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Skill-Biased Technical Change and the Cost of Higher Education: An Exploratory Model

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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 unbalanced 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 1959 and 2000. 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.

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

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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 unbalanced 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 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 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

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

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 0.07%. 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 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 prices (tuition). 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

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[2]Most notably, our model includes physical capital, while Castro and Coen-Pirani use a richer model of human capital.
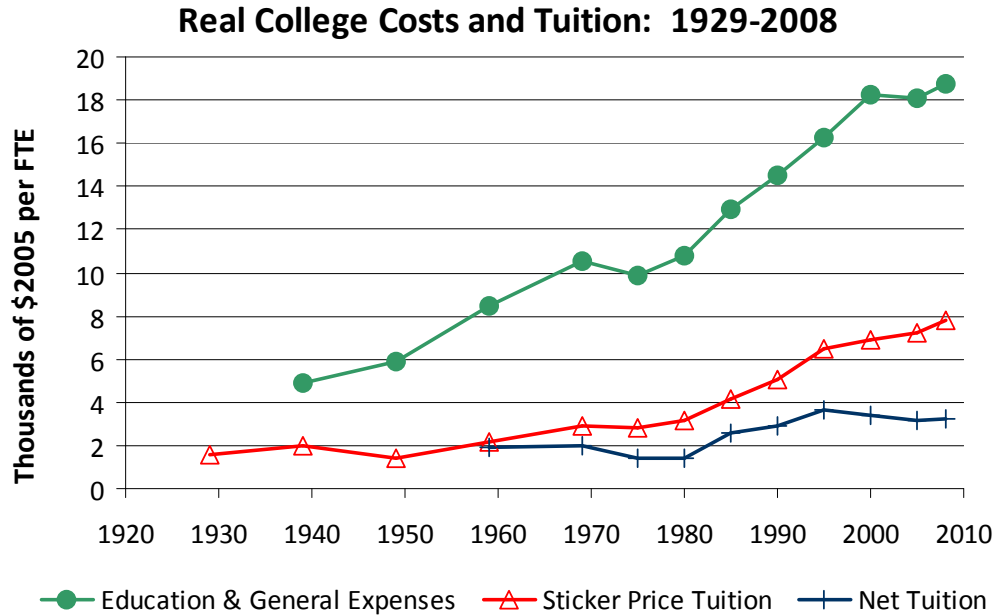
Real College Costs and Tuition: 1929-2008

Figure 1

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 degrees. 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. 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. We consider the subset of costs included in the education and general category. Among the costs excluded from this category are auxiliary operations such as dormitories.[3] Average expenditures have more than trebled over time, from under $5,000 in 1939 to over $18,000 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.

The second line in the figures 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.[4] This series also requires splicing per-FTE and per-enrollee data. 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, exclusive of veterans benefits.[5] 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. 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 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 (Council of Economic Advisors, 2010).[6] These data show that, with the exception of 1939, education and general expen-

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[3]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.

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

[5]Our calculations also 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.

[6]Consistent with the model below, our measure of population consists of people aged 16-64. 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
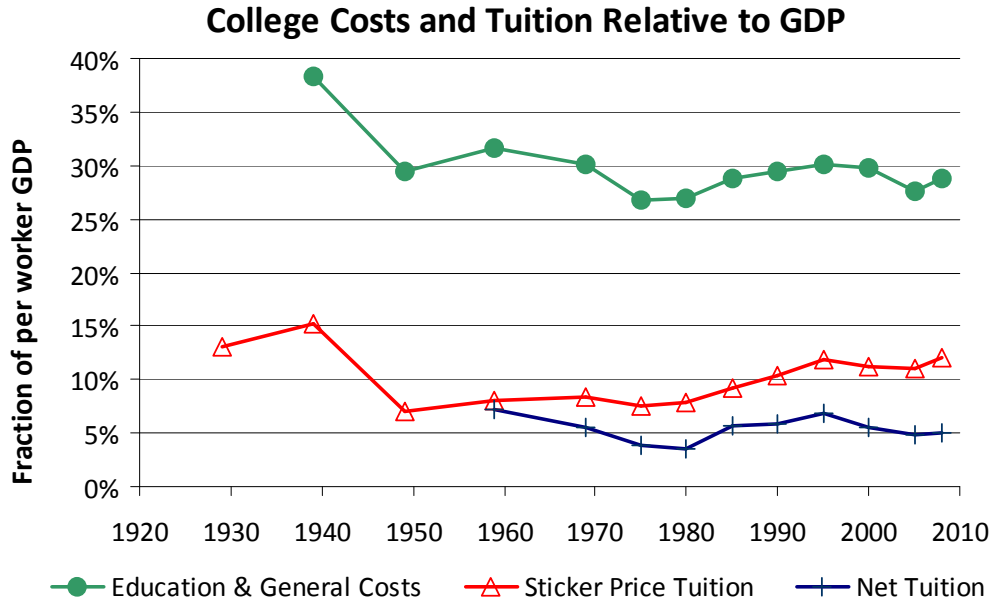
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College Costs and Tuition Relative to GDP

Figure 2

ditures have stayed between 28 and 32 percent of per capita GDP. This is consistent with the hypothesis that higher education has enjoyed few, if any, 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 sharp decline in private sector expenditures between 1995 and 2000. Given that the public sector shows no such decline, the break in the series probably reflects changes in the Department of Education's data measures. Figure 3 also shows expenditures for non-profit private institutions. In the recent decade for-profit institutions have grown rapidly, from 4 percent of private enrollment in 1980 to 29 percent in 2008. Because for-profit institutions tend to have lower costs, their growth has pulled

