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The Role of Mathematical and Verbal Skills on the Returns to Graduate and Professional Education

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August 2007

Students in majors with higher average quantitative GRE scores are less likely to attend graduate school while students in majors with higher average verbal GRE scores are more likely to attend graduate school. This sorting effect means that students whose cognitive skills are associated with lower earnings at the bachelor's level are the most likely to attend graduate school. As a result, there is a substantial downward bias in estimated returns to graduate education. Correcting for the sorting effect raises estimated annualized returns to a Master's or doctoral degree from about 5% to 7.3% and 12.8% respectively. Estimated returns to professional degrees rise from 13.9% to 16.6%. These findings correspond to a large increase in relative earnings received by postgraduate degree holders in the United States over the past 20 years.

JEL: J3

KEYWORDS: Postgraduate, Rate of return, Demand for schooling, Quantitative skills, Qualitative skills, Sorting

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I. Background

A wealth of economic research has documented an increase in the returns to education in the 1980s. Most of this research has concentrated on the relative returns to a bachelor's degree relative to lower levels of education. Since the 1980s, there has been a well-documented increase in returns to a college education relative to lower levels of schooling. The trend in relative earnings for bachelor's degree holders relative to high school graduates between 1976 and 1998 is illustrated in Figure 1. The bachelor's degree premium over a high school degree rose from 25% in 1976 to 45% in 1998 with the gains beginning in the early 1980s. Not as commonly known is that returns for those who entered or completed some postgraduate training rose even more rapidly. Over the period, the premium earned by graduate degree recipients above the average for those with bachelor's degrees rose from 32% to 67%.

This study has two objectives. The first is to measure the returns to postgraduate training, controlling for likely joint choices of years of schooling and their associated returns. Past estimates reported by Jaeger and Page (1996) and Graham and Smith (2005) imply very low annualized returns to graduate education of around 5% per year. However, those estimates may be clouded by nonrandom sorting on ability. The second objective is to determine if the increase in returns to postgraduate training can be explained by changes in the quality of more recent cohorts of graduate students relative to their older colleagues or if we need to seek other explanations for the rising returns to graduate education.

We focus on the roles of quantitative and verbal skills on education choice and observed returns to those choices. Several studies have documented changes in the returns to quantitative skills in the 1980s. Murnane, Willett and Levy (1995) found that rising returns to mathematics skills can explain a substantial fraction of the observed increase in returns to college between 1978 and 1986. Grogger and Eide (1995) and Levine and Zimmerman (1995) also reported that higher standardized mathematics scores or having taken more mathematics classes had a significant positive impact on women's wages but not men's wages.

The mechanism by which mathematical skills influence wages is not clear. It is likely that stronger quantitative skills are complementary with the use of information technologies that are widely suspected to have raised worker productivity and wages. However, quantitative skills may also affect the type of training individuals receive. Willis and Rosen (1979), Murnane, Willett and Levy (1995) and Taber (2001) all found that stronger mathematical skills in high school increased the likelihood of attending college. Paglin and Rufolo (1990) found that quantitative skills influenced choice of graduate major.

There is a presumption that quantitative and verbal skills increase in importance as the education level rises, and so changes in the value of these skills would be expected to affect the measured returns to post-graduate training. Two effects are potentially at work:

- 1) Rising returns to cognitive skills may have increased the opportunity costs of attending graduate school, limiting incentives to pursue post-graduate education in the areas where the returns are rising the most rapidly. Consequently, the most able students opt not to pursue graduate education in favor of capturing returns to those skills in jobs they can acquire with a bachelor's degree.
- 2) The marginal product of cognitive skills may have risen atypically in post-graduate training, raising the returns to graduate training relative to lower education levels.

These two possibilities would have opposite effects on incentives to attend graduate school and on observed wages. The former implies that the observed wage differentials between graduate and undergraduate degree holders would underestimate the true returns to graduate education because the earnings of those stopping at the bachelor's degree overstate the opportunity costs of those who attended graduate school. The latter would suggest that it is the most able who attend graduate school, and so the observed wage differential between graduate and undergraduate degree holders is an upward biased measure of the returns to graduate school. The comprehensive review by Card (1999) suggests that studies that control for nonrandom sorting into lower levels of education routinely obtain higher estimated returns to schooling when employing instrumental variables than from ordinary least squares estimation.¹ To our knowledge, previous studies of returns to graduate education have not explored the direction of bias from nonrandom sorting into graduate school.

There are many studies that examine incentives to enter individual majors and the returns to those decisions. However, more general studies of returns to graduate education are rare.² The advantage of exploring returns to graduate education across rather than within disciplines and degree programs is that quantitative and verbal skills undoubtedly sort individuals across majors and degrees. Nonrandom sorting means that the group of students in a particular major or degree program will not reflect the universe of potential students.

Our findings suggest that least squares estimates of the returns to graduate education are strongly biased downward by nonrandom sorting into graduate school. The nonrandom sorting occurs on both verbal and quantitative skills: bachelor's degree recipients in majors with stronger quantitative skills and weaker verbal skills are more likely to take a job after the bachelor's degree rather than going for further schooling. Consequently, the

observed average earnings for those opting for employment with a bachelor's degree overstate the average earnings of those opting to enter graduate school. Rising returns to quantitative skills and falling returns to verbal skills suggest that the downward bias in least squares estimates of returns to graduate education has been increasing over time. Correcting for nonrandom sorting raises estimated returns to levels similar to or larger than the returns to a bachelor's degree.

