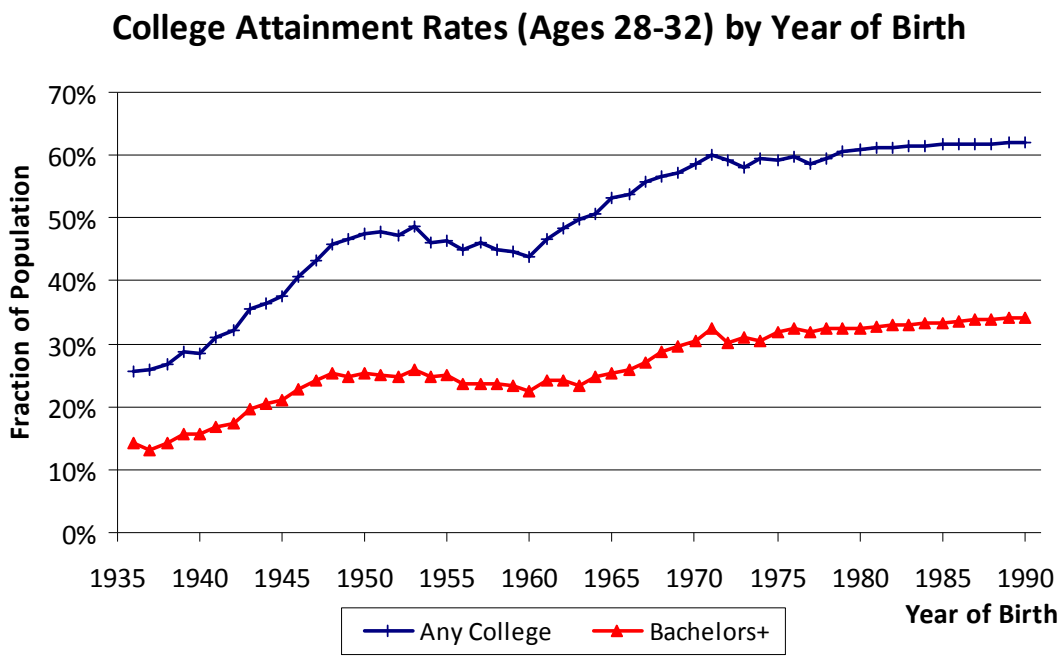

Figure 7

degree earned 118 percent more than high school graduates. By 2010, the premium had risen to 163 percent. During the same period, the college wage premium, which does not account for hours of work, rose from 58 percent to 93 percent. This rise in college premia is well-known. While the premia reflect differences in ability as well as human capital accumulation, they suggest that the returns to college are probably increasing.

2.5 Key Findings

Our review of the data reveals several trends:

- Expenditures per college student tend to grow at the same rate as per capita GDP.
- Since World War II, sticker price tuition has grown faster than GDP, while tuition net of grant aid has grown at the same rate.
- Since at least 1976, staffing at institutions of higher education has remained constant, although there have been changes in its composition.
- Capital per student has remained more or less constant over time.

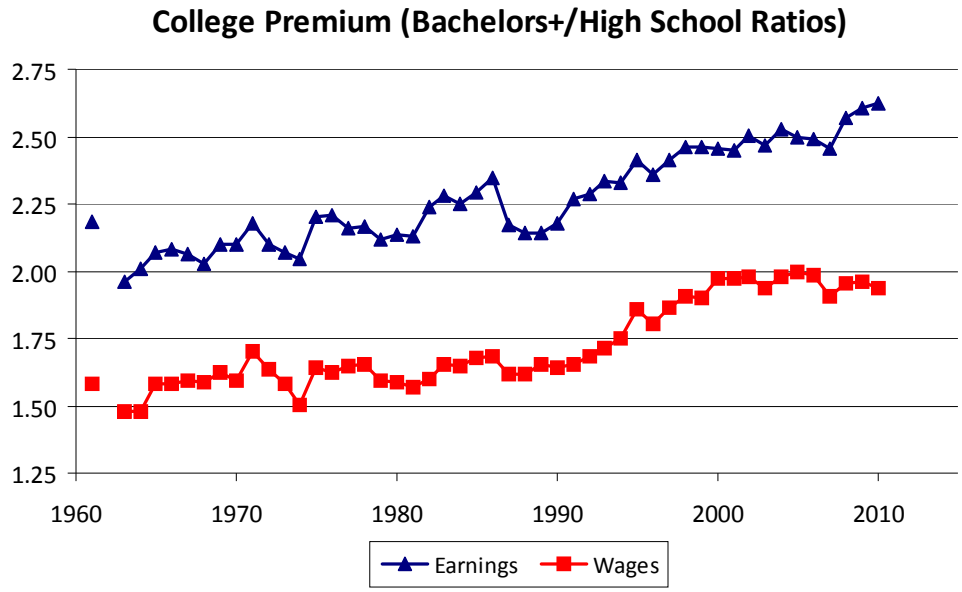

Figure 8

- Since 1965, the educational attainment of 30-year-olds, whether measured by attendance or 4-year degrees, has more than doubled.
- Since 1960, the earnings premium for college-educated workers has grown significantly.

3 Model

3.1 Goods sector

We consider an economy with two sectors: the goods-producing sector and an education sector. The goods sector produces output (Y_t) using two skill categories of workers, white-collar and blue-collar, and homogeneous capital. Specifically, production at time t is given by the nested CES form

$$Y_t = A_t K_t^{\alpha} [\omega_t W_t^{1-\varsigma} + (1-\omega_t) B_t^{1-\varsigma}]^{(1-\alpha)/(1-\varsigma)} \tag{1a}$$

$$= A_t K_t^{\alpha} L_t^{1-\alpha}, \tag{1b}$$

$$L_t \equiv [\omega_t W_t^{1-\varsigma} + (1-\omega_t) B_t^{1-\varsigma}]^{1/(1-\varsigma)}, \tag{1c}$$

where B_t denotes total units of blue-collar skill, W_t denotes white-collar skill, L_t denotes total labor inputs, K_t denotes capital, and A_t indexes aggregate productivity. The parameter ς governs the substitutability between white- and blue-collar labor (the elasticity of substitution is $1/\varsigma$). Heckman, et al. (1998a) estimate a version of this model where K_t and L_t are also nested in a CES aggregator, but find the elasticity of substitution for these two factors is close to 1. To capture skill-biased and skill-neutral technical change, we allow the weight ω_t and the shifter A_t to vary over time.

Firms are perfectly competitive. The equilibrium pricing conditions are:

$$r_t + \delta = \alpha \frac{Y_t}{K_t} = \alpha A_t \left(\frac{K_t}{L_t}\right)^{\alpha-1}, \tag{2}$$

$$w_t^B = (1-\alpha)(1-\omega_t)\frac{Y_t}{L_t}\left(\frac{B_t}{L_t}\right)^{-\varsigma}, \tag{3}$$

$$w_t^W = (1-\alpha)\omega_t \frac{Y_t}{L_t}\left(\frac{W_t}{L_t}\right)^{-\varsigma}, \tag{4}$$

where r is the real interest rate, δ is the depreciation rate, and w_t^B and w_t^W are the unit prices of blue-collar and white-collar skill, respectively. The skill price ratio is:

$$\frac{w_t^W}{w_t^B} = \frac{\omega_t}{1-\omega_t}\left(\frac{W_t}{B_t}\right)^{-\varsigma}. \tag{5}$$

3.2 Individuals

Each year, a new cohort b $(= t)$ starts its economic life. At this date, the surviving members of cohort b are of age $a = t - b$. Individuals live from ages 18 $(a = 0)$ to 74 $(a = 56)$, for a total of $T = 57$ periods. The size of cohort a at time t is denoted by $N_{a,t}$.