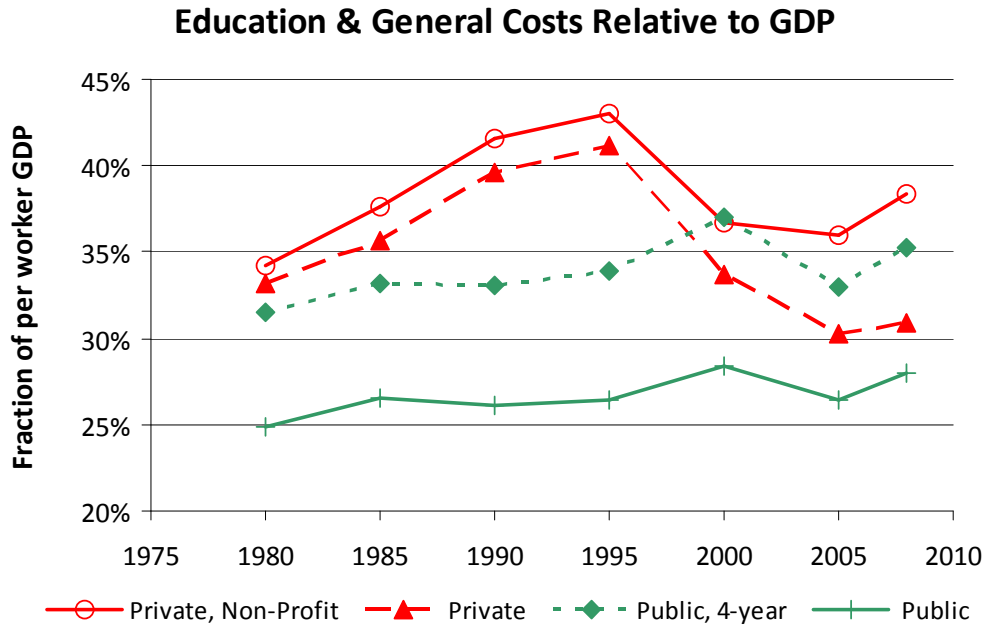values.

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Education & General Costs Relative to GDP

Figure 3

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 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 colleges follow a trajectory similar to that at 4-year institutions; Archibald and Feldman (2011) view this as evidence against the "arms race" hypothesis.

Figure 4 displays disaggregated sticker price tuition. The data break in the late 1990s appears to have an effect here as well. However, the distinction between non-profit and for-profit private institutions is 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.
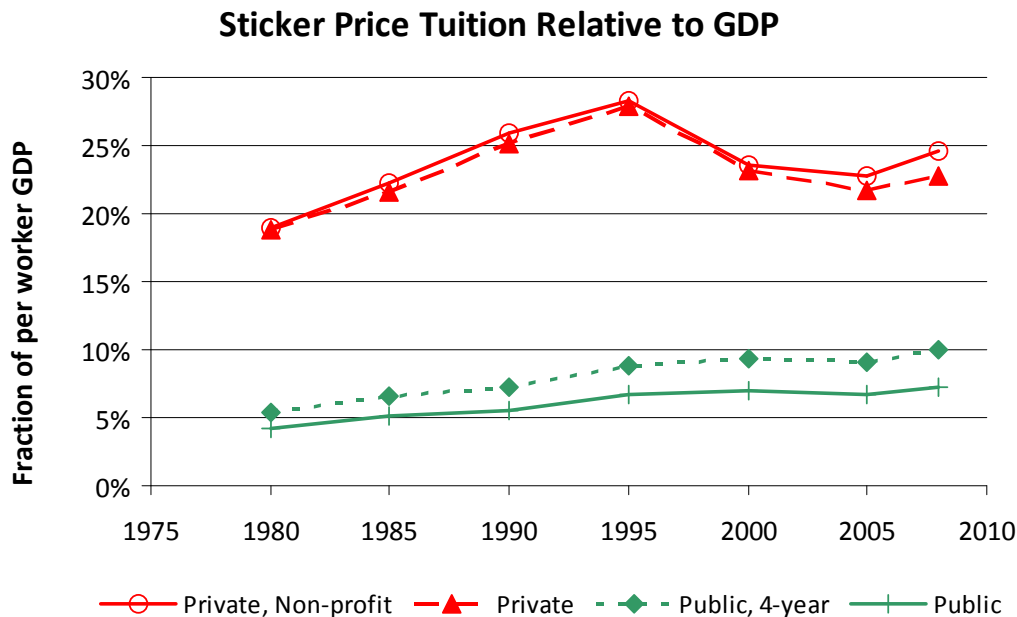
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Sticker Price Tuition Relative to GDP

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 staffing costs, data from the Digest of Education Statistics shows that faculty compensation has in fact grown very slowly. Figure 5 shows that salaries for full-time instructional faculty have fallen relative to GDP. Controlling for faculty rank and including benefits (not rank-differentiated) does not change the trend. Figure 6 also 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.
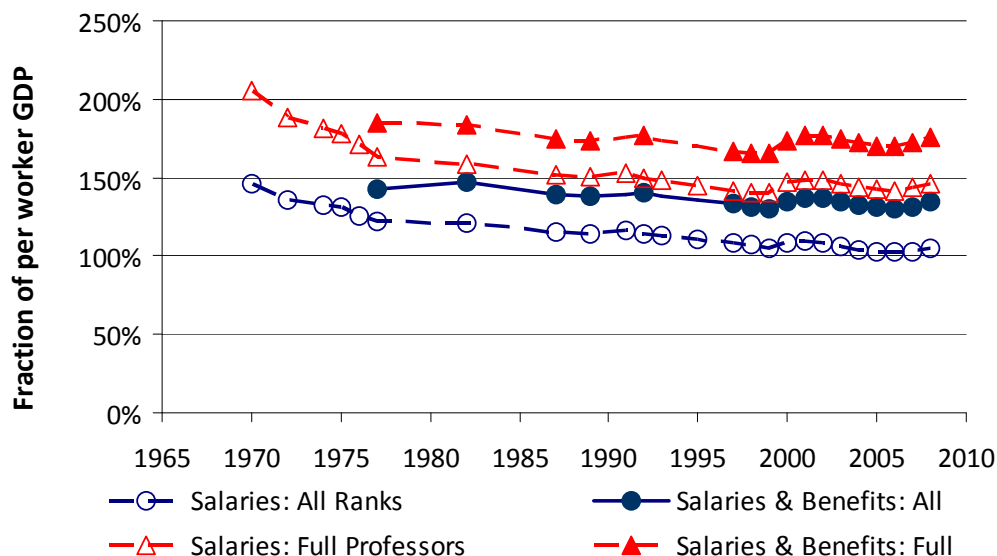
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Faculty Compensation Relative to GDP