II. Estimation Model

We are interested in evaluating how verbal and mathematical abilities affect a bachelor degree recipient's choice to obtain a degree and on the returns to that degree. To begin, we assume that individual i 's skills are defined by

$$(1) \quad \mu_i = \mu_i^M + \eta_i$$

where μ_i^M is a vector of average mathematical and verbal skills associated with the individual's undergraduate major and η_i is an individual-specific ability component that does not vary across schooling levels. These individual skills combine with a vector X_i of individual characteristics and a vector Z_i of factors that shift the individual's taste for or cost of obtaining degree l to generate utility associated with each possible degree. Expected utility from the degree program is

$$(2) \quad V_{li} = X_i \theta_l^X + Z_i \theta_l^Z + \mu_i \theta_l^\mu ; \quad l = B, M, D, P.$$

The θ_l^j are parameters that translate the respective attributes or skills into expected utilities for each possible degree, $l = B$: Bachelor's, M : Master's, D : Doctorate, and P : Professional degree (mainly law or medicine). The expected gain in utility from pursuing degree l rather than staying at the bachelor's degree is

$$(3) \quad V_{li} - V_{Bi} = X_i (\theta_l^X - \theta_B^X) + Z_i (\theta_l^Z - \theta_B^Z) + \mu_i^M (\theta_l^\mu - \theta_B^\mu) + \eta_i (\theta_l^\mu - \theta_B^\mu) ; \quad l = M, D, P$$

The relative utilities are not observed, but we can estimate how the various factors affect relative utilities by placing some additional structure on (3). Let the probability that individual i completes degree program l be defined as

$$(4) \quad S_{li} = \Pr(V_{li} - V_{Bi} > 0) = \Pr \{ \{ X_i (\theta_l^X - \theta_B^X) + Z_i (\theta_l^Z - \theta_B^Z) + \mu_i^M (\theta_l^\mu - \theta_B^\mu) \} > \varepsilon_{li} \} ; \quad l = M, D, P.$$

We assume that $\varepsilon_{li} = \eta_i (\theta_l^\mu - \theta_B^\mu)$ is randomly drawn from an extreme value distribution with mean zero. Then, we can estimate the parameters $(\theta_l^j - \theta_B^j)$ using multinomial logit. The estimated parameters and knowledge of X_b , Z_b

and μ_i^M will allow us to estimate the probability that each individual selects any of the four degree programs

S_{Bi} , S_{Mi} , S_{Di} , or S_{Pi} .

Estimates of equation (4) and the resulting predicted probabilities have an interest in themselves, but they also come in handy for our other interest in deriving estimates of the returns to graduate education. Using the standard log-earnings framework:

$$(5) \quad \ln y_i = S_i \beta_S + X_i \beta_X + \mu_i^M \beta_\mu + (\eta_i \beta_\mu + u_i) = S_i \beta_S + X_i \beta_X + \mu_i^M \beta_\mu + \xi_i.$$

$\ln y_i$ is the observed earnings of the i^{th} individual; S_i is the observed schooling level measured by a vector of dummy variables with the value of one indicating the individual's highest degree earned; u_i is a random error term; and β_S , β_μ and β_X represent respectively the estimated returns to schooling level, individual attributes, and measured ability of the individual's major. The regression error term is $\xi_i = (\eta_i \beta_\mu + u_i)$. The problem with estimating (5) directly is that η_i enters the decision of how much schooling to undertake, and so

$E(S_i \xi_i) = E(S_i \eta_i \beta_\mu) \neq 0$. As a consequence, the coefficients derived from least squares estimation of (5) will be biased.

The predicted probabilities S_{Bi} , S_{Mi} , S_{Di} , and S_{Pi} are uncorrelated with η_i by construction, and so we insert three of them into (5) in place of the endogenous S_i to generate unbiased estimates of β_S under the maintained hypothesis that $E(Z_i \varepsilon_{li}) = E(Z_i \eta_i) = 0$. This requires plausible elements of the vector Z_i that affect degree choice but not the returns to the degree. We use measures of the direct cost of postgraduate education such as graduate or professional tuition levels and the likelihood of getting graduate support in the year of receipt of the bachelor's degree. We also included measures of parental education as elements of Z_i . The justification is that parents who have pursued postgraduate education can lower their children's search costs and psychic costs of pursuing a postgraduate degree.³

This two-step procedure is inefficient because it does not incorporate the sampling errors in the parameter estimation of the multinomial logit estimates of (4) into the estimation of the log earnings equation (5). We correct the second-stage standard errors using a bootstrapping procedure in which the two-step estimation was replicated 100 times, sampling with replacement, and sampling variation in the resulting estimates used to compute the second-stage standard errors.

If major-specific skills at the bachelor's degree level are increasing in market value, then they will tend to lower incentives to pursue graduate work in that field. Conversely, majors whose skills are falling in value at the bachelor's level will have disproportionately high numbers of graduate students. If this sorting effect drives lower earning bachelor's degree recipients into graduate school and drives higher earning bachelor's degree recipients out of graduate school, it would tend to depress estimated returns to graduate work. Least squares estimates of the returns to graduate school that ignored the role of major-specific ability measures would tend to understate the true returns. Our empirical work provides evidence consistent with this sorting hypothesis.