Each individual is endowed with the ability level h. At the beginning of their lives, individuals choose whether to spend 4 periods attending college. If the individual chooses not to go to college, he works as a unskilled labor with human capital h. If the individual chooses to attend college, he becomes a "skilled" agent and his human capital is

$$\gamma(h) = \gamma_0[h + \gamma_1(h - \gamma_2)^3]. \tag{6}$$

The shape of this transformation draws on Heckman et al.'s (1998a, Tables I and II) estimates of how earnings vary by ability and education. The productivity of both blue- and white-collar workers varies exogenously over their life cycles. We allow the profiles

themselves to vary over time, to reflect changes in health and retirement patterns. Let $\varepsilon^B_{a,t}$ denote the relative efficiency of a blue-collar worker of age a at time t, and let $\varepsilon^W_{a,t}$ denote the corresponding quantity for a white-collar workers. The earnings of a blue-collar individual of type h and age a at time t are: $y^B_{h,a,t} = h \cdot \varepsilon^B_{a,t} \cdot w^B_t$. The earnings of the same individual when she works as white-collar worker are: $y^W_{h,a,t} = \gamma(h) \cdot \varepsilon^W_{a,t} \cdot w^W_t$.

Individuals can borrow and lend freely at the rate r_t. We assume that an individual's preferences are given by the discounted value of her lifetime earnings, net of college costs. This implies that $U^W_{h,b}$ and $U^B_{h,b}$, the gross returns from going to college and not going to college, respectively, are

$$\begin{aligned} U^B_{h,b} &= \sum_{a=0}^{T-1} q(b,a) y^B_{h,a,b+a}; \quad U^W_{h,b} = \sum_{a=4}^{T-1} q(b,a) y^W_{h,a,b+a}, \\ q(b,a) &\equiv \begin{cases} \prod_{j=1}^{a} \frac{1}{1+r_{b+j}}, & a > 0, \\ 1, & a = 0 \end{cases} . \end{aligned}$$

The decision to go to college depends only on the cost and the expected returns to college. Let c_t denote annual cost of college at time t. Suppose that students at time t pay the fraction d_t of this cost, with the remainder funded by lump-sum taxes.[12] Let $C_b = \sum_{a=0}^{3} q(b,a) d_{b+a} c_{b+a}$ denote the lifetime cost of college for cohort b. An individual is indifferent between going to college and not if the expected utility gain from going to college is equal to 0. This gives us a threshold ability level h^*_b which satisfies the following equation:

$$0 \equiv \left(U^W_{h^*_b,b} - C_b \right) - U^B_{h^*_b,b} \tag{7}$$

Therefore an individual chooses to go to college if and only if $h > h^*_b$.

3.3 Higher education sector

Converting a blue-collar worker into a white-collar worker requires skilled labor and capital. The cost of these inputs are their outside opportunity costs, namely the wage w^W_t and the user cost $(r_t + \delta)$. The cost of going to college per year for an individual is thus

$$c_t = E^W w^W_t + E^K (r_t + \delta), \tag{8}$$

[12] Given our assumptions of linear preferences and full credit access, we will ignore these transfers in our discussion.

where E^W is the number of skilled labor units devoted to each student in a year, and E^K is the amount of capital.

3.4 Ability distribution

Each individual begins life with a draw of human capital, h, from a log-normal distribution: $\ln(h) \sim \mathcal{N}(\mu, \sigma^2)$. Using $m(\cdot)$ to denote this distribution function, let

$$e_b = 1 - \int_{h > h_b^*} dm(h), \tag{9}$$

denote the fraction of the population that attends or has attended college.

3.5 Equilibrium

We will work with an open economy framework, taking the sequence of interest rates $\{r_t\}$ as given.

Definition. An equilibrium consists of sequences of: capital and labor inputs $\{K_t, W_t, B_t\}$, wage rates $\{w_t^B, w_t^W\}$, costs $\{c_t\}$, and skill thresholds $\{h_t^*\}$ such that:

(i) Given $\{r_t, w_t^B, w_t^W, c_t\}$, $\{h_t^*\}$ is consistent with equation (7).

(ii) All markets clear:[13]

$$W_t = \sum_{a>3} N_{a,t}\, \varepsilon_{a,t}^W \int_{h > h_{t-a}^*} \gamma(h)\, dm(h) - E^W \sum_{a \leq 3} N_{a,t}\, e_{t-a}, \tag{10}$$

$$B_t = \sum_{a} N_{a,t}\, \varepsilon_{a,t}^B \int_{h < h_{t-a}^*} h\, dm(h). \tag{11}$$

(iii) The price of each factor equals its marginal product. That is, equations (2), (3), (4) hold.

4 Calibration

We calibrate the model for the period 1961-2300. We assume that total factor productivity $\{A_t\}$ grows at constant rate throughout the entire period, and that after 2200

[13] To evaluate equations (10) and (11), we use formulas for the moments of truncated distributions found in Jawitz (2004).

the population is constant, so that the economy converges to a balanced growth path.[14]

We find the equilibrium with a guess of the sequence of blue- and white-collar wages $\{B_t, W_t\}$ over the period 1961-2300. Using this guess, we find educational attainment for each cohort, which in turn allows us to find the aggregate supplies of blue- and white-collar skill for each year. These skill totals in turn provide us with new estimates of wages, calculated as marginal products. We search over wage sequences until we reach a fixed point.

4.1 Processes and Parameters Calibrated Outside the Model

4.1.1 Demographics

We begin with Census data (inclusive of Armed Forces overseas) for the period 1961-2000. For the period 2000-2050, we use the Census Bureau's 2008 projections. These detailed projections allow us to calculate "survival" rates (net of immigration) at every age and the growth rate of the birth cohorts. We project all of these rates for the period 2051-2100 by linearly extrapolating their values over the period 2040-2050, and use the projected rates to update the population. From 2100 forward we assume that the size of the birth cohort is constant,[15] and that the net survival rates are constant as well. By 2200 the population has converged to a stationary distribution. Our calculations use the subset of the age distribution covering ages 18-74.

Figure 9 shows how the age distribution of workers evolves over time, as the population ages.

4.1.2 Earnings Profiles

We estimate the earnings profiles $\{\varepsilon^W_{a,t}, \varepsilon^B_{a,t}\}$ from the CPS. Suppose that agent i is age a_{it} at time t. It follows that the agent's "birth year", c_i, equals $t - a_{it}$. Let $e_i \in \{B, W\}$ index the agent's education level. Modifying Kambourov and Manovskii (2009), we assume that log earnings, y_{it}, follow.

$$\begin{aligned} y_{it} &= \alpha^e_0 + \beta^e_1 a_{it} + \beta^e_2 a^2_{it} + \beta^e_3 a^3_{it} + \gamma^e_1 t \cdot a_{it} + \gamma^e_2 t \cdot a^2_{it} + \gamma^e_3 t_2 \cdot a_{it} + \gamma^e_4 t_2 a^2_{it} + \lambda^e_{c_i} + \varepsilon_{it} \quad (12) \\ &= \alpha^e_0 + \left(\beta^e_1 + \gamma^e_1 t + \gamma^e_3 t_2\right) a_{it} + \left(\beta^e_2 + \gamma^e_2 t + \gamma^e_4 t_2\right) a^2_{it} + \beta^e_3 a^3_{it} + \lambda^e_{c_i} + \varepsilon_{it}, \end{aligned}$$

[14] Because the cost of educating a college student includes a fixed capital component, $E^K(r+\delta)$, the balanced growth path is asymptotic. The economy eventually becomes so productive that the capital charge is irrelevant.

[15] In this respect, we follow Krueger and Ludwig (2007).