Figure 5

Table 1. Students per Employee			
	1976	1999	2009
All	5.4	4.8	5.4
Professional staff	9.8	7.5	7.6
Administrative	84.0	69.9	68.5
Faculty	16.6	14.9	16.0
Graduate assistants	100.5	110.4	109.1
Other professionals	50.9	23.0	21.7
Non-professional staff	11.9	13.4	18.6
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
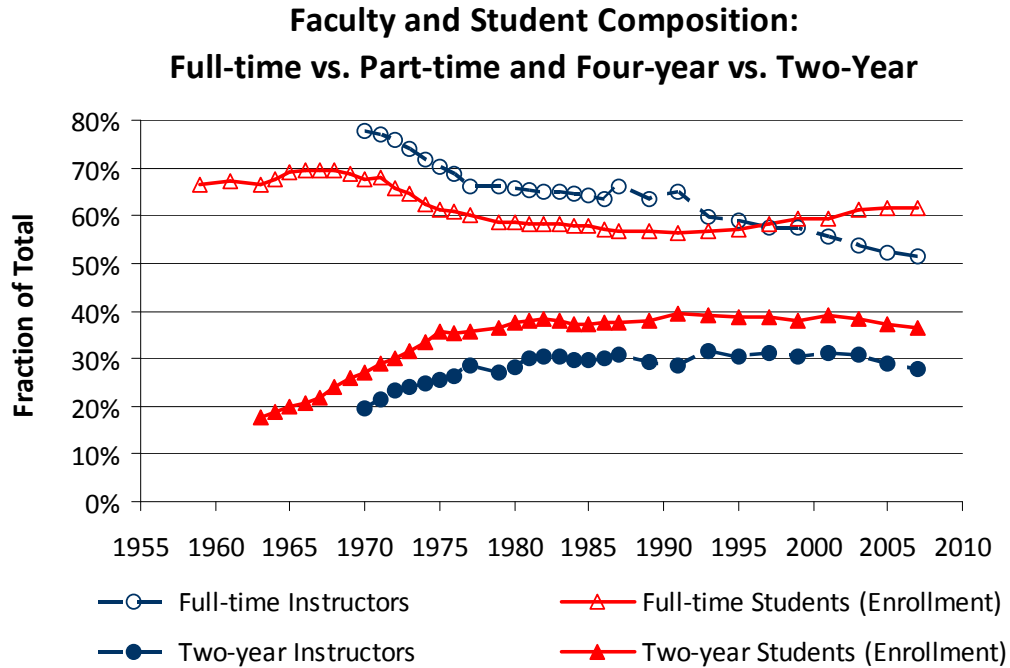
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Faculty and Student Composition:
Full-time vs. Part-time and Four-year vs. Two-Year

Figure 6

either efficiency or quality.

The reduction of non-professional staff in favor of non-faculty professionals has proba-
bly 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 the years 1929-30 through 1989-90. Unfortunately, these data do not divide
capital between "education and general uses", as opposed to auxiliary "current fund" uses
such as dormitories. Table 2 shows real 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 12 percent of plant) are a shrinking fraction of total current fund
expenditures.

	Table 2. Expenditures and Physical Plant			
	Expenditures			
	Current Fund	Education & General	Physical Plant	User Cost / CF Expenses
1929-30	5.59	4.16	22.76	48.9%
1939-40	6.60	5.11	26.95	49.0%
1949-50	7.97	6.06	17.04	25.6%
1959-60	10.53	8.81	25.47	29.0%
1969-70	14.02	11.22	28.04	24.0%
1979-80	14.66	11.47	21.57	17.6%
1989-90	19.43	15.23	23.75	14.7%
Note:	Costs are measured in 1,000s of $2005 per FTE.			

2.4 College Attainment and Earnings

Moving to the demand side of the higher education market, Table 3 presents college attainment for the past 70 years, using Census data.[7] In any given decade, the educational achievement of workers less than 25 years old is projected by the achievement of 30- to 34-year-olds in the *next* decade. This means, for example, 27.8% of the 20- to 24-years in 1960 attended college in the following decade. Because most people have completed their undergraduate studies by the time they reach 30, this is a good projection of ultimate educational attainment. Table 3 shows that the growth in college attendance is diminishing. For example, the fraction of people aged 25 or older that attended college rose from 32 percent in 1980 to 45 percent in 1990, an increase of 13 percentage points. Between 2000 and 2010, attendance grew by only 4 percentage points. In contrast, the fraction of people completing at least a Bachelor's degree continues to grow.[8]

Another piece of the puzzle is earnings. Census data indicate that in 1961, men who had attended college earned 46 percent more than high school graduates. By 2000, the premium had risen to 65 percent. During the same period, the earnings premium among those with least a Bachelors degree (relative to a high school diploma) rose from 59 percent to 107 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

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[7]Data through 2000 are from the Decennial Censuses. Data for 2010 are from the Current Population Survey.

[8]Table 1 shows that the fraction of college attendees receiving a Bachelors degree has grown modestly, from 46 percent in 1940 to 54 percent in 2010.

returns to college are at a minimum not decreasing.

	Table 3. College Attainment Rates (percent)			
	Attended College		Bachelors+	
	25+	30-34	25+	30-34
1940	10.1	NA	4.6	6.3
1950	13.6	16.3	6.2	7.4
1960	16.5	21.5	7.7	10.9
1970	21.3	27.8	10.7	14.4
1980	31.9	46.7	16.2	24.6
1990	45.2	55.1	20.3	24.3
2000	51.8	57.9	24.4	27.9
2010	55.9	61.1	29.9	34.1

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.

- Between 1940 and 2010, educational attainment, whether measured by attendance or 4-year degrees, more than quintupled.

- 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) using two skill categories of workers,

white-collar and blue-collar, and homogeneous capital. It is subject to an aggregate productivity shock A. Specifically, production is given by the following nested CES form

$$
\begin{align}
Y &= AK^\alpha[\omega W^{1-\varsigma} + (1-\omega)B^{1-\varsigma}]^{(1-\alpha)/(1-\varsigma)} \tag{1a} \\
&= AK^\alpha L^{1-\alpha}, \tag{1b} \\
L &\equiv [\omega W^{1-\varsigma} + (1-\omega)B^{1-\varsigma}]^{1/(1-\varsigma)}, \tag{1c}
\end{align}
$$

where B denotes total units of blue-collar skill, W denotes white-collar skill, K denotes capital, and L denotes total labor inputs. 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 and L are also nested in a CES aggregator, but find the elasticity of substitution for these two factors is close to 1.