III. Data

The primary data source for this study is the Scientist and Engineer Statistics Data System (SESTAT) collected by the National Science Foundation (NSF). The 1993 wave of SESTAT also incorporated the 1993 National Survey of College Graduates, a once-per-decade survey that also covered fields outside of the sciences and engineering. The full sample includes 133,399 individuals who received a bachelor's degree between 1939 and 1992. Our working sample excludes individuals who received the bachelor's degree before 1963 or after 1986. The 1963 limit was necessitated by the lack of information on Graduate Records Exam (GRE) scores by major before 1963. The 1986 limit was imposed because we needed to give bachelor's degree recipients sufficient time to enter and complete advanced degrees. Of the 84,595 individuals whose bachelor's degrees are between 1963 and 1986, we exclude 20% because of missing information required for the analysis, with three-quarters of these dropped because of missing salary information. That leaves us with a working sample of 67,565 individuals who received a bachelor's degree between 1963 and 1986. We use sample weights so that our subsample can replicate means for the relevant universe: the population of all bachelor's degree recipients in the United States between 1963 and 1986.

To conserve space, we report summary statistics in an earlier version of the paper that is available on line (Song and Orazem, 2007). Earnings of all college graduates in 1993 averaged just under \$54,000. Bachelor's recipients averaged \$48,000 while Master's recipients averaged \$53,000, Ph.D.s averaged \$60,000 and those with professional degrees averaged \$84,000. Fifty-five percent of the college graduate population did not earn a degree beyond the bachelor's level. Twenty-nine percent had a Master's degree, 10 percent held professional degrees, and 6 percent had doctorates. Explanatory variables included in the demographic vector X_i are potential work experience (1993 – graduation year of highest degree), gender, citizenship, and racial and ethnic dummy variables. We also included information on whether the individual was raised in a rural area. Tastes for graduate education as

well as the opportunity costs and anticipated returns from postgraduate training are likely to vary across these demographic factors.

The vector Z_i includes average real medical school and graduate school tuition, and the percentage of self-supporting graduate students for the year the individual received the first undergraduate diploma. These data were compiled from the National Center for Education Statistics. Due to data availability, these measures are averaged across all postgraduate degree programs. This means that we only have time series and not cross sectional variation in the direct costs of postgraduate schooling. Even so, because undergraduates in a given major can select from many different graduate degree programs, major-specific information would be endogenous. The considerable variation in post graduate support over time should help to explain variation in the probability of pursuing postgraduate education across bachelor's degree cohorts.

Information on individual bachelor's degree major and year of graduation enable us to append information on the average GRE mathematics and verbal score for the college major in the year of graduation.⁴ The GRE scores are used to approximate the skill content of the major. These measures are not fixed over time, as can be seen in Figure 2. Average verbal scores rose until 1975 and then fell thereafter. Average quantitative scores rose about 12 percent until 1975, retreated slightly over the next ten years, and then resumed modest growth. However, these time trends cannot accurately reflect the time path of skills for U.S. bachelor's degree recipients because of the large increase in the fraction of test takers from foreign countries. To correct for changes in the composition of foreign graduate students, we regressed the GRE scores by major on the proportion of foreign doctoral graduates in the major six year earlier.⁵ The regression residuals will measure changes in the skill content of college graduates that are orthogonal to the proportion of foreign test takers. As shown in Figure 2, the corrected verbal GRE path lies above the observed path as one would expect, but the shape is very similar to the uncorrected path. However, the corrected quantitative GRE path shows a much steeper decline in average scores after 1975 and a much steeper rebound after 1986. The timing of the decline in verbal and quantitative GRE scores occurs about four years after the initial decline in 12th grade scores found on the Iowa Test of Basic Skills (Bishop, 1989).

Average GRE scores vary across majors, genders, races, and education levels. This variation provides cross-sectional variation in the skill content of bachelor's degree recipients. As shown in Table 1, the students whose highest degrees were at the bachelor's level were in majors with the highest quantitative scores and the lowest verbal scores. This is consistent with the speculation that the sorting into graduate school may be based in

part on the cognitive skill content of majors. Undergraduate majors in the sciences and engineering had markedly higher average quantitative scores while Engineering and Business had markedly lower average verbal scores. If returns to these skills have changed over time, there will be asymmetric changes in the relative incentives to seek post-graduate training across majors. Because demographic groups concentrate in different majors, there is cross-sectional variation in major GRE scores by race, ethnicity and gender. Males and Asians tended to select majors with higher average quantitative GREs and marginally lower verbal GREs.

IV. Estimation Results

A. Schooling Choices

Our primary interest is in deriving estimates of equation (5), but we also have an interest in assessing how bachelor degree recipients decide to continue on in school. Results from the weighted multinomial logit estimation of the schooling choice equation are reported in Table 2. The estimation uses the bachelor's degree as the reference group, and so positive (negative) signs indicate an increased (decreased) probability of obtaining the advanced degree relative to the baccalaureate level.

Family background variables are highly significant in influencing the choice of whether or not to pursue an advanced degree. As mother's and father's education levels rise, the probability of seeking an advanced degree increases. The effect is strongest at the PhD level. B.A. recipients who grew up in rural areas are less likely to pursue an advanced degree. U.S. citizens are less likely to seek a Master's or doctorate but are more likely to pursue a professional degree. Asians are more likely than whites to pursue a Master's or Ph.D., while Hispanics and Blacks are less likely to pursue the doctorate.

Measures of expected cost of pursuing a graduate degree performed as expected. Individuals who received the bachelor's degree in years with higher real graduate and medical school tuition levels were less likely to pursue an advanced degree. However, the negative effect is only statistically significant for the effect of graduate school tuition on PhD or Professional degrees. The percentage of self-supporting graduate students significantly decreased the probability of pursuing all three advanced degrees. The coefficient on an interaction between the probability of self-support and parental education shows whether parents with higher education levels moderate the adverse effects of a low probability of receiving graduate support.⁶ All signs on the interacted terms were positive, although only marginally significant in predicting the likelihood of obtaining a professional degree. The joint significance test of the six elements of Z_i easily reject the null hypothesis of no effect. Later, we found modest evidence that real

graduate tuition may not be a legitimate instrument. Although our results are not changed when we treat graduate tuition as an instrument, we restricted our set of instruments to the remaining five. These also easily passed joint tests of significance.