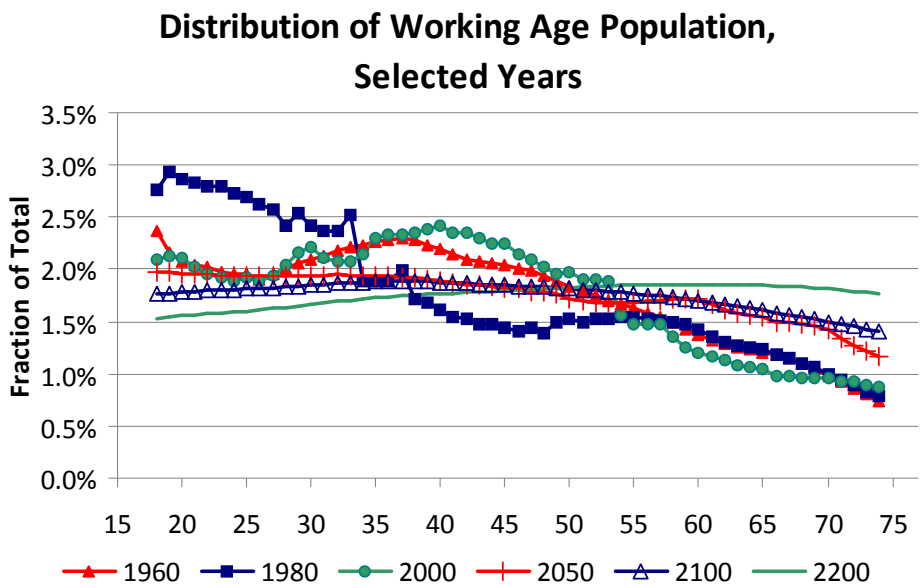

Figure 9

where: $t_2 = \max\{t-1990, 0\}$ is a spline term; $\lambda^e_{c_i}$ is a cohort-specific effect; and ε_{it} is a zero-mean error uncorrelated with the explanatory variables. The coefficients $\{\gamma^e_1, \gamma^e_2, \gamma^e_3, \gamma^e_4\}$ capture date-specific trends in life cycle labor supply and human capital accumulation. We treat these trends as exogenous and include them in the profiles that we feed in our model. The dummy coefficients $\{\lambda^e_{c_i}\}$ capture composition effects – who goes to college or not – as well as other cohort-specific influences. We treat these cohort effects as endogenous to our model; the profiles we feed the model use only the average cohort effect. Because we are interested in overall earnings, including those of non-workers, we estimate equation (12) on a synthetic cohort (Deaton, 1985): each value of y_{it} in our estimation dataset is the log of average earnings in a particular calendar year for all individuals of a particular age.

Figure 10 shows the profiles generated by our earnings model for workers born in 1917, 1942 and 1966. Like Kambourov and Manovskii (2009), we find that earnings profiles flatten over time. The changes are most notable after age 60. Two sources of this shift are increased participation by women, and an increase in male retirement ages over the past 15 years (French and Jones, 2012). We assume that earnings profiles continue to evolve in this fashion until the 1975 cohort is reached, after which they remain constant.

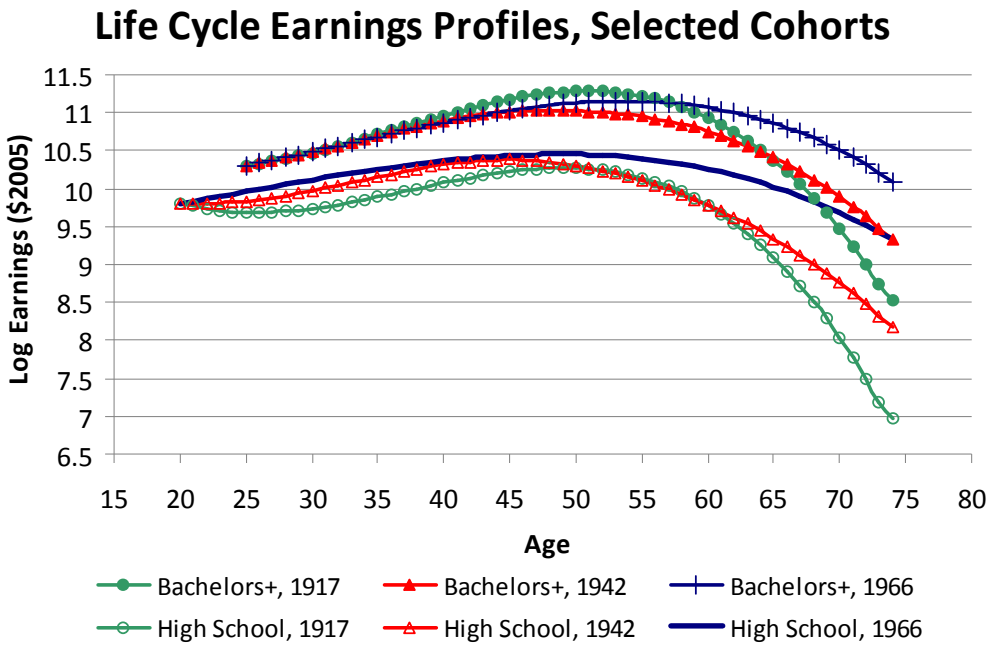

Figure 10

4.1.3 Financial Aid

Our measure of the tuition co-pay rate, d, is the ratio of net tuition to total costs, both of which are taken from the data described in Section 2. To be consistent with our modelling of the education decision, we base our measure on data for 4-year institutions. Separate cost data for 2-year and 4-year institutions are first available in the Digest of Education statistics in 1977, and then only for public institutions. However, about 90 percent of 2-year students are in public institutions, and if one is willing to assume the ratio of 2-year to 4-year tuition is constant over time, one can use attendence data to make an approximate adjustment. Since 1985, d has ranged between 23 and 28%. We assume that d remains at its 2009 value of 27.7% through 2300. Missing values for earlier years are linearly interpolated.

4.1.4 Educational Attainment, Older Cohorts

The educational attainment, the fraction of the population with at least a Bachelors degree, of people 19 and older in 1961 – cohorts born before 1943 – is taken from the CPS. When possible, we measure education attainment as the average over ages 28-32; for older cohorts we take averages across the 5 (if available) youngest ages observed in

our data.

4.1.5 Miscellaneous Parameters

We set $\delta = 0.05$; $r = 0.04$; and $\varsigma = 0.7$. The first two values are standard, while the fourth is taken from Heckman et al.(1998a, Table III, OLS). The capital requirement $E^K = \$21,531$ is the average of the values shown in Table 2 over 1959-1990.

4.2 Parameters Calibrated Using the Model

The following parameters are calibrated within the model:

1. Total factor productivity, $\{A_t\}$. We assume that the log of TFP follows a linear trend: $\ln(A_t) = A_{1961} + g_A t$. We calibrate A_{1961} and g_A.

2. The skill weights, $\{\omega_t\}$. Following Heckman et al., (1998a), we assume that ω_t follows a logistic trend:
$$\omega_t = \frac{\exp(\iota_0 + \iota_1 t)}{1 + \exp(\iota_0 + \iota_1 t)} \iota_2,$$
with the upper bound $\iota_2 \in (0, 1)$. We calibrate ι_0, ι_1 and ι_2.

3. The quantity of skilled labor required to educate a college student for a year, E^W.

4. The parameters of the skill transformation function, equation (6), γ_0, γ_1 and γ_2.

5. The parameters of the lognormal skill distribution, $\ln(h) \sim \mathcal{N}(\mu, \sigma^2)$.

6. The parameter α, the weight on capital in the production function.

To select these parameters, we match the following moments:

1. The educational attainment – the fraction of the population with at least a Bachelors degree – of each of the cohorts born between 1943 and 1990.

2. The college earnings premium, as measured in Figure 8 in Section 2, for each of the years 1961-2009; the model analog to this quantity is mwr_t, the ratio of the average wage for college-educated workers to the average wage for blue-collar workers among

people aged 30-74:

$$mwr_t = \frac{w_t^W \left[\sum_{a>11} N_{a,t}\, \varepsilon_{a,t}^W \int\limits_{h>h_{t-a}^*} \gamma(h)\, dm(h) \right] / \left[\sum_{a>11} N_{a,t} e_{t-a} \right]}{w_t^B \left[\sum_{a>11} N_{a,t}\, \varepsilon_{a,t}^B \int\limits_{h<h_{t-a}^*} h\, dm(h) \right] / \left[\sum_{a>11} N_{a,t} (1 - e_{t-a}) \right]}. \tag{13}$$

3. GDP for each of the years 1961-2009.

4. The ratio of colleges costs (for "4-year" institutions) to GDP per capita, c/y, for each of the years 1961-2009.[16]

5. A constant capital-output ratio of 3.3, its average real value over 1961-2010.

Because we have more moments than parameters, we choose the parameters by minimizing

$$\sum_{j=1}^{J} \left(\frac{s_j^m - s_j^d}{s_j^d} \right)^2,$$

where s_j^d is a data moment from the list immediately above, and s_j^m is its model counterpart.

