

Ryoo, Jaewoo; Rosen, Sherwin

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The Market for Engineers

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Working Paper No. 83

“The Market for Engineers”

**Sherwin Rosen
And
Jaewoo Ryoo**

**George J. Stigler Center
for the Study of
the Economy and the State**

The University of Chicago

THE MARKET FOR ENGINEERS

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Center for the Study of the Economy and the State
The University of Chicago
1101 East 58th Street
Chicago, Illinois 60637

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ABSTRACT

The national market for engineers in the United States is described over the 1950-90 period. Stocks of practitioners, new entrants and relative wages and salaries are tracked alongside such demand shifters as durable-goods production, R&D activities and national defense spending, and such supply shifters as wage prospects and opportunities in competing professions. We find that accounting and business careers appear to compete more strongly for new entrants than other occupations and that entrants respond quite strongly to relative earnings prospects assessed over careers at the time of their decision to study engineering. The supply elasticity of new entrants to engineering with respect to the present value of future engineering earnings relative to that of all college graduates is 2.5, among the largest that has been found for any profession. This large market response suggests that possible future shortfalls of engineers will not be a problem and that training engineers ahead of demand is not warranted.

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The Market for Engineers *

Jaewoo Ryoo

University of Pennsylvania

Sherwin Rosen

University of Chicago

1 Introduction

The decline in engineering and science bachelor's degrees since the mid-1980s has caused alarm in some quarters. Will stocks of technical talent be sufficient to support the research activities that sustain continual growth and rising standards of living over the long term (Lederman [1991], Fechter [1990], Atkinson [1990], NSF [1990])?

Similar concerns have arisen from time-to-time in the past. Shortages of scientists and engineers were thought to be observed in the 1950s. Professional interest in theories of permanent shortage (Arrow and Capron [1959]) has vanished, but the very idea of it indexes strength of opinion about the problem back then. Empirical studies provoked by these debates (Blank and Stigler [1957] and Hansen [1961]) were among the first modern, economically informed works on occupational choice.

Worries of shortages of science and engineering manpower disappeared with strong economic growth of the 1960s and the visible success of such public projects as the space program. Economists continued to investigate the question,

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most notably in the detailed studies of Richard Freeman (1971), extended to engineers (1976) and physicists (1975), where human capital concepts and the stock-flow adjustment mechanisms of modern investment theory were applied to the problem. These papers still help set the standard for work in this field.

This paper describes the national market for engineers from 1950 to the present. It focuses on the economic determinants of entry of college educated persons into the engineering profession. Our ultimate goal is to answer such questions as the following: From which alternative occupations are engineers drawn when engineering enrollments rise? What alternatives do potential engineers choose when enrollments fall? For example, did the explosive growth in the legal and business professions in the 1980s affect entry into engineering professions? The effect on entrants of earnings prospects in both engineering and other professions is studied using CPS and other data.

This study is largely descriptive and exploratory. The next section briefly outlines the demand and supply framework which organizes our thinking. A time-series depiction of the market over the past four decades is presented in Section 3. Section 4 adds more detailed description of the earnings and employment of engineers. Section 5 examines how changes in the relative earnings prospects in engineering and related professions affected entry. We find that elasticity of supply responses to changing market conditions are large, in the range of 2-3, and that business-related fields probably are the most competitive alternatives to engineering careers for new entrants.

2 Nature of the Market

There are reasons to believe that the demand for engineering services is more volatile than that of other skilled professionals (Cain, Freeman and Hansen [1973]). After all, other professionals tend to work in the Service Sector,

whereas engineers are most frequently found in the more volatile Durable Goods Manufacturing Sector. Durable goods account for a large fraction of business cycle employment variations. In addition, many engineers are employed in industries directly or indirectly connected with national defense. Demands for defense goods vary with the state of the economy as well as with international politics, because the federal budget is so sensitive to it.

Greater demand fluctuations increase the relative earnings risk of engineers compared to other skilled professions, but the organization of engineering careers has adapted to limit exposure to these risks, as well as to the risks of obsolescence. Careers are configured so that engineers tend to move into more business and management related positions over their life-cycle. Little data are available on these transitions, but it is estimated that as many as one-third of engineers are in sales and managerial positions at any point in time (NSF[1986]). This immediately raises questions about how to define the engineering profession for labor market analysis. No definition suits all purposes. From the point of view of demand, a definition that is work-related and based on specific engineering tasks is best. However, careers are the relevant concept for supply, and these include all probabilistic transitions into all other jobs over working life, whether or not they are engineering related.

Most of the data we have found useful are limited to survey respondents who report themselves as engineers, or in some instances, to those who maintain membership in engineering professional societies (Alden[1989]), so we are more or less constrained to the first concept. The obsolescence factor suggests that transitions back to engineering from other job titles are unimportant, so new entrants surely account for most gross entry.

The model we have in mind is based on traditional demand-and-supply concepts, but since the results in this paper are not model specific, the main ideas need be summarized only briefly. The high costs and long entry delays during training and the fact that annual net entry is a small fraction of existing stocks imply that the supply of engineers is much more elastic in the long run than in the short run. At any given time the stock of engineering-practitioners is fairly fixed and the supply of entrants largely is limited to students in the pipeline who already chose to invest in engineering some years earlier. This means that changes in demand for engineering services, arising mainly from changes in demand for high-tech intensive goods in defense and other durable goods industries, are the main determinant of year-to-year wage changes. Business cycles are influential here, as are more idiosyncratic events such oil price shocks and the computer revolution.

Demand-induced changes in wages and employment have long-term consequences in so far as they affect career prospects of new entrants and the propensity of engineers is the amount necessary to attract talented people into the field, to compensate for the extra costs and effort of engineering education compared to the many available alternatives. The financial attractiveness of these alternatives act as supply shifters. Changes in demand and opportunities for careers in legal, business, medical, science and many other services change the supply of new engineers. Another important aspect of supply arises from the fact that virtually all new entrants are young people. The number of people in a position to choose engineering careers is limited by the size of birth cohorts some 20 years earlier, college participation rates, and by immigration policies. We must distinguish between the fraction of a cohort choosing engineering, that is, the "participation rate," and cohort size itself. For example, if financial

incentives and tastes were constant and the engineering participation rate remained unchanged, there could be a large increase in supply if earlier birth cohorts were very large. Demographics are an important exogenous supply shifter in all labor markets.

The transitions between short- and long-run supply are so complicated that there is little consensus about them among economists. Since flows in and out of the engineering profession are a small fraction of existing stocks, significant long-term shifts in demand and supply are required for the effects to accumulate and significantly affect the allocation of resources in engineering. The problem is further complicated by the long training delays, the relative inexperience of students in making these decisions, and the difficulties of separating uncertainty about one's personal talent and interests on the one hand, and the general long-term state of the market in the future on the other. What is the timing and nature of the market information that prospective entrants examine in making their decisions? Are entrants myopic in looking only at the experience of current or slightly earlier cohorts, such as starting salaries, number of offers to new graduates and like, or are they farsighted and examine the whole range of lifetime career possibilities? And since students must commit to study long before they are in a position to practice the trade, how do they extrapolate conditions to the time they actually will enter? These two poles have been described in the literature. The myopic one (the "cobweb") by Freeman (1976) and the far-sighted one (rational expectations) by Pashigian (1977), Siow (1984), Zarkin (1985), and Pierce (1990). The truth probably lies in some grey area in-between.