GRE scores have an interesting impact on the probability of pursuing a higher degree. The simulations in Figure 3 show how the probability of selecting each degree level changes with the average GRE scores for undergraduate majors. Undergraduates in majors with higher verbal scores are more likely to pursue the doctorate or professional degrees. However, undergraduates in majors characterized by stronger quantitative skills are much more likely to complete their schooling at the bachelor's degree level. In separate regressions, we found that the impact of the quantitative score on schooling choice has been stable over time. If returns to quantitative skills have risen, the rising returns must have been similar across education levels. The marginal effects of GRE verbal scores on schooling choice increased slightly over time, but the effect is much smaller than that of the quantitative score on degree choice.

We show how changes in average quantitative and verbal skills have affected postgraduate degree attainment in Figure 4. These simulated effects of the multinomial logit model hold all factors at their sample means except for the GRE scores which are allowed to vary at historical levels. Simulations are carried through to 1993 because all necessary information was available, although the parameter estimates are based on data just through 1986. The net impact of falling verbal skills and rising quantitative skills has been to lower the supply of doctorates since the late 1970s and to lower the supply of professional degree recipients since 1985. The incentives to stop at the bachelor's degree have been rising particularly since 1985.

B. Estimated Returns to Postgraduate Education

Table 3 reports the results from Ordinary Least Squares and two-stage estimation of the log earnings equation (5). Both sets of results correct for sample weights. Least squares estimates of returns to graduate education are positive and significant. However, the implied annual returns are very small compared to returns to lower schooling levels. Assuming a Master's program takes two years and a PhD program takes 6, the implied annual returns are only 5.6% and 4.1% respectively.⁷ Annualized returns to professional degrees are more reasonable at 13.9%, assuming a four year program. There is a significant positive return to majors with higher GRE mathematics scores but a significant reduction in earnings from majors with higher GRE verbal skills.

Holding those skills fixed, we find a significant premium for undergraduate degrees in engineering, social sciences, and particularly in business, and a significant discount for degrees in the sciences.

Controlling for the likely endogeneity of the schooling choices raises the measured returns to advanced degrees.⁸ The implied annual return to a Master's degree rises to 7.3%, near the lower bound of the corrected returns reported by Card (1999). The returns to a Ph.D. rise to 12.8%, toward the upper bound of the corrected returns reported by Card. The annualized return to a professional degree rises to 16.6%.⁹ These estimates seem much more plausible than the very low returns obtained from least squares estimates and seem more consistent with the presumption that technological change has led to rising returns to skill.

In estimates reported in Song and Orazem (2007), we replicate this estimation for individual undergraduate majors. There is less variation in opportunity costs and returns within majors which makes it more difficult to generate precise estimates. Nevertheless, those estimates are broadly consistent with those of Table 3 that correcting for endogeneity raises estimated postgraduate returns.

Returning to the two alternative possibilities discussed at the beginning of the paper, our findings suggest that least squares estimates of returns to postgraduate training are biased downward. Those who do not go on to graduate school are drawn atypically from the upper tail of the GRE quantitative distribution and the lower tail of the GRE verbal distribution, both of which are expected to raise their earnings. On the other hand, those who go on to graduate school are drawn disproportionately from the lower tail of the quantitative GRE distribution and from the upper tail of the GRE verbal distribution, both of which lower their opportunity costs of graduate school. Consequently, average earnings of bachelor's degree recipients overstate the opportunity cost faced by those opting to pursue advanced degrees, and so the observed premium of average earnings for postgraduate degree holders over bachelor's degree recipients understates the true returns to graduate school. Correcting for the sorting raises the estimated returns, as found in Table 3.

C. Unobserved Ability

In equation (1), we proposed that there would also be individual abilities within the major as well as the major average. These unobserved individual abilities may also affect the likelihood of pursuing an advanced degree. To test that hypothesis, we follow Rosenzweig and Schultz (1983) by collecting the residuals from the earnings equation. These residuals represent individual earnings of BA major recipients that are uncorrelated with education level, average verbal and quantitative skills in their major, or other demographic variables included in the earnings

function. They will also include random noise in the earnings function, so they will measure the unobserved ability with error. An auxiliary multinomial logit estimation of education choices on the earnings residuals will illustrate the direction of the effect of unobserved ability to earn income on the probability of seeking graduate or professional education. Note that the measurement error inherent in this method will tend to bias the coefficients toward zero.

Table 4 reports the estimated marginal effect of the earnings residual on the probability of pursuing each degree. Those with higher unobserved ability to earn income were more likely to pursue advanced degrees of all types, especially professional degrees. Consequently, unobserved abilities sort BA recipients in the opposite direction as sorting on observed quantitative skills, and in the same direction as sorting on observed verbal skills. Individuals with atypically large unobserved skill endowments particularly sort toward professional degrees such as law and medical schools.

V. Conclusions

Returns to advanced degrees are positive and significant. Least squares estimates for returns to Master's or doctoral education are quite low, on the order of 5% per year. Estimates increase in magnitude after controlling for likely endogeneity of the choice of pursuing an advanced degree. Our estimates of 7.3% return per year for a Master's degree and 12.8% return per year for a doctoral degree are of comparable size to those estimated for lower levels of schooling. Our finding of downward bias in least squares estimates of returns to graduate education are similar to the conclusions from estimated returns to lower levels of schooling.