Firms are perfectly competitive. The equilibrium pricing conditions are:

$$
r + \delta = \alpha\frac{Y}{K} = \alpha A \left(\frac{K}{L}\right)^{\alpha-1}, \tag{2}
$$

$$
w^B = (1-\alpha)(1-\omega)\frac{Y}{L}\left(\frac{B}{L}\right)^{-\varsigma}, \tag{3}
$$

$$
w^W = (1-\alpha)\omega\frac{Y}{L}\left(\frac{W}{L}\right)^{-\varsigma}, \tag{4}
$$

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

$$
\frac{w^W}{w^B} = \frac{\omega}{1-\omega}\left(\frac{W}{B}\right)^{-\varsigma}. \tag{5}
$$

3.2   Individuals

Individuals live from ages 18 to 65, for a total of $T = 47$ periods. Each individual is endowed with the skill level h. At the beginning of their lives, individual 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

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

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. Assume unskilled workers work L^B hours per year on average, and skilled workers work L^W hours. Let y_h^B denote the earnings of an individual of type h, with "raw" human capital h, if she works as unskilled worker: $y_h^B = h \cdot w^B \cdot L^B$. Let y_h^W denote the earnings of the same individual when she works as skilled worker: $y_h^W = \gamma(h) \cdot w^W \cdot L^W$.

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_h^W and U_h^B, the returns from going to college and not going to college, respectively, are

$$
\begin{aligned}
U_h^B &= N^B y_h^B; & U_h^W &= N^W y_h^W, \\
N^B &\equiv \sum_{t=0}^{T-1} \beta^t; & N^W &\equiv \sum_{t=4}^{T-1} \beta^t,
\end{aligned} \tag{6}
$$

where β is the discount factor.

Individuals can borrow and lend freely at the rate r. The decision to go to college thus depends only on the cost and the expected returns to college. Let c denote annual cost, and $C = c \sum_{t=0}^{3} \beta^t \equiv N^C c$ the lifetime cost, of college. Suppose that students pay the fraction d of this cost, with the remainder funded by lump-sum taxes.[9] 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^* which satisfies the following equation:

$$
\begin{aligned}
0 &\equiv \left(U_{h^*}^W - dC \right) - U_{h^*}^B \\
&= N^W \gamma(h^*) w^W L^W - N^C dc - N^B h^* w^B L^B.
\end{aligned} \tag{7}
$$

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

3.3   Higher education sector

Converting an 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 and the user cost $(r + \delta)$. The cost of going to college per year for an individual is

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

thus

$$c = E^W w^W + E^K(r + \delta), \tag{8}$$

where E^W is the number of skilled labor units devoted to each student in a year, and E^W is the amount of capital. Combining equations (8) and (7) allows us to restate the college skill threshold:

$$N^W \gamma(h^*) \frac{w^W}{w^B} L^W = N^C d \left[E^W \left(\frac{w^W}{w^B} \right) + E^K \left(\frac{r + \delta}{w^B} \right) \right] + N^B h^* L^B. \tag{9}$$

3.4   Ability distribution

Each individual begins life with a draw of human capital, h, from a log-normal distribution: $\ln(h) \sim \mathcal{N}(\mu, \sigma^2)$. Let

$$e = 1 - F(h^*), \tag{10}$$

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 interest rate r as given.

Definition 1 *A steady-state equilibrium is given by: the capital stock K and the labor quantities W and B; the skill threshold h^*; the wage rates w^B and w^W; and a distribution of people from age 18 to 65, $m(h)$, such that the following conditions hold:*
   (i) Given the interest rate and the wages, h^* is consistent with equation (7).
   (ii) All markets clear:

$$W = \frac{43}{47} \cdot L^W \cdot \int_{h > h^*} \gamma(h) \, m(dh) - \frac{4}{47} E^W e, \tag{11}$$

$$B = L^B \cdot \int_{h \leq h^*} h \, m(dh). \tag{12}$$

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

An important equilibrium statistic is mwr, the ratio of the average wage for college-educated workers to the average wage for blue-collar workers:

$$mwr = \frac{w^W \left[W + \frac{4}{47} E^W e \right] / \left[\frac{43}{47} e \right]}{w^B B / (1 - e)}. \tag{13}$$

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3.6 Transition Adjustment

Because the parameters of the model are shifting over time, the actual economy is in a transition path where the fraction of the population enrolled is increasing over time. This can be crudely approximated in our model by distinguishing between the current enrollment rate e_1 and the education attainment rate of older workers, e_0. Associated with these enrollment rates are the skill cutoffs h_1 and h_0. We proceed as follows:

1. h_1 is found by solving equation (9); we are assuming agents are myopic. h_0 is found by inserting e_0 – which is taken as given – into equation (10).

2. The overall enrollment rate is e:

$$e = \frac{4}{47}e_1 + \frac{43}{47}e_0 = \frac{4}{47}\left[1 - F(h_1)\right] + \frac{43}{47}\left[1 - F(h_0)\right]. \tag{14}$$

3. The new supplies of white and blue collar skill are:

$$W = \frac{43}{47} \cdot L^W \cdot \int_{h>h_0} \gamma(h)\, m(dh) - \frac{4}{47} \cdot E^W \cdot \int_{h>h_1} m(dh), \tag{15}$$

$$B = \frac{43}{47} \cdot L^B \cdot \int_{h \leq h_0} h\, m(dh) + \frac{4}{47} \cdot L^B \cdot \int_{h \leq h_1} h\, m(dh). \tag{16}$$

4. The equilibrium is defined much as before, replacing (10), (11) and (16) with (14), (15) and (16), respectively. The mean wage ratio is adjusted slightly:

$$mwr = \frac{w^W \left[W + \frac{4}{47}E^W e_1\right] / \left[\frac{43}{47}e_0\right]}{w^B B / \left[1 - \frac{43}{47}e_0 - \frac{4}{47}e_1\right]}.$$

4 Calibration

4.1 Procedure

We calibrate the model assuming the economy is in transition, taking the enrollment of the older cohort, e_0, as given. Our target years are 1959-60 and 2000-01.

We pick the following parameters from the data described above or from other studies: $\delta = 0.08$; $r = 0.04$; $\beta = 1/(1+r)$; $L^W = L^B = 1$; $\varsigma = 0.7$ (Heckman et al., 1998, Table III, OLS); $d^{1959} = 0.2363$; $d^{2000} = 0.2426$; $e_0^{1959} = 0.077$ (1960 value); $e_0^{2000} = 0.244$; and $E^K = 18,573$. The capital requirement E^K is found by scaling the capital figures in Table 3 by the ratio of education and general to current-fund expenditures, and taking

the average. We are measuring college attainment as the fraction of the population with at least a 4-year degree. We assume that the capital-output ratio is constant at 2.666, its average value since 1929.