3 Changing Market for Engineers

We generally study the 1950-90 period, but micro data from the March Supplement of the Current Population Survey only goes back to the mid-1960s. A complete list of data sources, construction of alternative series and description of extrapolation methods for missing observations are in the Data Appendix.

3.1 Stocks of Engineers

Figure 1 shows alternative estimates of stocks of engineers. All sources agree on trends and the general character of deviations around them, but there are unresolvable differences in the late 1960s and early 1970s. Unpublished NSF data derived from the CPS show that stocks decreased by an implausibly large 119,000 between 1969 and 1972. And, in data we drew from the CPS March tapes, the number of employed engineers declined by more than 100,000 during 1967-68, 1970-71, and 1982-83. The proportions of engineers who are unemployed reach as high as 3 percent in these years, with 6 percent not in the labor force in both 1971 and 1983, but those figures are not nearly big enough to generate those changes in stocks. The changes between 1967 and 1968 and between 1982 and 1983 in Figure 1 from the CPS tapes are probably caused by sampling error and are not confirmed by unpublished NSF data.¹

Figure 1 shows that many engineers do not have bachelor's degrees, but learn their trade through experience and training programs within firms. The number of such persons is fairly constant over the CPS data period (460,000 in 1968 and 507,000 in 1987), so the main increase in numbers in Figure 1 is

¹ The changes around 1971 are more controversial. Cutbacks in federal expenditures for defense, space, and R&D and a recession caused the markets for engineers and scientists to decline in that period. (Crowley [1972], Naughton [1972], and Freeman [1975] [1976]). Yet there is no change in numbers between 1969 and 1970 in BLS data, and another NSF data source shows that the numbers remained the same between 1970 and 1972.

accounted for by college educated engineers. There were 707,000 college educated engineers or 60.4 percent of the total in 1967 and 1,386,000 or 77.5 percent in 1987. The proportion of engineers with two or more years of graduate education also increased, from 19.2 percent of the college educated in 1967 to 26.2 percent in 1987. The share of engineers without college degrees has been steadily declining, but their numbers are substantial, and they cannot be ignored in the overall market for engineering services.

3.2 Enrollments and Graduates

Figure 2 illustrates the volatility of entry into engineering. There are substantial fluctuations around trend of engineering bachelor's degrees over the period, including the late 1980s when the number of graduates declined in absolute terms. The upward trend in numbers has increased at a greater pace than the labor force. Nonetheless, engineering graduates as a proportion of all bachelor's degrees have fallen over the period due to the enormous increase in total college degree production over the period, itself caused by changing size of birth cohorts and increasing college participation over successive cohorts, especially of women.² Stocks in Figure 1 are smoother than flows in Figure 2 because flows are a small percentage of stocks: For example, in 1985 the 78,000 new engineering graduates were less than 5 percent of the stock of about 1.7 million practicing engineers. The figure also shows first year enrollments data (lagged by 4 years) and the "completion" rate--defined as the number of B.A.s in engineering in year t divided by the number of freshman enrollments in year $t-4$. Freshmen enrollments in engineering are highly correlated with the number of degrees granted. Still, the absolute number of enrollments declined

² Since most engineering students are male, we also examined the ratio of engineering graduates to male college graduates. Its pattern is very similar to the ratio of all college graduates in Figure 2.

from the late 1950s to the early 1970s, even though the number of conferred degrees increased. Completion percentages are negatively correlated with enrollment. For example, from 1973 to 1984, total freshman engineering enrollment doubled, while the completion rate declined from 80 percent to 67 percent. This supports Freeman's (1971) suggestion that relatively large classes are likely to contain a greater proportion of less qualified students. In any event, it appears that a significant portion of the final recipients of engineering degrees differ from those who began engineering study: many entrants drop out of engineering programs and some others apparently enter in their later years of college.

Statistics on graduate education provide a fuller picture of entry into engineering (see Ehrenberg [1992] for related analysis). Graduate degrees have increased over time in parallel to the trend in undergraduate degrees (Figure 3). The proportions of engineering degree recipients among all graduates at corresponding levels (Figure 4) move in a synchronous manner, with the Ph.D.s naturally lagging the M.A.s which, in turn, lag the B.A.s. The timing of entry decisions into engineering programs at different levels by cohort seem largely unaffected by general market conditions.

3.3 Wages and Salaries

Median earnings data for engineers are available from the National Society of Professional Engineers (NSPE), and the Engineering Manpower Commission of the American Association of Engineering Society (EMC); starting salaries are available from the College Placement Council (CPC), the Placement Office of the Northwestern University (NW), and Bureau of Labor Statistics (BLS); and we calculated annual average earnings of all engineers with 16 and 18 or more years of education from the CPS tapes. CPS engineers include only those who report

themselves as such, but some of those in managerial positions are included in NSPE and EMC. Alternative earnings series are shown in Figure 5. All figures are deflated by the CPI and expressed as real 1987 dollars.

The figure shows a pattern that characterizes wage changes among many skilled occupations. Real earnings rose steadily up to the early 1970s, declined from the early to mid-1970s, but turned up and increased again in the early 1980s. This wave-like pattern is widely observed among all college graduates. However, its precise timing and amplitude vary among occupations, and these differences generate substantial changes over time in relative earnings between engineering and other professions.

There is general conformity among wage series of engineers from different sources and for different groups, as well as some differences in detail. Most notably, the peak in starting salaries in the 1960s occurred about five years earlier than the 1970s' peak in average earnings. Wage series for all workers and for new entrants may differ if there is imperfect substitution between old and young workers. A composition effect is also possible: as the sizes of entering cohorts change over time, the weights for different age groups in the computation of average earnings systematically change. We take up this question below.

3.4 Demand Shifters

Demand shifters known to be important for the engineering labor market include the overall level of economic activity, R&D expenditures, the defense sector, and durable-goods manufactures. In 1986 fully 42 percent of all engineers, including management, were doing R&D related work, 19 percent were employed in defense industries, and 46 percent were employed in durable goods manufacturing. Various demand indices are plotted in Figure 6. The major

recessions are clearly indicated in durable-goods production, and those of 1971, 1975 and 1981 are particularly reflected in the employment, entry and wage series of previous figures. Changes in Industrial Production-Defense and Space Equipment, total R&D Expenditure divided by GDP, and real Defense Department Outlays-Military Functions and Military Assistance are more closely correlated with changes in engineering salaries and enrollments than is total production.

A good overall proxy for labor demand conditions is the Help-wanted Index. Figure 7 contrasts it to the science-and-engineering-specific High-Technology Recruitment Index. The high-tech index is somewhat more volatile of the two, especially in the late 1960s and early 1970s, when there were drastic cuts in production of defense and space equipment. The series diverge in the late 1980s, with the decline in high-tech contributing to the decline in enrollments and earnings of engineers. Markets for scientists and engineers experienced something that was not shared by other labor markets in those years.

3.5 Employment of Engineers by Industry

The proportion of engineers in the civilian non-agricultural labor force steadily increased from 0.79 percent in 1950 to 1.6 percent by 1989. This trend has both within- and between-industry components. Engineering employment by industry is available from BLS sources for 1950 through 1970 and from the CPS tapes for 1967 through 1987. The employment figures do not match exactly for overlapping survey years, and we did not attempt to link them.