Our study points out an interesting role for cognitive skills in the market for advanced degrees. Students in majors with higher average quantitative GRE scores are less likely to attend graduate school, even though such students presumably are more likely to be successful in graduate education. The opposite happens for verbal skills—students in majors with higher average verbal GRE scores are more likely to attend graduate school. This leads to a sorting effect whereby students whose cognitive skills would suggest lower earnings at the bachelor's level are more likely to attend graduate school. This sorting effect appears to be part of the cause of the downward bias in estimated returns to graduate education—the average earnings of those who do not go to graduate school overstate the opportunity costs of graduate education for those who do pursue advanced degrees.

Nevertheless, changes in verbal and quantitative skills over time as indexed by the changes in average GRE scores play only a minor role in explaining the large increases in relative returns to graduate and professional education since 1980. While quantitative skills have large and significant returns, the positive direct effect of rising

GRE scores on earnings is counteracted by the negative effect of improving quantitative skills on the probability of seeking advanced degrees. Verbal skills have no significant direct effect on earnings and declining skills have tended to reduce the probability of seeking advanced degrees since 1980.

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Table 1: Average GRE Score for the major, by attributes of individuals in the major

Individual Attribute	Verbal GRE	Quantitative GRE
BA	500.8	581.9
MA	502.4	568.7
PhD	508.2	573.0
Professional Degree	515.4	555.7
Science Majors	512.0	606.0
Engineering Majors	469.2	649.5
Social Science Majors	518.6	518.5
Business Major	475.4	542.3
Other Majors	502.4	507.5
White	503.6	573.9
Black	504.9	553.2
Asian	497.1	604.0
Native America	506.9	563.2
Male	501.0	585.3
Female	509.0	547.8

Data Source: NSF 1993 SESTAT, Educational Testing Service

Table 2. Multinomial Logit Estimation of Higher Education Choices

Variable	MA		PhD		Professional	
Family Background						
Mother's Education ^a	-0.044	(0.019)	0.039	(0.019)	0.031	(0.03)
Father's Education ^a	-0.010	(0.018)	0.057	(0.018)	0.101	(0.03)
Schooling Costs						
Medical School Tuition/100 ^a	-0.555	(0.54)	-0.003	(0.006)	-0.003	(0.009)
Graduate School Tuition/100	-1.76	(2.28)	-0.104	(0.025)	-0.06	(0.04)
% Self-Supported ^a	-.087	(0.019)	-0.067	(0.02)	-0.072	(0.03)
Parent Ed 16+*% Self-Supported ^a	0.004	(0.001)	0.002	(0.001)	0.003	(0.002)
Graduate Records Exam						
Verbal mean/100	0.350	(0.098)	1.38	(0.10)	1.84	(0.14)
Quant. Mean/100	0.033	(0.056)	-0.51	(0.05)	-1.58	(0.09)
Foreign Student Ratio	-0.442	(0.157)	1.59	(0.12)	1.64	(0.18)
Undergraduate major						
Science Majors	-0.658	(0.069)	0.052	(0.07)	2.202	(0.15)
Engineering Majors	-0.353	(0.096)	-0.288	(0.10)	1.257	(0.24)
Social science Majors	-0.527	(0.056)	-0.825	(0.06)	0.889	(0.13)
Business Major	-0.456	(0.095)	-1.420	(0.18)	-1.368	(0.55)
Demographics						
Experience/100	0.434	(5.31)	0.234	(5.43)	7.73	(8.39)
Experience squared/100	0.010	(0.12)	0.081	(0.12)	-0.337	(0.19)
Rural background	-0.172	(0.03)	-0.208	(0.04)	-0.380	(0.06)
Male	-0.244	(0.04)	0.333	(0.04)	0.667	(0.06)
Citizen	-0.411	(0.06)	-1.566	(0.06)	0.346	(0.12)
Hispanic	0.006	(0.06)	-0.208	(0.08)	0.098	(0.09)
Black	0.002	(0.05)	-0.241	(0.09)	-0.138	(0.09)
Asian	0.261	(0.04)	0.429	(0.05)	-0.076	(0.08)
Native Am.	0.129	(0.15)	0.277	(0.17)	-0.550	(0.27)
Constant	0.704	(0.87)	-2.976	(0.93)	-4.057	(1.38)

Pseudo R² = 0.078

Standard errors in parentheses. Tuition is in constant 1983-84 dollars.

^a Instrument used in second stage estimationJoint test of significance of five instruments: $\chi^2(15) = 725.6$

Data Source: NSF 1993 SESTAT, Educational Testing Service

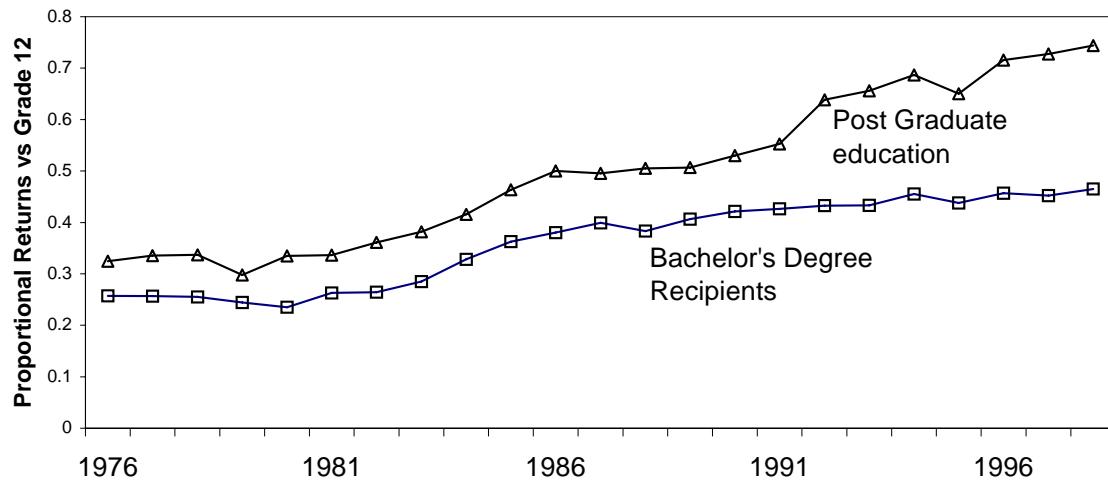
Table 3: Ordinary Least Squares and Two-Stage Estimation of the Log Earnings Function