We use the year-1959 and year-2000 values of $\{Y, K, e, c, mwr\}$, and year-1959 values of W and B to find the parameter vector $\{\sigma, \mu, \gamma_0, \gamma_1, \gamma_2, E^W, \alpha^{1959}, A^{1959}, \omega^{1959}, A^{2000}, \omega^{2000}, \alpha^{2000}\}$. We do this in three steps:

1. Given σ and γ_2, we choose 7 parameters, $\{E^W, A^{1959}, \gamma_0, \gamma_1, \mu, \alpha^{1959}, \omega^{1959}\}$, to match the following 7 moments in 1959: aggregate capital K, aggregate output Y, cost of higher education c, fraction enrolled e_1, mean wage ratio mwr, and the average skill levels of white-collar and blue-collar workers, both of which are 1. The final two targets are a normalization; as Lee and Wolpin (2010) point out, W and B are not identified separately from A and ω. To evaluate equations (15) and (16), we use formulas for the moments of truncated distributions found in Jawitz (2004).

2. We use the year-2000 values of $\{Y, K, e\}$, to find h^*, K, W, B, w^W, w^B, and the parameters $\{A^{2000}, \omega^{2000}, \alpha^{2000}\}$.

3. Finally, we iterate over σ and γ_2 (repeating steps 1 and 2), to minimize the distance between the observed and predicted year-2000 values of c/Y and mwr:

$$c = E^W \frac{Y - (r + \delta)K}{W + B \cdot w^B/w^W} + E^K(r + \delta),$$

$$mwr = \frac{[w^W W + \frac{4}{47} E^W w^W e_1] \left(1 - \frac{43}{47} e_0 - \frac{4}{47} e_1\right)}{w^B B} \cdot \frac{1}{\left[\frac{43}{47} e_0\right]}.$$

Appendix 7.2 provides a detailed description. Perhaps the most important calibration target in this process is the level of college costs, c. Our preferred measure of costs excludes both institutional aid and 2-year institutions.[10] Table 4 shows this measure, which appears as Case 4, is an intermediate case.

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[10]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 costs is constant over time, one can use attendence data to make an approximate adjustment.

	Institutional Aid	2-year Institutions	$(c/Y)^{1959}$	$(c/Y)^{2000}$
	Table 4: College Expenditures as a Fraction of GDP			
Case 1	Included	Included	32.77%	33.09%
Case 2	Included	Excluded	35.04%	40.13%
Case 3	Excluded	Included	31.56%	29.77%
Case 4	Excluded	Excluded	33.70%	35.74%

4.2 Results

Table 5 shows the value of parameters estimated from the model. We notice that skill-neutral technology, A, increases by 132% from 1959. The weight on white-collar skill in the labor composite, ω, increases from 0.2101 to 0.4748. The weight on capital, α, stays the same, which follows from equation (2) under a constant capital-output ratio and a constant interest rate. Recall that the level of white-collar skill is normalized so that the average worker in 1959 has 1 unit of skill. The calibrated value of E^W thus implies that each student requires 0.23 "typical" white-collar workers, or that each typical higher education worker serves about $1/E^W \approx 4$ students. This is fairly close to the values reported in the Digest of Education Statistics, which (since 1976) is around 5.

	Table 5. Calibrated Parameters		
		Values	
Parameters		in 1959	in 2000
A	skill-neutral productivity level	1,045	2,421
α	weight on capital	0.3199	0.3199
ω	weight on white-collar skill composite	0.2101	0.4748
γ_0	cubic production function of skill	0.9125	
γ_1	cubic production function of skill	54.8096	
γ_2	shifter in production function of skill	1.2397	
μ	mean of log ability	0.0096	
σ	standard deviation of log ability	0.0688	
E^W	skilled labor units per student per year	0.2324	

Table 6 assesses the model's fit of the calibration targets. The model matches all the data moments. 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.

		Y	K	c	mwr	e_1
Table 6. Data and model moments						
in 1959	data	26,740	71,280	9,010	1.651	0.144
	model	26,740	71,280	9,010	1.651	0.144
in 2000	data	61,290	163,400	21,890	2.074	0.341
	model	61,290	163,400	21,890	2.074	0.341
Note:	Output and capital per worker and college costs per student are measured in \$2005.					

5 Experiments

Between 1959 and 2000, three parameters changed: the skill weight ω, the productivity parameter A, and the tuition discount factor d. To assess the effects of each parameter, we perform a decomposition exercise, solving the model at its 1959 parameter values, and then changing each of the three parameters in isolation. First we look at skill-biased technological change (ω), then hicks-neutral technological change (A), and finally, change in tuition discount rate d.

5.1 In Transition

We assume that in both 1959 and 2000, the economy is in transition. In each experiment we fix $e_0^{2000} = 0.244$ as in the data. We can think of each change as an unexpected shock which affects the economy in 2000, but not the enrollment decisions made by previous cohorts.

Table 7 shows how the aggregate moments change in the full model and in each experiment. Enrollment, for both the youngest cohort and for all ages (e, given by equation (14)), is measured as absolute changes. Everything else is measured as the ratio of year-2000 values to year-1959 values. Notice that the enrollment of the existing cohort in 2000, $e_0^{2000} = 0.244$ is much higher than enrollment in 1959, $e_0^{1959} = 0.077$. Therefore, in the absence of other changes, white-collar skill becomes more abundant, which reduces the skill premium in each experiment. Notice from equation (2), capital and output always change in the same proportion, and if A is fixed, capital, aggregate labor (L) and output

always change in the same proportion.

	data	model	ω only	A only	d only
Table 7:	Effects of parameter changes—Transition				
Y	2.29	2.29	0.67	3.35	0.98
K	2.29	2.29	0.67	3.35	0.98
W	-	2.72	2.72	2.82	2.82
B	-	0.80	0.80	0.83	0.83
L	-	0.67	0.67	0.98	0.98
c/Y	1.06	1.06	1.32	0.44	0.62
mwr	1.26	1.26	1.26	0.37	0.37
w^W/w^B	-	1.44	1.44	0.43	0.43
e_1	0.197	0.197	0.197	-0.144	-0.144
e	0.170	0.170	0.170	0.141	0.141

Note: Table shows ratio of year-2000 values to year-1959 values, except for enrollment (e_1 and e), which are expressed as absolute changes.