Figure 8 plots the proportions of engineers within major industries. Both the level and rate of change of engineering intensity are largest for durable-goods industries. The fourfold increase in the last four decades occurred in two distinct episodes, 1950-64 and 1974-87. Durable goods is the single most important employer and is the main reason why engineering employment intensity

in the economy increased. However, the proportion of engineers in durables among total engineers has remained almost the same (or mildly declined) since the mid-1950s, because the employment share of manufacturing declined.

The next most intensive users of engineers are transportation and public utilities. They show only a mildly increasing trend in intensity. Intensity increased in the construction industry until the mid-1960s, and decreased since then; intensity among nondurable goods industries increased mildly, and service industries show little trend. But as services have become more important in total employment, more engineers are engaged there. The share of total engineers in services increased from 14.9 percent in 1970 to 21.2 percent in 1987. Many of them are concentrated in "miscellaneous business service" and "engineering service" industries. The statistical decomposition indicates that 53 percent of the change in number of engineers between 1950 and 1987 is attributable to changes in intensity within industries. Furthermore, both the between-and-within changes evolve smoothly over time, in trend-like fashions.

4 The Structure of Earnings

This section describes more details about how earnings changed over time. Table 1 reports the results of earnings regression coefficients for engineers from CPS data. The dependent variable is the log of total earnings (wage and salary plus self-employment earnings) and the sample is all year-round, full-time employed engineers in the combined 1967-87 March CPS tapes.

Columns 1 and 2 use all engineers.³ Engineers who are female, nonwhite, not married, employed by the government, and living outside SMSAs earn significantly less than their counterparts. Engineers with graduate degrees earn about 10 percent more than those with bachelor's degrees, but engineers with college degrees earn 25 percent more than engineers without degrees. When additional year dummies and year-interaction variables are introduced in Column 2, the sex differential and self-employment premium are found to be falling over time, while the college degree and non-government premiums are increasing. Column 3 uses white male college graduates only. The estimates remain unchanged because engineering is largely a white male field: less than 5 percent of the sample are female or nonwhite.

Hours worked by engineers are not included in these earnings regressions because a consistent measure is not available in the March CPS for the whole period. Hours worked in a typical week last year were included only after the 1975 surveys. However, since the sample consists of year-around, full-time workers only, differences between annual earnings and average hourly earnings regressions should be minor. To check, Column 4 shows an hours regression where the dependent variable is hours worked per typical week last year for survey years after 1975 and is hours worked in the survey week for the survey years before 1976. Almost all coefficients are small in magnitude and have the same signs as the earnings regressions, indicating that demographic differences in mean hourly earnings are slightly smaller than differences in annual earnings.

³ All regressions include dummies for cases where earnings of respondents were imputed. Imputed wage-and-salary earnings tend to be significantly undervalued and the undervaluation has increased over time. Imputed self-employed earnings are less biased. Regressions including dummies indicating years before and after 1976, when the imputation method changed (see Juhn, Murphy, and Pierce [1990]), were statistically significant, but did not change the basic results.

Note that government employees work 5 percent fewer hours, and the self-employed work 13 percent more than their counterparts, so their relative hourly earnings are rather different than indicated in Columns 1-3.

How does the changing demographic composition of engineers affect year-by-year mean earnings in Figure 5? As it happens, not very much. Figure 11 contrasts the unadjusted raw mean earnings in each year to average earnings after controlling for compositional effects.⁴ The adjusted means are slightly smoother than the unadjusted means but the differences between the two series are negligible because the age-composition of engineers was relatively stable compared to other fields. We also analyzed CPS earnings data across engineering subfields, including aerospace and astronautical, chemical, civil, industrial, and mechanical engineering. Earnings in most subfields have been very stable, except for civil and industrial engineers, whose earnings relative to other engineers have declined since the mid-1970s. Overall, average earnings of engineers have been unaffected by changes in the structure of earnings among subfields.

5 Relative Earnings and Entry

How do engineering enrollments respond to changing market conditions and to relative earnings prospects of engineering? To begin to answer this important question, we examine whether various relative earnings measures can account for variations in the proportion of engineering B.A. degrees among total B.A.s and in the engineering share of college freshman enrollments.

Two practical issues emerge. First, which group of workers do prospective engineering students use as a basis for comparison in making entry decisions?

⁴ The adjusted means are the normalized time dummy coefficients in an earnings regression with no time interactions.

Measured changes in relative prospects are sensitive to the empirical choice of alternative occupation. Second, what specific measure of relative earnings prospects do entrants use--starting salaries, average earnings, or lifetime earnings? This question is of more general interest to the economics of occupational choice. Of course, data availability greatly limits the number of occupations and earning categories that can be examined.

5.1 Relative Prospects in Terms of Starting Salaries

The top panel in Figure 10 plots relative starting salaries of engineers (Engineers I) to several other occupations in BLS data. The figure also shows the engineering shares of college freshman enrollment and engineering bachelor's degrees conferred, lagged four years to account for the delay between the entry decision and actual entry. Starting wages of engineers relative to lawyers (Attorney I) and to auditors (Auditor I) track the degree and enrollment series quite well. Starting wages relative to accountants (Accountants I) and chemists (Chemists I) do not. Corresponding series from the College Placement Office (CPC) and the Northwestern University (NW) surveys appear in the other panels of Figure 10. The accounting major closely tracks the degree share in CPC data. The same is true in the NW surveys only after the mid-1960s. Prior to that correlations with starting salaries are poor in NW data.

Taking the three data sources together, accounting alternatives (or auditors in the BLS data) for the years after the mid-1960s track degree and enrollment shares better than the others. Surprisingly, engineering wages relative to wages in natural sciences do not track engineering entry very well. This is also confirmed in relative starting wages of engineering M.A.s and Ph.D.s in the CPC data. Apparently prospective engineering students consider business

related fields to be more relevant alternative fields than natural science fields.

Freeman (1971) reported that 21 percent of engineering students planned to work in business and accounting occupations. Only economics and business majors had higher proportions expecting to work in those occupations. Almost no engineering students intended to work in natural science related occupations even though engineering students considered natural sciences to be closer alternatives to their intended career than business related fields. However, business related majors are considered to be the closest alternatives by a significant portion of engineering students. If such students are nearer to the margin of choice and are more mobile, then relative entry into engineering would be more sensitive to relative wage changes in business related fields than to others. This would be reinforced if those students are more "money oriented" and tended to seek "professional" careers that don't require post-college education.⁵

Aptitudes of engineering students may be closer to students in business related fields than science students. NSF sources show that engineering students score higher in the mathematics GRE exam than social sciences students, but score lower than natural sciences students. The reverse is true for verbal scores. Though available data are insufficient for checking the similarity of engineering students to students in accounting and related fields and GRE data refer to

⁵ Paolillo and Estes (1982) find that more engineering students than any other majors have decided their college majors in high school. About 75 percent of mechanical engineers in their sample chose their field in high school or before. Corresponding numbers for physicians, attorneys, and accountants were 64 percent, 24 percent, and 24 percent respectively. The corresponding proportion for engineers is lower in Freeman's (1971) sample (25 percent). Note also that engineers tend to come from relatively low income families than other professions.

graduate students, it seems safe to conclude that engineering graduate students differ substantially from natural sciences graduate students.

Figure 10 demonstrates that the empirical choice of alternative occupation and data sources can affect analysis. Any specific alternative occupation is inevitably arbitrary because relative earnings figures are confounded by wage changes which are unique to particular alternatives in different epochs. Measuring engineers' initial earnings relative to average starting salaries of all college graduates eliminates that source of noise but those data are not available for the entire post-1950 period.