Table 3 shows the value of parameters estimated inside the model. Skill-neutral technology, A_t, increases at a rate of 0.98%. In the cubic production function of skill γ_0 is close to zero.

[16] To be consistent with our data targets, our measure of educational cost excludes interest expenditures.

Table 3. Calibrated Parameters		
Parameters		Values
A_{1961}	skill-neutral productivity level	743.3002
g_A	growth rate of skill-neutral productivity	0.0098
α	weight on capital	0.3475
γ_0	skill production function	16.1092×10^{-8}
γ_1	skill production function, cubic weight	261.68×10^{5}
γ_2	cubic shifter in skill production function	0.1392
μ	mean of log ability	-0.1400
σ	standard deviation of log ability	0.1928
E^W	skilled labor units per student per year	0.8999
ι_0	evolution of skill weight ω, intercept	0.0447
ι_1	evolution of skill weight ω, trend	-0.6841
ι_2	limit value of ω	0.5202

Figure 11 plots $\ln(A_t)$ and ω_t, the weight on white-collar skill in the labor composite. Starting from a value of 0.15 in 1961, ω_t increases dramatically, and then levels off at around 0.52 by 2100.

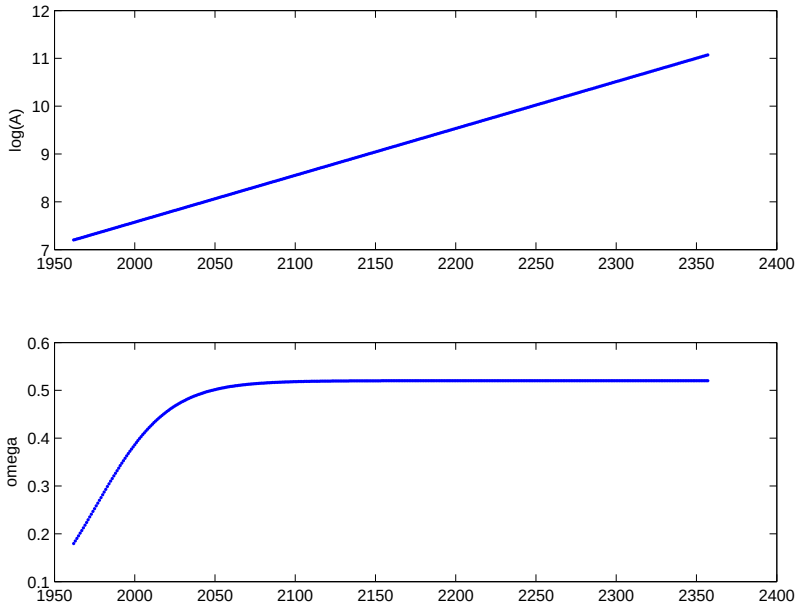

Figure 11: Calibrated parameters

4.3 Model Fit

Figure 12 assesses the model's fit of the calibration targets. The model matches very well the data moments, especially the fast growth of output and college enrollment. The rapid growth in the mean wage ratio suggests that higher education, being skill-intensive, should become increasingly expensive relative to GDP. This tendency is offset by capital costs, which are constant in absolute terms and decreasing relative to GDP. The offsetting forces allow the model to replicate the observed growth in college expenditures, while holding constant the resources devoted to each student.

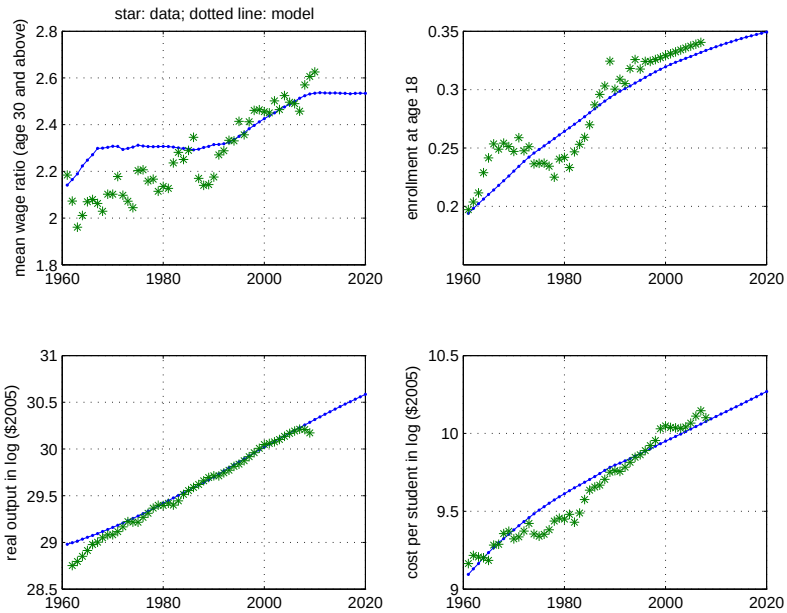

Figure 12: Model fit of calibration targets

5 Experiments

Between 1961 and 2300, five sets of parameters changed: the skill weight ω, the productivity parameter A, the tuition discount factor d, the lifecycle earnings profiles $\{\varepsilon^W_{a,t}, \varepsilon^B_{a,t}\}$, and the population quantities $\{N_{a,t}\}$. To assess the effects of the parameters, we perform a decomposition exercise, changing each of the five parameter sets in isolation. We first assess how the parameters affect the economy's steady state, and then their effects on the economy's transition path.

5.1 Steady state

Table 4 shows the steady states generated by the year-1961 parameters and various combinations of the year-2300 paramters. We find the steady-state by requiring that all cohorts have the same enrollment rate, which they choose optimally. With a lower level of total factor productivity and a smaller population, output and labor are much lower in 1961 than in 2300. College enrollment is also much lower, due to a lower skill premium.

Turning to the steady state decomposition, notice that if A is fixed, aggregate labor and output always change in the same proportion. The decomposition shows that the increase in enrollment is almost entirely due to skill-biased technological change in ω. An isolated increase in ω reduces the marginal product of blue-collar workers, resulting in a reduction of blue-collar skill and a increase in the skill premium. Enrollment increases a lot. As a result, total stock of white-collar skill increases and total stock of blue-collar skill decreases. The cost of college rises significantly. Output increases but remains much lower than in the benchmark model.

Table 4. Effects of parameter changes—Steady state

	year-2300 parameters	year-1961 parameters	ω_{2300} only	A_{2300} only	d_{2300} only	$\varepsilon^B_{a,2300}, \varepsilon^W_{a,2300}$ only	$N_{a,2300}$ only
Y	502.9499	0.3935	0.3810	96.9567	0.3935	0.4820	1.5906
W	5.5515	0.3555	1.0263	0.3763	0.3545	0.4136	1.4643
B	3.3370	0.9959	0.6295	0.9874	0.9963	1.2299	4.0134
L	4.3908	0.8460	0.8190	0.8464	0.8460	1.0362	3.4197
c/Y	0.3122	0.3079	0.4190	0.2702	0.3085	0.2598	0.3233
mwr	2.4249	2.3616	2.5892	2.2110	2.3697	2.2938	2.4633
w^W/w^B	0.7589	0.4504	0.7700	0.4303	0.4515	0.4697	0.4437
e	0.3610	0.0718	0.3583	0.0777	0.0715	0.0711	0.0675

Note: Output is measured in 10^{13}s of \$2005. W, B, and L are measured in 10^8s.

A skill-neutral increase of A increases the demand for both types of skill, raising all wages. The cost of college drops because output has grown relative to capital inputs, E^K. In a steady state, this drop in costs modestly increases college attainment, resulting in more white-collar skill and less blue-collar skill. As a result, the skill premium decreases slightly.