Equation Variables	OLS Estimates		IV Estimates	
	Coefficient	Std. Err. ^a	Coefficient	Std. Err. ^b
Degree				
MA	0.112	(0.007)	0.146	(0.118)
PhD	0.243	(0.008)	0.766	(0.103)
Professional Degree	0.554	(0.013)	0.662	(0.081)
Graduate Records Exam				
Verbal mean/100	-0.070	(0.020)	-0.129	(0.301)
Quant. mean/100	0.181	(0.012)	0.210	(0.008)
Foreign Student Ratio	-0.020	(0.028)	-0.098	(0.038)
Undergraduate Major				
Science Majors	-0.036	(0.014)	-0.055	(0.012)
Engineering Majors	0.031	(0.012)	0.023	(0.009)
Social Science Majors	0.037	(0.011)	0.055	(0.012)
Business Major	0.118	(0.018)	0.140	(0.033)
Demographics				
Experience/100	2.42	(0.331)	2.722	(2.32)
Experience Squared/100	-0.027	(0.008)	-0.039	(1.09)
Rural	-0.084	(0.007)	-0.075	(0.108)
Male	0.170	(0.007)	0.158	(0.012)
Citizen	0.108	(0.013)	0.176	(0.021)
Hispanic	-0.061	(0.011)	-0.050	(0.032)
Black	-0.094	(0.009)	-0.083	(0.030)
Asian	-0.088	(0.009)	-0.100	(0.019)
Native Am.	-0.127	(0.034)	-0.141	(0.025)
Posdoc	-0.369	(0.011)	-0.262	(0.040)
Graduate School Tuition/100	-0.010	(0.002)	-0.008	(0.008)
Constant	9.698	(0.109)	9.660	(0.022)
R ²	0.234		0.144	
N	67,565		67,565	
Robust ^a or bootstrapped ^b standard errors in parentheses.				
Overidentification test: $\chi^2(5) = 3.38$. Critical value at 0.10 level is 9.24.				
Data Source: NSF 1993 SESTAT, Educational Testing Service				

Table 4. Marginal Effect of Individual Heterogeneity on Probability of Pursuing an Advanced Degree

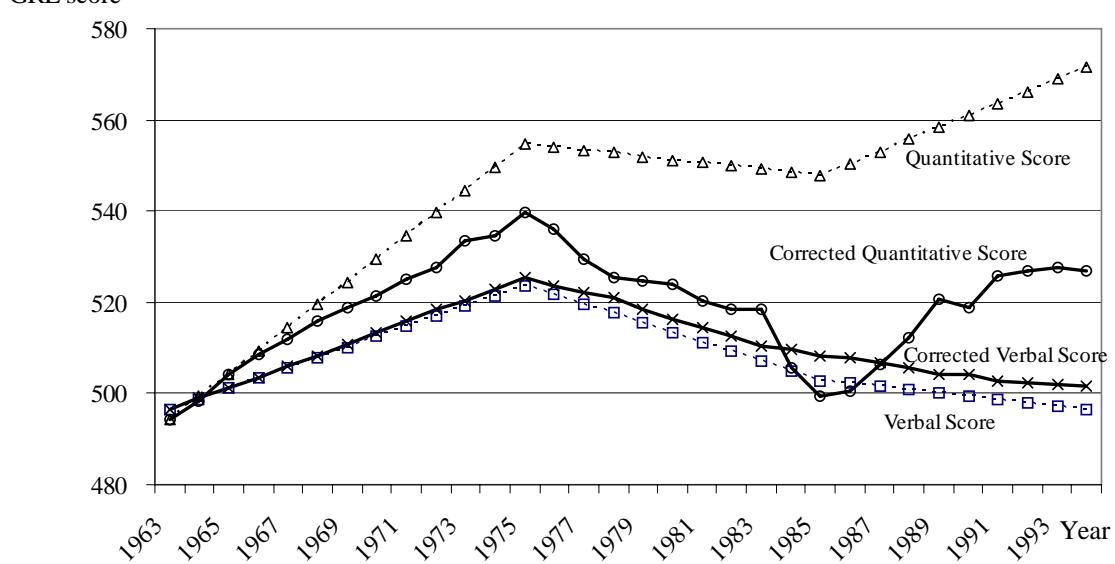
Dependent Variable	Marginal Effect	Std. Err.
BA	-0.224	(0.007)
MA	0.029	(0.007)
Ph.D.	0.038	(0.002)
Professional Degree	0.157	(0.004)
Data Source: NSF 1993 SESTAT		

Figure 1: Estimated Returns to Schooling Relative to High School Graduates: 1976-1998



Notes: Values based on coefficients from annual regressions of log weekly wage on a vector of dummy variables indicating educational attainment, age, age squared, and a vector of demographic dummy variables. Data taken from the March Current Population Survey (1976-1998).