5.2 Relative Earnings of All Workers

Average earnings of all employed engineers and workers employed in alternative occupations can be used instead of starting salaries. These were calculated from the CPS tapes beginning in 1967. Figure 11 shows that the ratios of average earnings of all employed engineers with 16 or more years of schooling to average earnings of all lawyers or of all accountants track the engineering B.A. share data nearly as well as starting salaries do. The ratio to average earnings of all employed college male graduates does well too, even when it is adjusted for changing age and demographic composition of workers.⁶ Relative earnings of engineers declined in the 1960s, increased in the 1970s, and declined in the 1980s. The time-series pattern roughly coincides with that of relative entry. Using unadjusted college means (not shown) instead of standardized means reduces the variation in relative earnings, especially in the 1970s, because the

⁶ The college graduate wage data in Figure 11 are the exponential differences in the regression coefficients on year and year-engineers interaction dummies in a CPS sample of all male college graduates (including engineers). The regression includes all the usual explanatory variables, so these numbers are equivalent to Laspeyres relative wage indexes for engineers, given a fixed demographic composition. The regression is not corrected for selection bias.

average college graduate became much younger compared to the average engineer in that decade. Nonetheless, the general pattern is qualitatively similar for both adjusted and unadjusted wages.

A problem with CPS micro data is that it excludes engineers in management/sales/administrative positions, which may bias estimates of career prospects, and it only begins in the mid-1960s. Earnings of engineering graduates from the NSPE and EMC data are less subject to these problems. Incomes of college graduates with exactly 4 years of college education are interpolated from *Current Population Reports* back to the 1950s.⁷ The resulting relative earnings series based on NSPE and EMC data are also plotted in Figure 12. They trace the movements of the relative entry series since 1950 remarkably well, including the years before 1965, when relative starting salary series do poorly. Also notice that the size of the 1970s' increase in relative earnings of engineers in these series is conformable to the fully age-adjusted CPS micro data.

5.3 Relative Prospects in Terms of Lifetime Earnings

Lifetime earnings were calculated from both synthetic and actual cohorts, using the NSPE data for engineers and the CPS data for workers with 4 years of college education. Year-by-year market experience-earnings schedules were constructed for both engineers and college graduates and used to calculate discounted cross-section (synthetic cohort) lifetime earnings at alternative discount rates. This calculation summarizes all available current information on lifetime prospects in engineering compared to all other alternatives. In addition, ex post lifetime earnings were calculated from actual cohorts

⁷ NSPE and EMC data are bi-annual (and tri-annual in one instance) before 1980 and had to be interpolated to construct annual series. The methods are described in the Data appendix.

(successive cross-sections over time). Since these are truncated in 1989 for the NSPE and in 1987 for the CPS, we arbitrarily assumed that the experience-earning profile of 1989 persists forever for engineers and that the average experience-earning profiles for 1985-87 persists forever for college graduates. The results are not very sensitive to alternative growth assumptions after 1987 in the 1 to 2 percent range. These calculations assume that agents had perfect foresight over the future courses of market changes up to the data truncation points, and static expectations thereafter. Their ex post character means that they do not correspond to rational expectations because actual forecast errors for any year persist in present value calculation in all prior periods. We present it for exploratory purposes only.

The resulting relative lifetime earnings series are plotted in Figure 13 (synthetic cohort) and Figure 14 (actual cohort). The relative entry series in Figure 14 are pushed forward four years to accommodate the perfect foresight assumption. Career prospects calculated on synthetic cohort data reflect the degree series at least as well as the relative average earnings comparisons. In contrast, actual cohort discounted earnings poorly explains the changes in entry into engineering.

5.4 Discussion

Table 2 summarizes Figures 10 - 14. It reports OLS coefficients from regressing the log of relative entry on the log of relative earnings. Similar results are obtained when the engineering share of college freshman enrollments is used as the dependent variable and are not shown. The slope coefficients estimate the relative elasticity of supply into engineering. Estimates corrected for AR(1) autocorrelation do not change the D-W statistics very much because the supply curve is not strictly log linear.

The regressions of relative earnings prospects measured by relative starting salaries work well after the mid-1960s (Columns 1 and 2), but not for the entire period (Column 3). Freeman's (1976) relative earning series⁸ (Column 4) has negative coefficients. It is almost useless in predicting changes in relative entry over the entire period, though R^2 increased when the AR(1) model was used. Relative prospects measured by mean earnings of all workers (Column 5) better explains movements in degree production and enrollments, and lifetime earnings calculated from cross-section synthetic cohorts (Column 6) are even better. In contrast, relative prospects calculated from actual cohorts (Column 7) have negative coefficients. This is not consistent with Berger's (1988) general findings that ex post predicted future earnings calculated from longitudinal data better explain choice of college major than starting salaries (but see also Bamberger [1987]). Notice the timing of the entry and wage series. Earnings information in period t tracks freshman enrollments in t much better than earnings data four years later. Similarly, earnings data four years ago tracks current graduate percentages better than contemporaneous earnings.

These results hardly are definitive, but are interesting because Figure 13 and its implied regression in Table 2 are among the strongest results we have seen on the importance of economic considerations for occupational choice. Current capital value information from cross-sections accounts for enrollment rates much better than ex post information, but this is not definitive evidence on whether cobweb expectations are a better representation for choice than rational expectations. For instance, in some rational models the ex post wage and capital value data are fully "arbitraged" and basically orthogonal to entry

⁸ This is defined as the ratio of NW starting salaries of engineers to median earnings of Professional, Technical and Kindred Workers in Current Population Reports.

after the fact. It may be that the cross-section data afford the most information to entrants for rational forecasting.

Still, that kind of rationality is most compelling when there is a class of permanent market participants whose frequent and repeated trading activities are the principal source of their day-to-day incomes. Occupational choices are made early and at most only a few times during the lifecycle by young people, and their inexperience provides little natural knowledge about the dynamical structure of the market. Even "experts" in the manpower field often are seriously wrong in their market judgments and forecasts. Other sources of personal uncertainty, such as how well one will perform or learn the trade, probably loom larger in these decisions than general future anticipated market conditions for most people.

Nonetheless, the fact that measures containing lifecycle information (Column 6) outperform starting salaries does not confirm Freeman's (1976) earlier work. His finding that prospective entrants only consider starting salaries implies that agents are excessively myopic and "microscopic," and use virtually no relevant career information. Yet lifetime earnings calculated using whole age earning profiles in Column 6 are more informative than any other measures of relative prospects. Estimation of more fully specified dynamic models is necessary to further unravel these complicated issues.

6 Conclusion

Are there too few engineers? Several possible interpretations of this question must be distinguished. One interpretation is whether our economy has enough engineers compared to some "socially optimal" level. Perhaps the social product of engineers exceeds their private product, but we are not aware of convincing evidence one way or the other, or of feasible methods for finding out.

Another interpretation is that tastes of prospective engineering students are inappropriate and should be shifted. Perhaps better pre-college education and generating more youth interest in science will induce more college students to choose engineering at current earning differentials. Evidence is lacking on this point also. How such interests are provoked, independent of demand conditions, seems problematic.