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 (e_0) found in the data, resulting in an increase of the skill premium. As a result, the enrollment of the new cohort increases, resulting in a bigger reduction of blue-collar skill than in the benchmark model. With higher enrollment, more skill is used in the provision of higher education. Because college students are not yet working, this shift into higher education means that the amount of white-collar skill devoted to final goods production is smaller in this experiment than under the benchmark model. Aggregate labor decreases and as a result, both capital and output decrease. Although college costs as a fraction of output increase, the cost itself actually decreases.

A skill-neutral increase in A increases the demand for capital, white-collar skill and blue-collar skill. As is indicated in equation (2), capital increases relatively more than aggregate labor does. Because e_0 increases, white-collar skill increases relative to its 1959 value, and with ω unchanged, the skill premium drops. The college enrollment of the youngest cohort drops to zero to meet the increased demand for blue-collar skill, and to release white-collar skill from the higher education sector. With the diversion of all college-aged workers into blue-collar occupations, blue-collar skill increases by a bigger proportion. As a result, the skill premium and mean wage ratio are much lower than

in 1959. With no labor diverted to higher education, capital and output both increase a lot. With an excess of white-collar skill depressing white-collar wages, and output having grown relative to capital needs (E^K), college costs drop dramatically.

An decrease in d is a reduction in the discount rate of tuition (an increase of net tuition). While lower net tuition encourages college enrollment, the reduction in the skill premium caused by the increase in e_0 drives enrollment to zero.

5.2 In Steady State

In solving the transition model, we assume that agents predict their future earnings myopically. An alternative approach is to assume that the economy is in a steady state, so that myopic expectations are fully rational. We thus revise the our experiments, using the same parameter values but assuming that the economy is in a steady-state in both 1959 and 2000. We do so by requiring that all cohorts have the same enrollment rate, $e_0 = e_1 = e$, which they choose optimally. We first compute steady-state equilibria for 1959 and 2000, and then conduct the same decomposition as before. We find that when all the parameter changes are considered together, the transition and steady-state versions of the model deliver similar results. The results for the decomposition exercises differ more.

Table 7 shows the results. Notice from equation (2) that capital and output always change in the same proportion, and if A is fixed, capital, aggregate labor and output always change in the same proportion.

Relative to the benchmark transition model, in the steady state for 1959, enrollment for the older cohorts is higher and enrollment for the youngest cohort is lower. Average enrollment (e) is modestly higher in the steady state model. In the transition model, $e^{1959} = 8.3\%$; in the steady state the corresponding value is 8.6%. The total stock of white-collar skill is higher in the steady state because less skill is used in the higher education sector and also because there is a larger existing stock of skill held by older cohorts, due to their higher enrollment. Treating 1959 as a steady state generates a lower stock of blue-collar skill for older cohorts but increases that of the new cohort, who are now less likely to attend college. The former effect is dominated by the latter, and total blue-collar skill increases. Since both blue-collar skill and white-collar skill increase, aggregate labor increases. As a result, the total stock of capital is higher than in the benchmark model. While both types of skill increase, white-collar skill becomes relatively more abundant, so that the cost of college and the mean wage ratio are lower than in the benchmark model. The changes in the relative supply of skills, however, have small

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effects on total labor inputs (L) or output. For example, output for 1959 is $26,700 in the benchmark model and $27,000 in the steady state.

Table 8: Effects of parameter changes—Steady state

	1959	2000	total change	ω only	A only	d only
Y	2.70	6.25	2.31	0.67	3.44	1.0000
K	7.20	16.65	2.31	0.67	3.44	1.0000
W	0.076	0.209	2.75	2.74	1.00	0.9995
B	0.914	0.700	0.76	0.77	1.00	1.0001
L	0.619	0.416	0.67	0.67	1.00	1.0000
c/Y	0.315	0.327	1.04	1.32	0.81	1.0003
mwr	1.50	1.77	1.18	1.19	1.00	1.0004
w^W/w^B	1.51	2.10	1.39	1.39	1.00	1.0004
e	0.086	0.285	0.199	0.198	0.00	-0.000048

Note: Output and capital are measured in 10,000s of $2005. Final 4 columns show ratio of year-2000 values to year-1959 values, except for enrollment (e_1 and e), which are expressed as absolute changes.

The comparison between the year-2000 steady state reported in Table 8 and the year-2000 economy in transition reported in Table 6 is similar to the comparison for 1959. It follows that the changes from the year-1959 steady state to the year-2000 steady state are similar to the changes for the transition model reported in Table 7.

The steady state decomposition shows that the increase in enrollment is almost entirely due to skill-biased technological change. 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 and blue-collar skill decreases a lot. The cost of college rises significantly.

A skill-neutral increase of A increases the demand for capital, and both types of skill. The cost of college drops because output has grown relative to capital inputs, E^K. In a steady state, this drop in costs has a negligible effect on college attainment. During the transition, the current prices of blue- and white-collar skill affect the enrollment decisions of only the youngest cohort. In a steady state, relative skill prices affect enrollment across all cohorts, making the aggregate quantity of skill much more elastic. As a result, changes in the tuition discount rate are largely offset by changes in skill prices, and have

little effect on steady-state attainment. Labor inputs and wages change only slightly. It then follows from equation (2) that the increase in output and capital is almost exactly $(A^{2000}/A^{1959})^{1/(1-\alpha)}$.

If tuition as fraction of cost rises from 0.2363 to 0.2426, enrollment increases slightly, resulting in less blue-collar skill and more white-collar skill in the steady state. As a result, the skill premium and the relative price decrease. The cost of higher education also decreases, reinforcing the effect of large tuition discounts. The overall effect is very small, however, because of general equilibrium effects. In particular, we find that a 0.825% decrease in the tuition discount rate $(1 - d)$ results in a 0.056% increase in enrollment, implying an elasticity of 0.07.[11]   More radical experiments, such as setting $d = 0$ or $d = 1$, produce elasticities of similar magnitudes. Heckman, Lochner and Taber (1998b) and Castro and Coen-Pirani (2011) also find similar results. Aggregate labor decreases slightly and, as a result, both output and capital decrease slightly as well.

6   Discussion and Conclusions

In this paper, we show that a simple general equilibrium model with biased techno-logical 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 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.

An important limitation to the current analysis is that we model the endpoints of the 1959-2000 transition, rather than the entire trajectory. This restriction also leads us to assume that agents predict the returns to college myopically. Although our expectation is that our main findings do not depend on these assumptions, a full dynamic analysis is in order.