In switching from 1961 to 2300, tuition as a fraction of cost rises slightly, from 0.21826 to 0.27680. An increase in d is a reduction in the tuition discount rate or, equivalently,

an increase in net tuition. Higher net tuition discourages college enrollment. As a result, the skill premium and the relative price increase. The cost of higher education also increases, reinforcing the effect of smaller tuition discounts. The overall effect is very small, however, because of general equilibrium effects. In particular, we find that a 8.0946% decrease in the tuition discount rate $(1-d)$ results in a 0.6506% decrease in enrollment, implying an elasticity of 0.0803. The standard price elasticity, based on d itself, is 0.024.[17] More radical experiments, such as setting $d=0$ or $d=1$, produce elasticities of similar magnitudes. As Heckman, Lochner and Taber (1998b) note, changes in wages, which accumulate over an individual's entire working life, almost completely offset the changes in net tuition. In contrast, a number of empirical studies, based on micro-level interventions, find larger effects. (See Dynarski, 2003, and the papers referenced therein.) When wages are held fixed at their 1961-steady-state values, the enrollment elasticities rise from 0.08 to 0.26, and from 0.02 to 0.08. By way of comparison, Dynarski (2003) finds that the enrollment elasticity to total "schooling costs" is 1.5. Because most of this cost total consists of forgone earnings, Dynarski's estimates imply a tuition elasticity of 0.14, somewhat similar to ours.[18]

Changing the efficiency profiles increases both stocks of skills, but blue-collar skill increases relatively more, raising the college premium. On the other hand, the newer efficiency profiles imply lower earnings at younger ages and higher earnings at older ages. This decreases the discounted value of a college education, and enrollment decreases slightly.

A larger population increases total output, and stocks of both types of labor. As shown in Figure 9, the population distribution in 2300 puts more weight on the elderly and less on the young. Since the relative efficiciency of white-collar workers is higher when old, the relative amount of white-collar skill increases, causing both the skill premium and enrollment to decrease.

5.2 Transition Path

Figures 13-19 show how the aggregate moments change in the benchmark model and in each experiment during the transition between 1961 and 2300. We consider enrollment at age 18, total stocks of both skills, total output, skill premium, cost per student as a

[17] The proportional change in enrollment is $(0.07178-0.07149)/0.07149$, while the proportional change in the tuition discount rate is $(0.76212-0.76877)/0.76877$. The more standard price elasticity, based on the change in d itself, $(0.21826 \ -0.27680)/0.27680 = 7.149\%$, is $0.6506/7.149 = 0.02426$.

[18] Dynarski finds tuition and fees to be \$1,900, while foregone earnings are \$18,500, implying that her tuition elasticity is $1.5 \times (1900/(1900+18500))$.

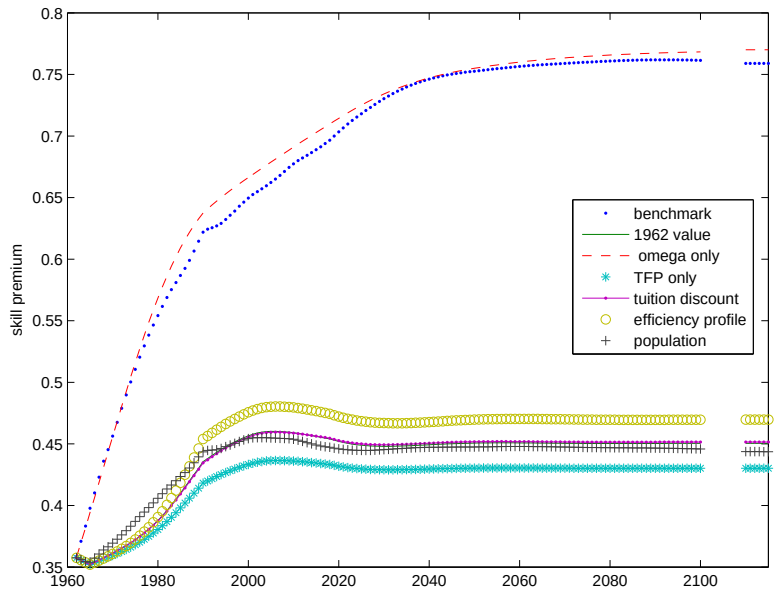

Figure 13: Skill premium (w^W/w^B)

fraction of output per worker, and mean wage ratio. For ease of comparison, we focus on the period 1961-2100, and plot the year-2300 steady state values at the right end of each figure.

If we fix parameter values at their 1961 values, the economy transitions to the long run steady state described in Table 4 above. When the skill weight ω is frozen at its 1961 value, the older cohorts alive at 1961 have in the aggregate accumulated too *much* college education. (These workers presumably expected ω to continue rising, as in the benchmark model.) The skill premium (Figure 13) initially drops. Enrollment (Figure 14, left-hand scale) starts low, and increases gradually. Blue-collar skill (Figure 15) gradually increases. White collar skill (Figure 16) initially rises, as the very oldest cohorts, who have low education, leave the labor market and the cohorts educated just before 1961 enter their most productive years. The low educational attainment of younger workers reverses these gains; the stock of white collar skill declines, then stabilizes. At the same time, skill premium stops declining, reverses its loss, and rises above its initial value. Because the cost of college (Figure 18) depends heavily on the price of skilled labor, it tracks the skill premium closely. In contrast, the mean wage ratio (Figure 19), the ratio of college to high school earnings, keeps on decreasing even after the skill premium increases. This is because of the composition effects: with a cubic production function for skill, people that are relatively indifferent about college have much less skill than the average college

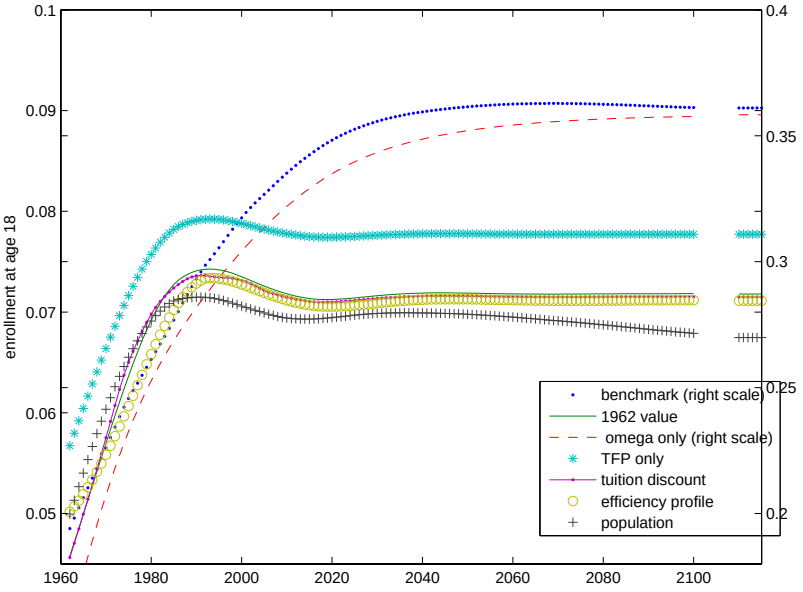

Figure 14: Enrollment at age 18 (benchmark and omega-only experiments use right scale)