A third interpretation concerns "shortages." No one argues that we are in a shortage situation currently. Rather, fears have been expressed that some future shortfalls are in the works. Our evidence suggests that these fears are overdrawn. The elasticity of supply of new engineers is large, in the range of 2.0 to 3.0. Therefore, relative wage changes induced by changing demand will increase the number of engineers fairly quickly, so long as there is no substantial decline in the number of college graduates, which are not expected to drop appreciably in the future. Further, there is no evidence that the supply elasticity is smaller at higher relative wages. Hence it is uneconomical to stockpile engineers on this account. Indeed, if students can be induced to choose engineering professions artificially, much talent and many resources will be wasted if conditions turn out the other way. High supply elasticities mean that the social and private option values of waiting are large. Building ahead of possible future demand is desirable when there are bottlenecks and large adjustment costs of expanding the educational system. Yet the system seems to have adopted reasonably well to the enormous run-up in enrollments between 1975 and 1985. The subsequent drop in enrollments suggests reasonable slack currently. It appears that adjustment costs are not a major concern in the market for engineers, so waiting is warranted on this account too.

DATA APPENDIX

I. Micro Data

Twenty-five years of March Demographic Files of Current Population Survey are available from 1964 to 1988. The tapes begin in 1964 but a 3-digit engineering occupation classification only began in the 1968 survey.

A. Engineers Sample

CPS engineers are workers who reported themselves as such in their longest job held during the previous year. The CPS identifies only those who are engineers currently. It excludes former engineers who have moved to other occupations. Population aggregates were obtained by multiplying each observation by its demographic weight. CPS earnings are based on full-year, full-time workers, those who worked 50 or more weeks a year and 35 hours or more in a typical work week. If earnings divided by weeks worked (or that number divided by 35) is smaller than the minimum wage multiplied by 35 (or the minimum wage), the observation is excluded. Earnings are measured as the sum of the wage-and-salary and self-employment earnings.

Top-coded observations were extrapolated by fitting Pareto distributions to the upper tail by least-squares, for each year: $\ln(1 - F(y)) = \alpha - \beta \cdot \ln y$, where y is earnings. Then the conditional mean $\beta e^{\alpha/\beta}/(\beta-1)$ was assigned to top-coded wage-salary or self-employment income records in each year. The estimated conditional means were very high for some years, such as 1973.

B. College Graduates

CPS data for college graduates (including accountants and lawyers) are for year-around, full-time workers with 16 or more years of schooling, except that

college and university teachers include those working 32 weeks or more in the previous year. Again, observations with average weekly or hourly earnings smaller than the weekly or hourly minimum wage were dropped. We follow Juhn, Murphy and Pierce (1992) in assigning 1.45 times the top-code for top-coded wage-and-salary and self-employment earnings. Total earnings are defined as the sum of these two earnings sources.

A lifetime earnings series for college graduates over 1950 to 1990 is constructed as follows. First, a subsample of white, male workers with 16 years of education was drawn from the college graduates' sample and used to calculate experience-mean earnings profiles for each year from 1963 to 1987. Then earnings of each experience level were averaged over 1963 to 1966. This 1963-1966 average profile was applied to annual mean earnings of male workers with 16 years of schooling for the years 1950-1962. Thus experience-earning profiles of the years before 1963 have the same shape with different means.

II. Aggregate Data

A. Wages

1. *Professional Engineers' Income and Salary Survey (NSPE)*: biannual (1952-79), annual (1979-)

The National Society of Professional Engineers (NSPE) conducts mail surveys of its members, excluding members of the Armed Forces, full-time students, the retired, and the unemployed. The sample size is relatively large: in 1952 there were 12,443 observations and in 1990 there were 12,486. Almost all the respondents have at least B.S. degrees and professional engineering licenses, so reported incomes from this source are larger than those in other sources. Respondents report actual incomes in the surveys before 1964 and after 1980. In-between they report annual incomes estimated at the time when questionnaires were

actually filled out. Fringe benefits are not included. Before 1977 engineers were asked to report total incomes including salaries, commissions, bonuses, and fees. It seems that the majority of respondents also included overtime payments as well as incomes from secondary or part-time employments. After 1979 only base salary and additional cash payment from the primary employer are included in income.

The NSPE surveys are bi-annual before 1979 (and tri-annual between 1964 and 1967). Missing data points were interpolated by regressing nominal earnings of all engineers on exponentials of t , t^2 , and t^3 , where $t = (\text{year}-1950)/39$, for the years between 1952 and 1982 ($R^2=0.9990$), and assigned predicted values to the missing years. This survey includes many, but not all, professional engineers in administrative/executive positions. Experience-salary data separately for each degree level are available only after 1967, so lifetime incomes are calculated using median earnings of all respondents, regardless of their highest degrees.

Lifetime earnings from the NSPE data were constructed as follows. First we constructed experience-earning profiles for each survey year. The reported experience categories are not conformable across years. After 1980 median earnings are reported for engineers with 0, 1, 2, 3, 4, 5-9, 10-14, 15-19, 20-24, 25-29, and 30+ years of experience. These are used to compute median earnings of workers with 0, 1, 2, 3, 4, 7, 12, 17, 22, 27, and 30 years of experience, respectively. Before 1980 reported experience categories differ and must be interpolated to these "standard" years. Here earnings in the nearest experience categories were used to linearly interpolate earnings of engineers in a given experience category. For example, if median earnings of the 22 years of experience group (Y_{22}) is not reported and only those with experience between 18

and 21 years (Y_{1821}) and between 22 and 24 years (Y_{2224}) are available, then Y_{22} is calculated as $(2.5 \cdot Y_{1821} + 1 \cdot Y_{2224})/3.5$. Second, if earnings are not reported for an experience level, the median earnings of the next lowest experience category is assigned to it. For example, the earnings of workers with 22 years of experience are assigned to workers with experience from 23 to 26. By these procedures, experience-earning schedules were constructed for experience levels from 0 to 40 years for all survey years. The final step is to construct an annual series of the experience-median earning schedule for nonsurvey years. Growth rates of annual median earnings in survey years were applied to experience-earning profiles of nonsurvey years. For example, the experience-earning schedule for nonsurvey year 1978 is gotten by applying the (gross) rate of growth of nominal median earnings between 1977 and 1978 to the experience-earning schedule of 1977. Deflating the earnings estimates by the CPI completes the construction of a table of experience and earning for the years from 1950 to 1989.

2. *Professional Income of Engineers (EMC)*: 1953, biannual (56-80), annual (80-)

These data are prepared by the Engineering Manpower Commission (EMC) of the American Association of Engineering Societies (Engineers Joint Council in earlier years). Mail questionnaires are sent to engineering employers in the early months of each survey year, asking for "annual salary" by "year of (or years since) B.S. degree." The sample is large. In 1989, there were 309 participating employers covering 121,262 engineers. In 1953 the numbers were 307 and 69,061, respectively. These data also cover all engineering graduates, including those in managerial positions, but exclude the self-employed. Separate data for different degree levels are only available for some sub-periods, so earnings

figures in the text are for all engineering graduates, including M.A.s and Ph.D.s. "Salary" is a base salary, including cost of living allowances and bonus if considered part of salary, but not including all irregular forms of compensation such as one-time bonuses, overtime payments, stock options, etc. Fringe benefits are excluded.

The data are bi-annual prior to 1980. The interpolation and extrapolation methods used for NSPE data were applied to construct an annual series of median earnings of engineering graduates with 10 years of experience: median earnings were regressed on exponentials of t , t^2 , and t^3 , where $t = (\text{year}-1950)/39$, for the years between 1952 and 1982 ($R^2=0.9992$), and the resulting predicted values were assigned to the years with no survey reports. Predicted values for 1950, 1951, and 1952 were assigned from a regression run only on the exponentials of t and t^2 for the years between 1953 and 1972.