Figure 2: Trends of Observed and Corrected GRE Verbal and Quantitative Scores, 1963-1997



Note: Corrected Scores remove the estimated effect of foreign test takers from the mean score. Data taken from the Educational Testing Service and the Survey of Earned Doctorates, various years.

Figure 3: Simulated probability of selecting each degree type by average GRE score of the undergraduate major, holding all other variables at sample means, based on the estimated multinomial logit model. Data Source: NSF 1993 SESTAT, Educational Testing Service

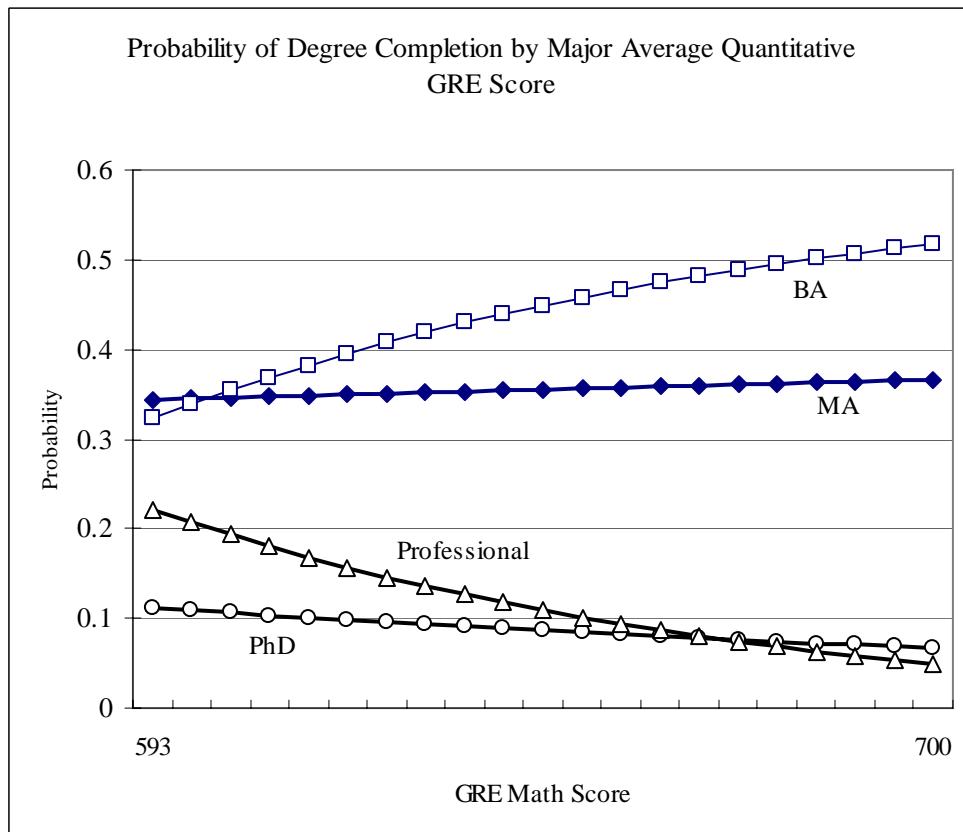
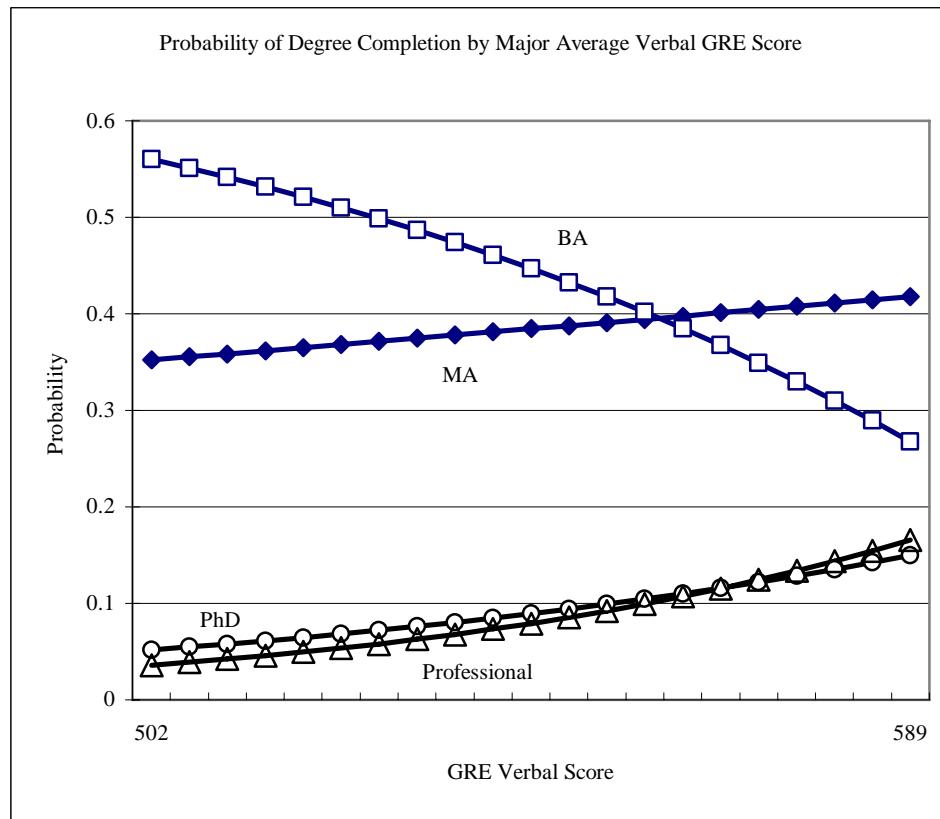
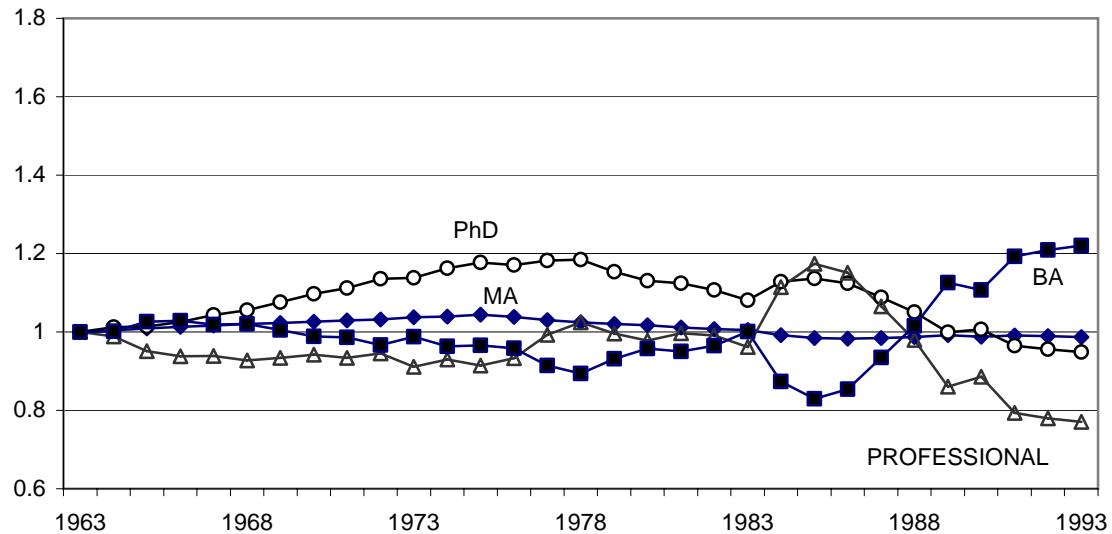