Our framework suggests that skill-biased technological change makes a college educa-tion 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

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[11]The exact calculation is $[-0.000048/0.0859]/[(0.7574-0.7637)/0.7637] = 0.068$. The more standard price elasticity is $0.00056/[(0.2426 - 0.2363)/0.2363] = 0.021$.

over the shorter-term. (See Dynarski, 2003, and the papers referenced therein.) 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 2000 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.

The model can also be enriched by introducing more heterogeneity in higher education, both in terms of quality and its price. As emphasized by Castro and Coen-Piranit (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 measures of our education measures.

Figure 7 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 7 reveals that scholarships and fellowships appear to have become increasingly important over time. In 2008, they equalled almost 4 per-
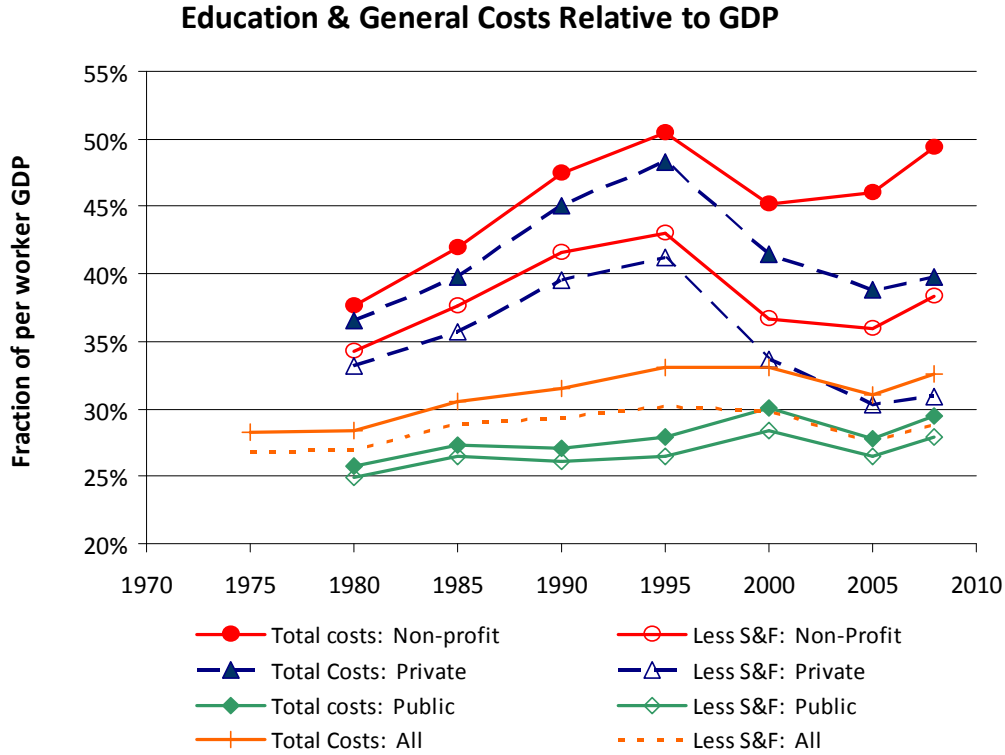
Education & General Costs Relative to GDP

Figure 7

cent of per worker GDP. Their effect appears to be most prevalent in private institutions, although this data is poorly measured.[12] 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. Since 1964, however, the Department of Education has estimated average undergraduate tuition, and since 1977, it has estimated average undergraduate tuition at 4-year institutions. Figure 8 compares the two measures of tuition. Prior to the data revisions of 1995, the measures moved together, with the revenue-based measures, which included graduate tuition, lying

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[12]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.
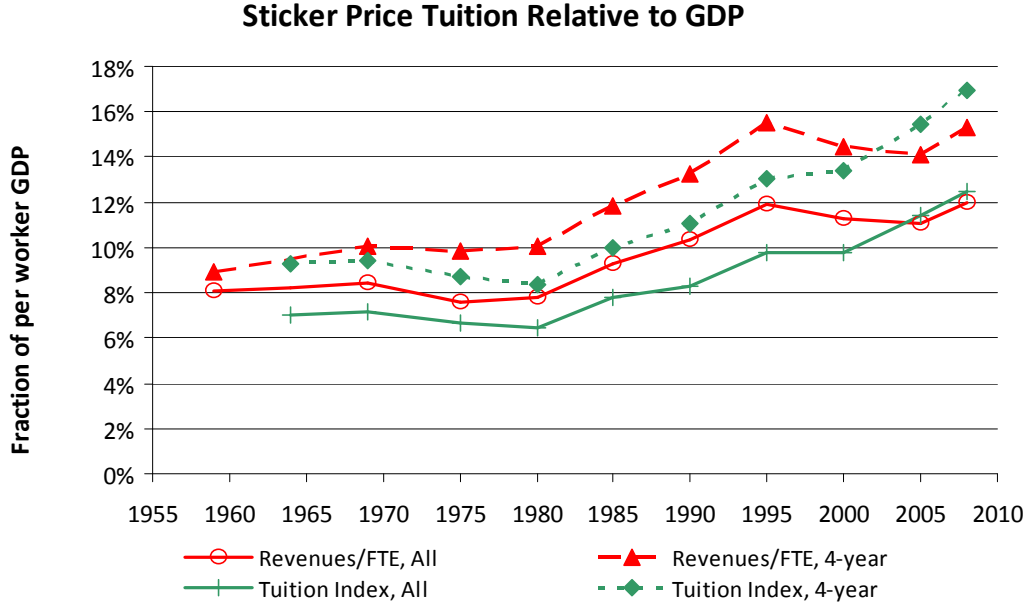
Sticker Price Tuition Relative to GDP

Figure 8

above the tuition index. After 1995, the revenue-based measures have levelled off, while the tuition indices have continued to grow. Over the period 1959-2000, however, the two sets of measures imply similar changes in tuition.

7.2 Calibration

We pick the following parameters from the data described above or from other studies: $\delta = 0.08$; $r = 0.04$; $\beta = 1/(1 + r)$; $L^W = L^B = 1$; $\varsigma = 0.7$ (Heckman et al., 1998, Table III, OLS); $d^{1959} = 0.1930$; $d^{2000} = 0.1846$; $e_0^{1959} = 0.077$ (1960 value); $e_0^{2000} = 0.244$; and $E^K = 18,573$.