3. CPC Salary Survey (CPC): annual (1960-)

The College Placement Council (CPC) compiles data collected from career planning offices of colleges and universities. It reports starting salary offers made to new male graduates. Data on female graduates are available only for later years. The salary offers are base salaries only, excluding bonuses, fringe benefits, and overtime rates. Since the survey reports offers (and not acceptances) and some students receive zero or multiple offers, these salary figures differ from those of actual hires. The sample size is relatively large: in 1990, 428 placement offices participated in the survey, covering more than 33,000 offers.

The average salary for each field is a weighted average of average starting salaries of subfields, with numbers of offers in those sub-fields used as weights. Engineering B.S. degrees cover Chemical, Electrical, Mechanical, and

Industrial Engineering. Engineering M.S.s and Ph.D.s cover Chemical, Electrical, and Mechanical Engineering. Natural Sciences B.S.s include Chemistry, Mathematics (excluding Computer Sciences for males), Physics (excluded for females), and Biology (for the years 1974 and after).

4. *Northwestern Lindquist-Endicott Report*⁹ (NW); annual (1947-)

The report is published by the Placement Office of Northwestern University. At the end of each year large and medium-sized national corporations are asked how many graduating students they are planning to hire next year in various fields. In 1990, 260 companies responded that they expected to hire 36,843 B.A.s, including 13,649 new engineering bachelor's degree recipients. The numbers in 1950 were 169, 7,352, and 2,373, respectively. We use data on the actual starting salaries of *males* in previous years because female salaries were only reported after 1975. Before 1961 the average starting salaries are weighted averages, with the number of companies used as weights. The expected number of hires at each salary level are used as weights in later years. The salary figures in these data are remarkably similar to those in the CPC report.

5. Entry Level Salaries in Selected Professions (BLS)

These are average annual salaries of attorneys, chemists, accountants, auditors, and engineers at entry level jobs for bachelor's degree holders, from U.S. Department of Labor, Bureau of Labor Statistics, *Handbook of Labor Statistics*, 1989. Original publication of this data is U.S.D.O.L., Bureau of Labor Statistics, *National Survey of Professional, Administrative, Technical, and Clerical Pay*.

⁹ The title of the report has been changed over time: *The Endicott Report* (1947-82), *Northwestern Endicott Report* (1983-86), *Northwestern Endicott-Lindquist Report* (1987-88), and *Northwestern Lindquist-Endicott Report* (1989-).

6. Annual Earnings of Males With 4 Years of College Education

Source: 1947-87; U.S. Department of Labor, *Current Population Reports, Series P-60*, various issues. The earning statistics in this series are for all employed college graduates, not confined to year-around, full-time workers. Only median earnings are available for 1988-89. Means were estimated for 1988 and 1989 by multiplying the median earnings of males with 4 years of college education (from *CPR*, 1991) by the mean/median ratio of earnings of the same group in 1987. Mean earnings data for 1947-66 are not available, and a simple method was used to extrapolate the series. Median earnings of workers with 4 and with 4 or more years of college education are available for the years 1958, 1961, and 1964-1989. Medians are available for those with 4 or more years of college in 1956 and 1963. First we used the ratio of median earnings of workers with 4 years of college to the median of workers with 4 or more years of college in 1958 to get the median earnings of the former group in 1956. Then the median earning series was regressed on $\exp(t/35)$ and $\exp((t/35)^2)$, $t = \text{year}-46$, for the years between 1946 and 1980 ($R^2=0.996$). Predicted regression values are used for the years with missing observations. Finally, actual mean earnings were regressed on median earnings constructed by the above method for the whole period ($R^2=0.9989$), and the resulting predicted values were assigned to the years before 1967. The resulting series was divided by the CPI to obtain real annual earnings.

B. Stocks of Engineers and Entrants

1. Conferred Degrees. Source: 1950-86; NSF, *Science and Engineering Degrees: 1950-86*, NSF 88-323, 1987-88; NSF, *Science and Engineering Degrees: 1966-88*, NSF 90-312.

For some sub-series there are small discrepancies between sources. The discrepancy is ignored when it is insignificant. Otherwise, the ratio of the number from the second source to that from the first source reported in 1986 was applied to the numbers from the second source reported in 1987 and 1988.

2. Enrollments

Engineering Enrollments are from Engineering Manpower Commission of Engineers Joint Council, *Engineering and Technology Enrollments*, various issues. Total Freshmen Enrollments for 4-Year colleges and universities for 1946-60 are from U.S. Department of Education, *Digest of Education Statistics*, 1966 and for 1961-87 from *Digest of Education Statistics*, 1990. Note: Freshmen enrollments for 4-year colleges and universities are not available prior to 1955. Total freshman enrollments for *all* post-secondary education institutions, including 2-year colleges, are available for those years. The ratio of enrollments in 4-year institutions to freshman enrollments in 1955 are applied to pre-1955 numbers.

3. Stocks of Employed Engineers

Number of Engineers are available for 1950-70 from BLS, *Employment of Scientists and Engineers 1950-70*, 1973; for 1950-66 from NSF, *Employment of Scientists and Engineers in the U.S.: 1950-66*, 1968, for 1960, 1962-70 and 1972-88 from unpublished NSF data derived from CPS tapes; and for 1970-80, NSF, *Science and Engineering Employment: 1970-80*, 1981. Employment of Engineers by Industry for 1940-70 is from U.S. Department of Labor, BLS, *Employment of Scientists and Engineers*, 1973 and is calculated from CPS tapes for 1971 onward.

C. Other Series

CPI: 1950-1988 from U.S. Department of Labor, *Handbook of Labor Statistics*, 1989, and 1989-1990 from *Monthly Labor Review*, January 1991.

GDP for 1947-82, from *The National Income and Product Accounts of the United States, 1929-82*, 1986, and for 1983-90 from *Survey of Current Business*, July issues.

GNP Consumption Deflator: 1950-1959; U.S. Department of Commerce, *Handbook of Cyclical Indicators*, 1984. 1960-90; NSF, *Science and Engineering Indicators*, 1989.

Index of Industrial Production, Index of Help-Wanted Advertising in Newspapers, Index of Industrial Production-Defense and Space Equipment, Defense Department Net Outlays-Military Functions and Military Assistance: prior to 1982 from U.S. Department of Commerce, *Handbook of Cyclical Indicators*, 1984; for 1983-89 from *Business Conditions Digest*, various issues and for 1990 from *Survey of Current Business*, Jan. 1991.

R&D for 1953-59 from NSF, *National Patterns of R&D Resources; Funds and Manpower in the United States 1953-73*, 1973, and for 1960- from NSF, *Science and Engineering Indicators-1989*, 1989.

High Technology Recruitment Index is an index of advertisements for engineers and scientists with 4 years of college education or more which appeared in 39 publications, including newspapers (Sunday classified) and technical journals, from Deutsch, Shea & Evans Inc., *High Technology Recruitment Index*, May 1989. Numbers in the text are annual averages.

Number of Employees on Nonagricultural Payrolls by Industry: BLS, *Handbook of Labor Statistics*, 1989.