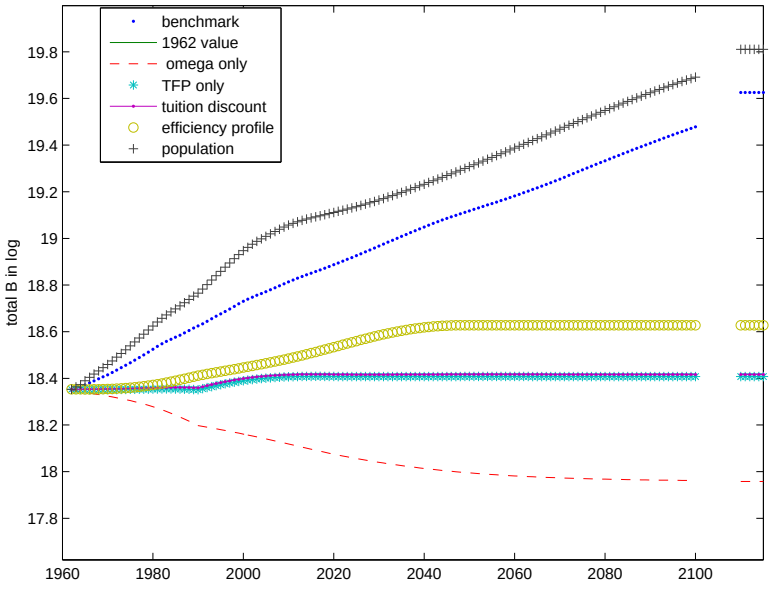

Figure 15: Total stock of blue-collar skill

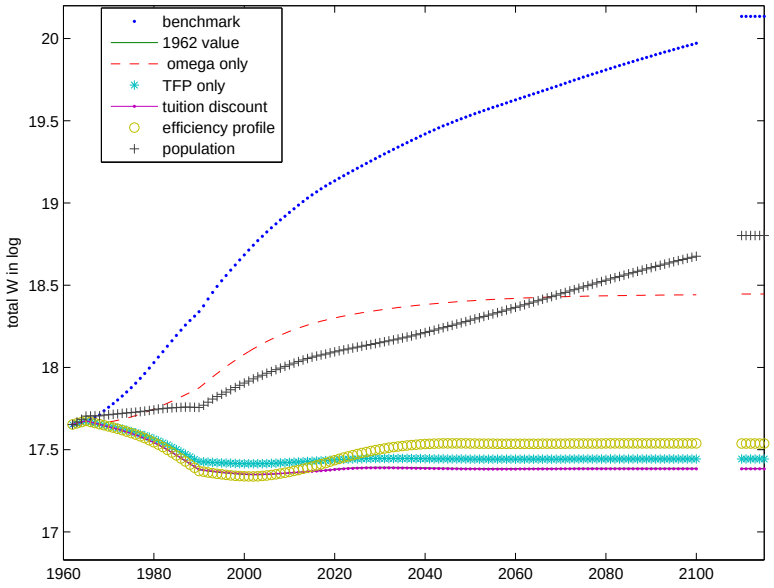

Figure 16: Total stock of white-collar skill

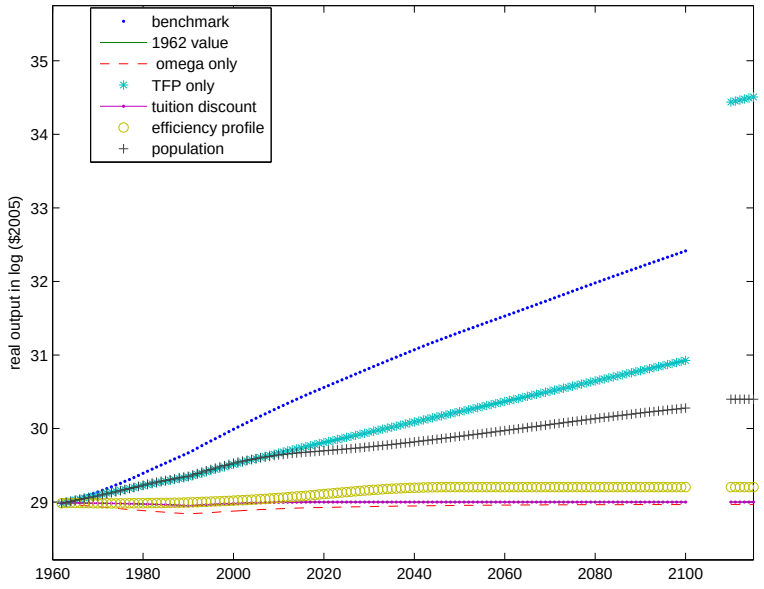

Figure 17: Total output

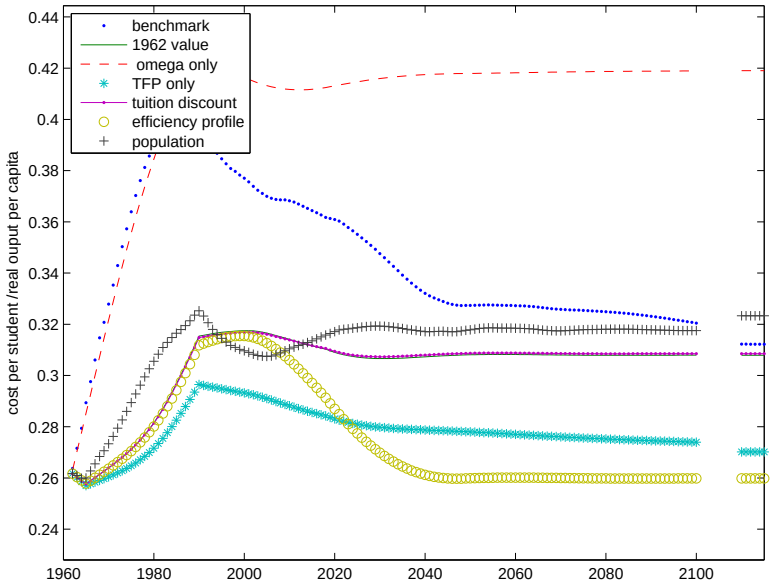

Figure 18: Cost per student relative to per capita output

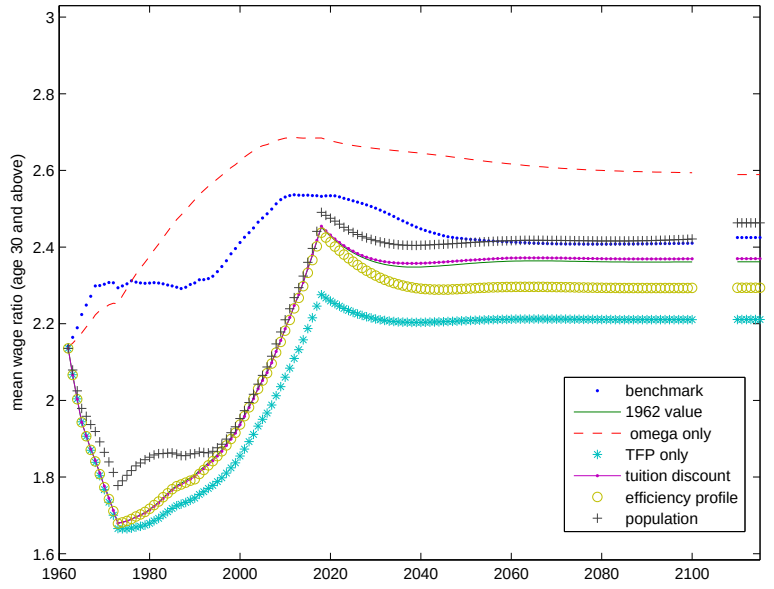

Figure 19: College earnings/high school earnings, age 30 and older

worker. As the cohorts who drastically reduced their enrollment in the 1960s age, the stock of white collar skill falls below its steady state level. This in turn causes the skill premium and enrollment to overshoot. Heckman at al. (1998a) find similar overshooting dynamics. After 2020 the economy moves steadily towards its steady state. Output (Figure 17) remains essentially unchanged throughout.

An increase in ω increases the demand for white-collar workers and decreases the demand for blue-collar workers. The increase in demand is bigger than the increase in supply from the older cohorts found in the data, and the skill premium rises significantly. As a result, the college enrollment of the youngest cohort increases (Figure 14, right-hand scale), by almost the same amount as in the full, benchmark model. Changing ω also reweights W and B in the labor composite L. Aggregate labor increases, leading capital and output (Figure 17) to increase as well.[19] With population and total factor productivity A held constant, the increases of labor and output are small compared with the benchmark model.

A skill-neutral increase in A increases the demand for capital, white-collar skill and blue-collar skill, leading to increases in both wage rates. With ω fixed at its 1961 values, the trajectory of skills, wages and enrollment is very similar to that of the no-change model. Because output grows relative to capital needs (E^K), college costs fall. This in turn raises enrollment above its no-change values.