Figure 4: Simulated probability of selecting each degree type by historical changes in average quantitative and verbal GRE score, all else equal
Data Source: NSF 1993 SESTAT. ETS (1963 normalized to 1)



ENDNOTES

¹ Past studies using instrumental variables have been criticized for the use of potentially invalid instruments. For example, frequently used family background variables (Willis and Rosen (1979), Altonji and Dunn (1996), Deschenes (2002)) may be correlated with unmeasured ability, rendering them invalid. In their study using twins data, Ashenfelter and Rouse (1998) found that family background variables strongly affected educational choices but did not affect earnings, exactly what one would want in an instrument. However, as Card (1999) argues, even that is not sufficient to validate family background measures as instruments if family background is correlated with unobservable ability.

² See Ehrenberg (1992) for a review. The most recent studies of which we are aware are Jaeger and Page (1996) and Graham and Smith (2005). Earlier studies include Ashenfelter and Mooney (1968) and Taubman and Wales (1973). There is a vast literature on incentives to enter and returns to specific graduate degrees, pioneered by Richard Freeman (1976 a, b; 1999).

³ Card (1999) cautioned that parental education might not be a legitimate instrument for years of schooling if parental education is correlated with the unobserved individual ability, η_i . His argument suggested that when parental education is used as an instrument for years of schooling, the estimated return should be biased upward. We found that we obtained even larger returns to schooling when parental education was treated as an element of X_i rather than Z_i , although the differences were not large. Consequently, use of parental education as an instrument for years of schooling does not appear to bias upward estimated returns.

⁴ The Educational Testing Service provided this data for selected years: 1963, 1974 to 1976, 1983 to 1986. The number of majors included in the report varied from 21 majors in 1963; 92 majors in 1974 – 76; and 98 majors in 1983 – 86. These were aggregated into 28 major groups to correspond with the majors reported in the SESTAT. The GRE did not report data on 9 of the majors 1963, and so the nearest included major was used: e.g. computer science was placed in mathematics; agricultural and food science was placed in biology; and so on. Once consistent data series were generated for the four reporting dates, the values were interpolated to generate continuous values for the intervening years. As most average scores change very slowly, this process is unlikely to generate wildly inaccurate estimates of average scores by major.

⁵ The proportion of foreign doctorate recipients by major for each year in the sample period is reported by the Survey of Earned Doctorates. We presume that the average doctoral program takes six years and that the percentage of foreign graduates completing the program is proportional to the percentage taking the GRE exam six years earlier.

⁶ Parents education level variable is 1 if both parents are more than college graduate, $\frac{1}{2}$ if either one of them is more than college graduate, and 0 if both are less than college graduate.

⁷ Jaeger and Page (1996) estimate similarly small returns to Master's and PhD degrees under the assumption of exogenous education levels. Their estimation method includes both years of schooling as well as dummy variables indicating degree, so our annualized results are not directly comparable to theirs. Our OLS estimates are also very similar to those reported by Graham and Smith (2005) under the assumption of exogenous education levels. Their focus is not on returns to graduate education, and so they do not discuss the low implied annual rate of return to Master's or Doctoral training.

⁸ Estimates that also included parental education in the second-stage earnings functions yielded comparable estimates of returns to graduate and professional education.

⁹ These are likely to be overstated in that we do not incorporate tuition costs into the estimated return to professional degrees, and so these returns are gross of tuition costs. In contrast, tuition is often waived in doctoral programs, so those estimates are presumably closer to the true net return.

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