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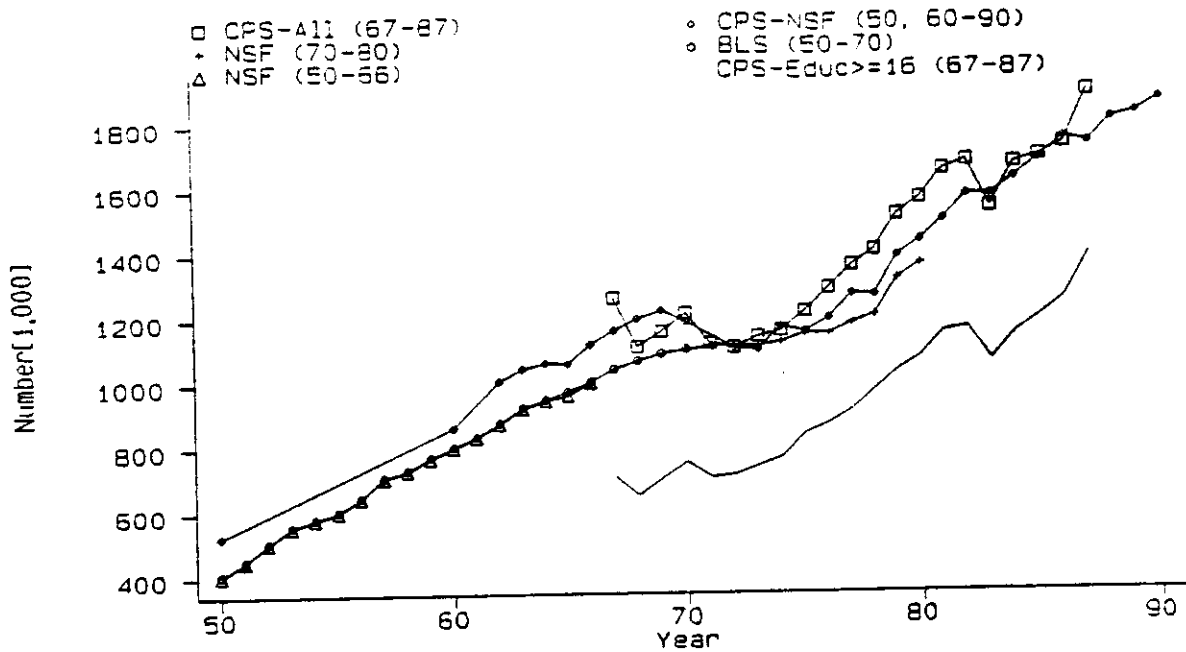
TABLE 1
REGRESSION COEFFICIENTS (t-Statistics)

DEPENDENT VAR.	LOG OF YEARLY EARNINGS			WEEKLY WORK HOURS	
	DEMOG. VBLS.	ALL WORKERS	ALL WORKERS	EDUC>=16 WHITE-MALE	ALL WORKERS
FEMALE	-0.1808 (-13.66)	-0.3590 (-8.660)			-2.0780 (-5.602)
NON-WHITE	-0.0999 (5.868)	-0.0508 (-1.157)			-0.7226 (-1.521)
EDUCATION<16	-0.2350 (-43.678)	-0.2101 (-18.892)			-0.2309 (-1.534)
EDUCATION>=18	0.1011 (14.947)	0.1153 (7.450)	0.0994 (14.478)		-0.0662 (-0.350)
SELF-EMPLOYED	0.0523 (3.306)	0.2297 (5.674)	0.0738 (4.129)		5.4870 (12.514)
GOVERNMENT	-0.0486 (-7.482)	0.0267 (1.959)	-0.0399 (-5.074)		-2.1971 (-12.134)
NOT-MARRIED	-0.0611 (-9.172)	-0.0654 (-3.969)	-0.0609 (-7.360)		-0.3169 (-1.692)
NOT IN SMSA	-0.0668 (-11.880)	-0.0791 (-6.268)	-0.0529 (-7.310)		0.7178 (4.527)
WAGE IMPUTED	-0.0435 (-6.080)	-0.1166 (-6.465)	-0.0552 (-6.211)		
SELF-EMPLOYMENT EARNING IMPUTED	0.0024 (0.208)	0.0280 (1.068)	-0.0277 (-1.911)		
EXPERIENCE	0.0384 (21.584)	0.0472 (12.327)	0.0376 (16.357)		0.0933 (1.880)
EXPERIENCE**2	-0.0009 (-9.539)	-0.0014 (-7.288)	-0.00083 (-6.160)		-0.0019 (-0.718)
EXPERIENCE**3	5.86E-05 (3.974)	1.21E-05 (3.994)	4.0E-06 (1.795)		-3.81E-05 (-0.928)
<u>TIME INTERACTIONS</u>					
FEMALE		0.0120 (4.670)			
NON-WHITE		-0.0032 (-1.067)			
EDUC<16		-0.0021 (-2.473)			
EDUC>=18		-0.0009 (-0.773)			
SELF EMPL.		-0.0131 (-4.597)			
GOVERNMENT		-0.0066 (-6.201)			
SMSA		-0.0012 (1.239)			
NOT-MARRIED		0.0084 (0.731)			
WS IMPUTED		0.0059 (4.699)			
SE IMPUTED		-0.0024 (-1.052)			
EXPERIENCE		-0.0002 (-0.507)			
EXPER**2		.000042 (2.751)			
EXPER**3		-4.6E-07 (-1.976)			
YEAR DUMMIES	NO 0.2673	YES 0.2806	YES 0.2256		YES 0.0344
N OF OBS.	17289	17289	11097		17289

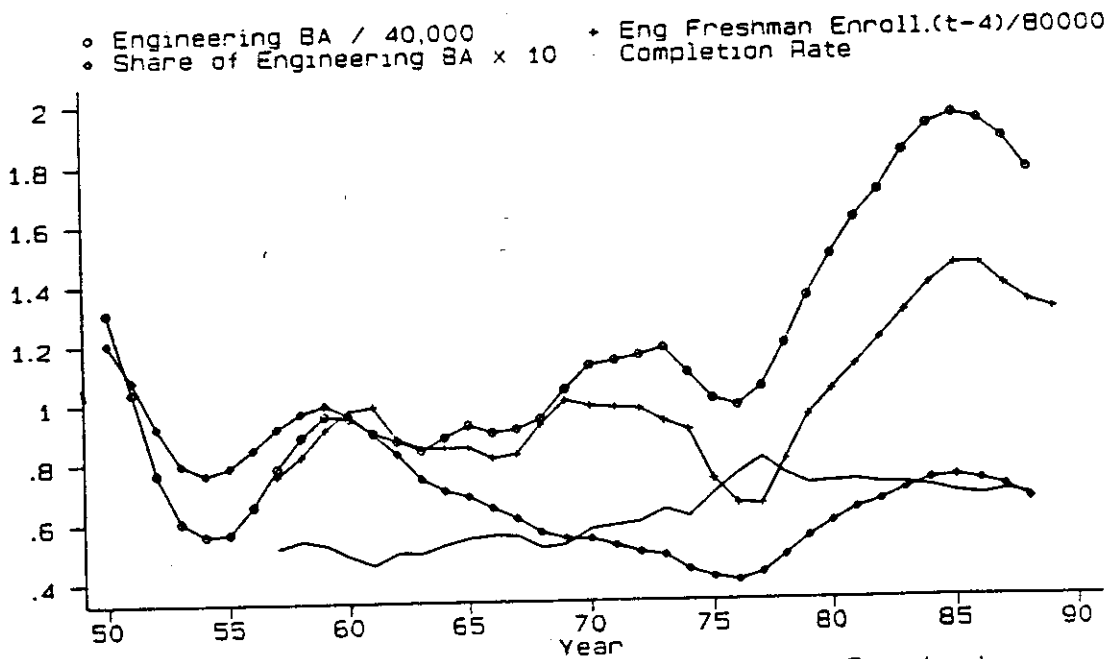
TABLE 2: SUPPLY ELASTICITIES
OF NEW ENTRANTS FOR ALTERNATIVE RELATIVE EARNINGS MEASURES *