The quantitative effect of an increase in d is small, for the reasons discussed above. Changing of the efficiency profiles also has only a minimal effect on the aggregate moments.

Compared with the model without any change, introducing population initially increases white-collar skill more than the blue-collar skill, but in by 2000 the demographic shifts lead to a larger increase in white-collar skill. As a result, the skill premium and enrollment initially rise more than in the no-change experiment, but in the long-run take on slightly lower values.

6 Discussion and Conclusions

In this paper, we show that a general equilibrium model with skill- and sector-biased technological change can replicate the increase in college costs observed over the past 40 years, along with the increase in college attainment and the increase in the relative wages earned by college graduates. Our model has two key features. The first is the assumption

[19] Holding W and B fixed, the effects of changing ω on the composite L depend on the relative sizes of W and B, which in turn depend on the normalizations used to scale W and B in the calibration. With different scaling, increases in ω can cause L to fall.

that educating a student requires a fixed amount of capital and skilled labor. The second is skill-biased technological change. We find that in general equilibrium changes in college prices, measured as changes in the tuition discount rate, have little long-run effect on human capital accumulation.

Our framework suggests that skill-biased technological change makes a college education more expensive as well as more valuable. The scope for policy intervention is limited, however, if college enrollment is as inelastic to tuition discounts as our model implies. A number of empirical studies suggest that college attendance is sensitive to tuition, at least over the shorter-term. One reason why enrollment may be more price elastic than we predict is that borrowing limits may prevent students from paying higher tuitions. A number of studies, including Cameron and Heckman (1998, 2001) and Cameron and Taber (2004) conclude that borrowing constraints do not significantly restrict college attendance. Keane and Wolpin (2001) argue that although the borrowing constraints that students face are quite strict, students can circumvent them by working. In contrast, Lochner and Monge-Naranjo (2010) find that while credit constraints might not have restricted access in the past, they probably restrict access now. They also stress the importance of modelling these credit constraints in a way consistent with the actual student lending process. Brown, Scholz and Seshadri (2011) find that students not receiving the "expected" amount of parental transfers (as defined in Federal financial aid formulae) are often financially constrained.

Another feature missing in our model is drop-out risk. Although 52% of the people aged 25 and older in the 2000 census had attended college, only 31% had earned a degree of any sort. Akyol and Athreya (2005) find that switching from a full tuition subsidy to none typically reduces the fraction of skilled workers by 5 to 7 percentage points. Ionescu (2009) finds that introducing flexibility in the repayment of Federal student loans significantly increases enrollment.

Our model also rules out technological progress in the production higher education. An important extension would be to relax this assumption, perhaps by allowing skilled labor and capital equipment to be substitutes.

Finally, the model can be enriched by introducing more heterogeneity in higher education, both in terms of quality and price. As emphasized by Castro and Coen-Pirani (2011), there are significant quality differences both between public and private institutions, and within each group. Even at a single institution, individuals with different levels of ability and family income usually face different prices.

7 Appendix: Background Calculations

7.1 Measurement Issues

In this section we consider some alternative versions of our education measures.

Figure 20 shows the effects of excluding scholarships and fellowships from our definition of education and general expenditures. Because the revisions in the late 1990s eliminated scholarships and fellowships data for private institutions, we use the College Board's measure of aggregate institutional grant aid to extrapolate aggregate scholarships and fellowships to the present. Figure 20 reveals that scholarships and fellowships appear to have become increasingly important over time. In 2008, they equalled almost 4 percent of per worker GDP. Their effect appears to be most prevalent in private institutions, although this data is poorly measured.[20] As Table 4 shows, however, excluding scholarships and fellowships from our cost measures has only a modest effect on our calibration targets.

A second data issue involves the measurement of tuition. The tuition data shown in Figures 1 and 4 are found by dividing tuition revenues by FTE. This measure is consistent with our measure of costs, and it can be extrapolated back to 1929. On the other hand, this measure combines both undergraduate and graduate tuition. Since 1964, the Department of Education has estimated average undergraduate tuition, and since 1977, it has estimated average undergraduate tuition at 4-year institutions.[21] Figure 21 compares the two measures of tuition. Over the period 1964-2008, the two sets of measures imply similar changes in tuition.

[20] We impute the missing data for private institutions in two steps. First, we use the College Board's measure of aggregate institutional grant aid to extrapolate aggregate scholarships and fellowships to the present. Second, we subtract from this measure public scholarships and fellowships, which we do observe, leaving us with a residual that we treat as private aid.

[21] Prior to 1977, we impute tuition at 4-year institutions using the approach described in the text.