We use the year-1959 and year-2000 values of $\{Y, K, e, c, mwr\}$, and year-1959 values of W and B to find the parameter vector $\left\{\sigma, \mu, \gamma_0, \gamma_1, \gamma_2, E^W, \alpha^{1959}, A^{1959}, \omega^{1959}, A^{2000}, \omega^{2000}, \alpha^{2000}\right\}$. We do this in three steps:

1. Given σ, γ_2, we choose the 7 parameters $\left\{E^W, A^{1959}, \gamma_0, \gamma_1, \mu, \alpha^{1959}, \omega^{1959}\right\}$ to match the following 7 moments in 1959: aggregate capital K, aggregate output Y, cost of higher education c, fraction enrolled e_1, mean wage ratio mwr, and to set average skill of white-collar and blue-collar workers to be 1. More specifically, we proceed as follows:

(a) From

$$mwr = \frac{\left[w^W W + \frac{4}{47}(c - E^K(r+\delta))e_1\right] / \left[\frac{43}{47}e_0\right]}{w^B B / \left[1 - \frac{43}{47}e_0 - \frac{4}{47}e_1\right]},$$

$$Y = w^W W + w^B B + (r+\delta)K$$

the income of each skill type is, respectively,

$$w^B B = \frac{Y - (r+\delta)K + \frac{4}{47}(c - E^K(r+\delta))e_1}{mwr \cdot \left[\frac{43}{47}e_0\right] \cdot \left[1 - \frac{43}{47}e_0 - \frac{4}{47}e_1\right] + 1},$$

$$w^W W = Y - (r+\delta)K - w^B B.$$

(b) We set average skill of white-collar skill to be 1: $\left[W + \frac{4}{47}E^W e_1\right] / \left[\frac{43}{47}e_0\right] = 1$, which implies $w^W = \left[W w^W + \frac{4}{47}(c - E^K(r+\delta))e_1\right] / \left[\frac{43}{47}e_0\right]$, and $W = \left(W w^W\right) / w^W$.

(c) From (5), we get $\omega = \frac{w^W}{w^B}\left(\frac{W}{B}\right)^{\varsigma} / \left[1 + \frac{w^W}{w^B}\left(\frac{W}{B}\right)^{\varsigma}\right]$

(d) $E^W = \left[c - E^K(r+\delta)\right] / w^W$

(e) We set average skill of blue-collar skill to be 1: $B / \left[1 - \frac{43}{47}e_0 - \frac{4}{47}e_1\right] = 1$, which implies $B = \left[1 - \frac{43}{47}e_0 - \frac{4}{47}e_1\right]$, and $w^B = \left(w^B B\right) / B$.

(f) Get L from (1c)

(g) Combining equations (2) and (4) yields

$$w^W = \omega\frac{1 - \alpha}{\alpha}\left(\frac{K}{L}\right)\left(\frac{W}{L}\right)^{-\varsigma}(r+\delta). \tag{17}$$

Using this equation, we solve for α

(h) Get A from (1a)

(i) Using e_1 and e_0, get h^* and μ by simultaneously solving equations (10), and (16).

(j) Solve for γ_1, γ_0 such that (9) and (15) hold at h^*. More specifically, solve γ_1 from

$$\frac{1}{[h^* + \gamma_1(h^* - \gamma_2)^3]}\int_{h > h^*}\left[h + \gamma_1(h - \gamma_2)^3\right]m(dh)$$

$$= \left[\frac{W + \frac{4}{47} \cdot E^W e_1}{\frac{43}{47} \cdot L^W}\right] / \left[\frac{N^C d(E^W \frac{w^W}{w^B} + \frac{E^K(r+\delta)}{\omega^B}) + N^B h^* L^B}{N^W \frac{w^W}{w^B} L^W}\right]$$

and γ_0 as

$$\gamma_0 = \frac{N^C d(E^W \frac{w^W}{w^B} + \frac{E^K(r+\delta)}{\omega^B}) + N^B h^* L^B}{N^W \frac{w^W}{w^B} L^W [h^* + \gamma_1(h^* - \gamma_2)^3]}.$$

2. We use the year-2000 values of $\{Y, K, e\}$ to find h^*, W, B, w^W, w^B, and parameters $\{A^{2000}, \omega^{2000}, \alpha^{2000}\}$ as follows:

   (a) Get h^* from (14)

   (b) Get W from (15) and get B from (16)

   (c) Get α^{2000} from (2)

   (d) Guess w^W/w^B, get w^B from $w^B = \frac{Y-(r+\delta)K}{\frac{w^W}{w^B}W+B}$, check (9) and iterate until convergence

   (e) From (5), get $\omega = \frac{w^W}{w^B} \left(\frac{W}{B}\right)^\varsigma / \left[1 + \frac{w^W}{w^B}\left(\frac{W}{B}\right)^\varsigma\right]$

   (f) Get A from (1a)

   (g) This procedure implies the following: Once we target enrolment, quantities such as W, and B, are fixed. The parameters A^{2000} and ω^{2000} adjust demand for blue-collar and white collar labor to clear each corresponding market.

3. Finally, we iterate over σ and γ_2 (repeating steps 1 and 2), to minimize the distance between the observed and predicted year-2000 values of c/Y and mwr:

$$c = E^W \frac{Y - (r + \delta)K}{W + B \cdot w^B/w^W} + E^K(r + \delta),$$

$$mwr = \frac{[w^W W + \frac{4}{47}E^W w^W e_1](1 - \frac{43}{47}e_0 - \frac{4}{47}e_1)}{w^B B \left[\frac{43}{47}e_0\right]}.$$

7.3 Solving the model—in transition

We assume that the economy is in a transition in 2000. In each experiment we fix $e_0^{2000} = 0.518$ as in the data. We find the year-2000 equilibrium h_1^*, e_1, W, B, K, Y, w^W, w^B as follows:

1. Make an initial guess of h_1^*

2. Get e_1 from (10)

3. Get W from (15) and get B from (16), thus W/B

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4. Get L from $(1c)$

5. Get K from (17)

6. Get Y from $(1a)$

7. Get w^W from (4) and w^B from (3)

8. Check (9), iterate over h_1^* until convergence

References

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

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

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

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

[5] 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.

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

[7] 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.

[8] 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.

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

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

[11] 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.

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

[13] Council of Economic Advisors. 2010. *Economic Report of the President 2010.* U.S. Government Printing Office, Washington, DC.

[14] 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.

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

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

[17] 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.

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

[19] 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.

[20] 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.

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

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

[23] 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.

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

[25] 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.

[26] 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.

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

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

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