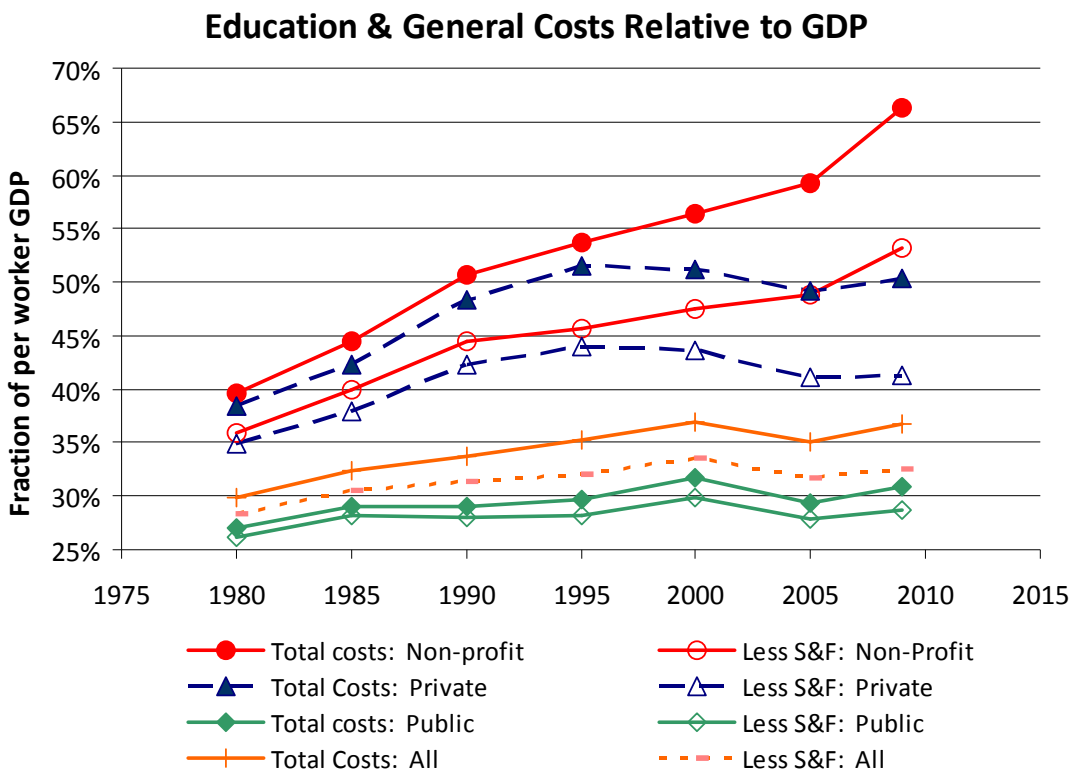

Figure 20

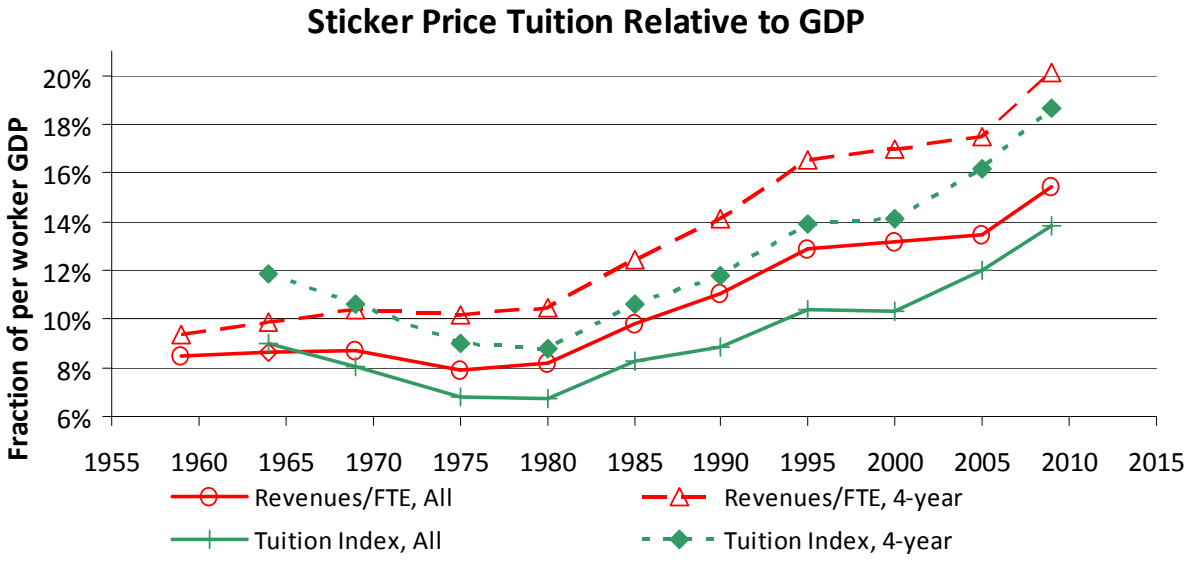

Figure 21

References

[1] Abraham, Katharine G., James R. Spletzer and Jay C. Stewart. 1998. "Divergent Trends in Alternative Wage Series." Haltiwanger, John, Marilyn E. Manser and Robert Topel, editors, *Labor Statistics Measurement Issues*. University of Chicago Press.

[2] Akyol, Ahmet., and Kartik Athreya. 2005. "Risky Higher Education and Subsidies." *Journal of Economic Dynamics and Control*, 29 979-1023.

[3] Angrist, Joshua D., and Stacey H. Chen. 2011. "Schooling and the Vietnam-Era GI Bill: Evidence from the Draft Lottery." *American Economic Journal: Applied Economics*, 3, 96–118

[4] Archibald, Robert and David Feldman. 2011. *Why Does College Cost So Much?* Oxford University Press.

[5] Baumol, William. J. 1967. "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis." *The American Economic Review*, 57, 415–426.

[6] Baumol, William J. and William G. Bowen. 1966. *Performing Arts: The Economic Dilemma*. New York: Twentieth Century Fund.

[7] Bowen, Howard. 1980. *The Costs of Higher Education: How Much Do Colleges and Universities Spend per Student and How Much Should They Spend?* San Francisco: Jossey-Bass.

[8] Brown, Meta, John Karl Scholz, and Ananth Seshadri. 2011. "A New Test of Borrowing Constraints for Education." Mimeo, forthcoming *Review of Economic Studies*.

[9] Cameron, Stephen, and James J. Heckman. 1998. "Life Cycle Schooling and Dynamic Selection Bias: Models and Evidence for Five Cohorts of American Males." *Journal of Political Economy*, 106, 262-333.

[10] Cameron, Stephen, and James J. Heckman. 2001. "The Dynamics of Educational Attainment for Black, Hispanic and White Males." *Journal of Political Economy*, 109, 455-499.

[11] Cameron, Stephen, and Christopher Taber. 2004. "Estimation of Educational Borrowing Constraints Using Returns to Schooling." *Journal of Political Economy*, 112, 132-182.

[12] Castro, Rui, and Daniele Coen-Pirani. 2011. "Public Policy and College Attainment." Mimeo.

[13] Censky, Annalyn. 2011. "Surging College Costs Price Out Middle Class." CNNMoney, June 13, 2011, http://money.cnn.com/2011/06/13/news/economy/college_tuition_middle_class/index.htm?hpt=hp_t2, downloaded June 13, 2011.

[14] The College Board. 2010. *Trends in Student Aid 2010: Data Files.* http://trends.collegeboard.org/downloads/2010_Trends_Student_Aid_All_Figures_Tables.xls.

[15] Dynarski, Susan. 2003. "Does Aid Matter? Measuring the Effect of Student Aid on College Attendance and Completion." *The American Economic Review*, 93(1), 279-288.

[16] French, Eric, and John Bailey Jones,. 2012. "Public Pensions and Labor Supply over the Life Cycle." *International Tax and Public Finance*,

[17] Gallipoli, Giovanni, Costas Meghir, and Giovanni L. Violante. 2010. "Equilibrium Effects of Education Policies: A Quantitative Evaluation." Mimeo.

[18] Goldin, Claudia, and Lawrence F. Katz. 2008. *The Race Between Education and Technology.* Cambridge, Massachusetts: Harvard University Press.

[19] Goldin, Claudia, and Robert Margo. 1992. "The Great Compression: The Wage Structure in the United States at Mid-century." *Quarterly Journal of Economics*, 107(1), 1-34.

[20] Harris, Douglas N., and Sara Goldrick-Rab. 2010. "The (Un)Productivity of American Higher Education: From 'Cost Disease' to Cost-Effectiveness." Mimeo.

[21] Heathcote, Jonathan, Fabrizio Perri, and Giovanni L. Violante. 2010. "Unequal We Stand: An Empirical Analysis of Economic Inequality in the United States, 1967–2006," *Review of Economic Dynamics* 13(1), 15-51.

[22] Heckman, James J., Lance Lochner, and Christopher Taber. 1998a. "Explaining Rising Wage Inequality: Explorations with a Dynamic General Equilibrium Model of Labor Earnings with Heterogeneous Agents." *Review of Economic Dynamics*, 1(1), 1-58.

[23] Heckman, James J., Lance Lochner, and Christopher Taber. 1998b. "General-Equilibrium Treatment Effects: A Study of Tuition Policy." *The American Economic Review*, 88(2), 381-386.

[24] Ionescu, Felicia. 2009. "The Federal Student Loan Program: Quantitative Implications for College Enrollment and Default Rates." *Review of Economic Dynamics*, 12, 205–231.

[25] Jawitz, James W. 2004. "Moments of Truncated Continuous Univariate Distributions." *Advances in Water Resources*, 27, 269-281.

[26] Kambourov, Gueorgui, and Iourii Manovskii. 2009. "Accounting for the Changing Life-Cycle Profile of Earnings." Mimeo.

[27] Keane, Micheal P., and Kenneth I. Wolpin. 2001. "The Effect of Parental Transfers and Borrowing Constraints on Educational Attainment." *International Economic Review*, 42(4), 1051-1103.

[28] Krueger, Dirk, and Alexander Ludwig. 2007. "On the consequences of Demographic Change for Rates of Returns to Capital, and the Distribution of Wealth and Welfare." *Journal of Monetary Economics*, 54(1), 49-87.

[29] Lee, Donghoon, and Kenneth I. Wolpin. 2006. "Intersectoral Labor Mobility and the Growth of the Service Sector," *Econometrica*, 74(1), 1-46.

[30] Lee, Donghoon, and Kenneth I. Wolpin. 2010. "Accounting for Wage and Employment Changes in the US from 1968-2000: A Dynamic Model of Labor Market Equilibrium," *Journal of Econometrics*, 156(1), 68-85.

[31] Leonhardt, David A. 2009. "Q. & A.: The Real Cost of College." *The New York Times*, posted November 19, 2009, http://economix.blogs.nytimes.com/2009/11/19/q-a-the-real-cost-of-college/#more-39767.

[32] Ljungqvist, Lars. 1993. "Economic Underdevelopment: The Case of a Missing Market for Human Capital." *Journal of Development Economics*, 40(2), 219-239.

[33] Lochner, Lance J., and Alexander Monge-Naranjo. 2010. "The Nature of Credit Constraints and Human Capital." Mimeo, forthcoming *American Economic Review*.

[34] United States Department of Education. Various years. *Digest of Education Statistics*. http://nces.ed.gov/Programs/digest/.