	Log Engineering Starting Salaries Relative to:				Log Average Earnings Relative to College Grads	Log Lifetime Earnings Relative to College	
	Starting Auditors (BLS)	Starting Accting (CPC)	Starting Accting (NW)	All Professionals (NW, CPR)		Cross Section	Actual Cohort
1. OLS							
Constant (t-value)	-3.4 (-38)	-3.2 (-113)	-2.9 (-34)	-2.9 (-35)	-4.0 (-30)	-3.4 (-63)	-3.0 (-12)
Elasticity (t-value)	2.7 (7.9)	2.0 (13)	1.2 (2.2)	-.9 (1.5)	3.9 (9.4)	2.5 (13.3)	1.2 (1.1)
R ²	.73	.90	.13	.07	.73	.84	.03
D-W	.59	.49	.05	.12	.62	.56	.08
2. AR(1)							
Correction Constant (t-value)	-3.0 (-17)	-3.2 (-105)	-3.0 (-30)	2.9 (-8)	-3.1 (-10)	-3.0 (-15)	-2.7 (-14)
Elasticity (t-value)	.28 (.9)	2.0 (12.8)	1.4 (2.3)	0.1 (.5)	0.8 (2.1)	0.9 (2.4)	-.6 (-1.1)
R ²	.90	.96	.42	.94	.95	.95	.94
D-W	.38	.76	.45	.35	.64	.75	.42
Period	61-84	63-84	50-84	51-83	50-84	50-84	50-88
N	24	22	35	33	35	35	39

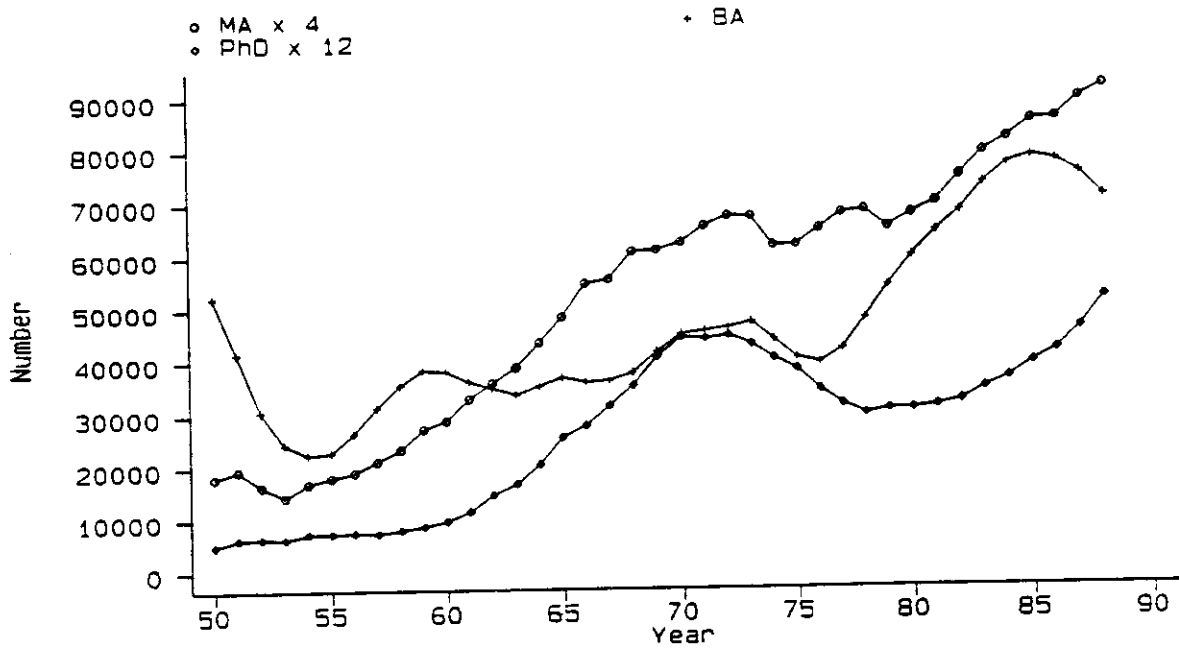
Note * Dependent variable is log of Engineering Bachelor's Degree share of total Bachelor's Degrees. Independent variable is the log of relative salaries, as indicated. All salary measures are lagged four years.



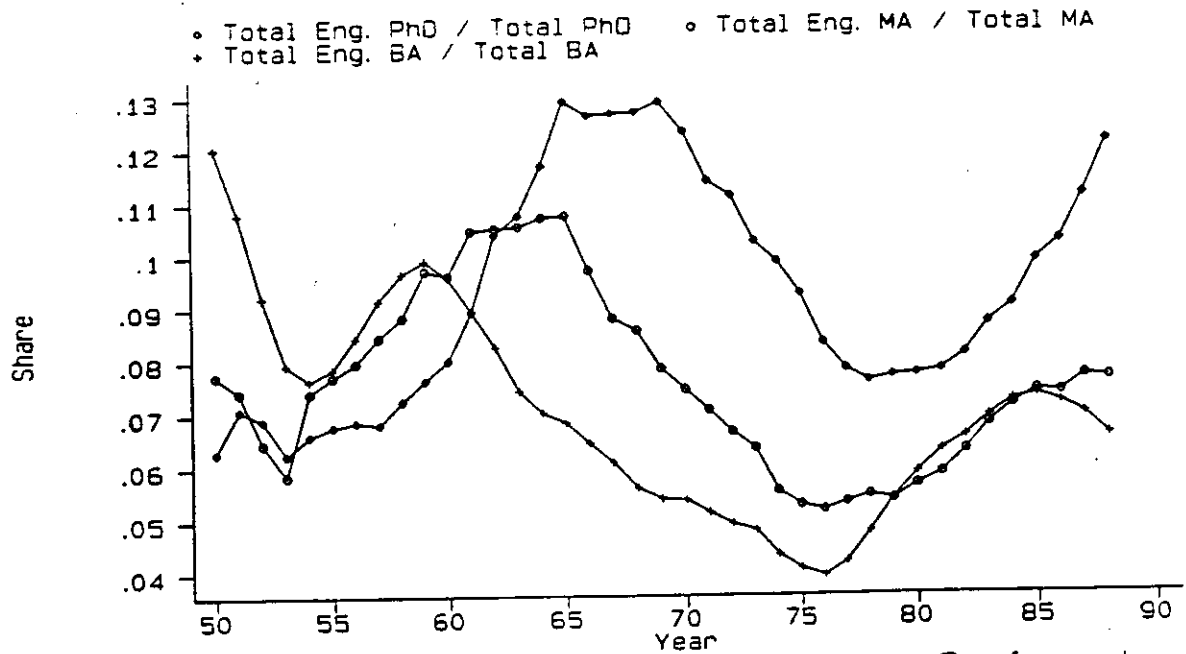
<Figure1> Number of Engineers



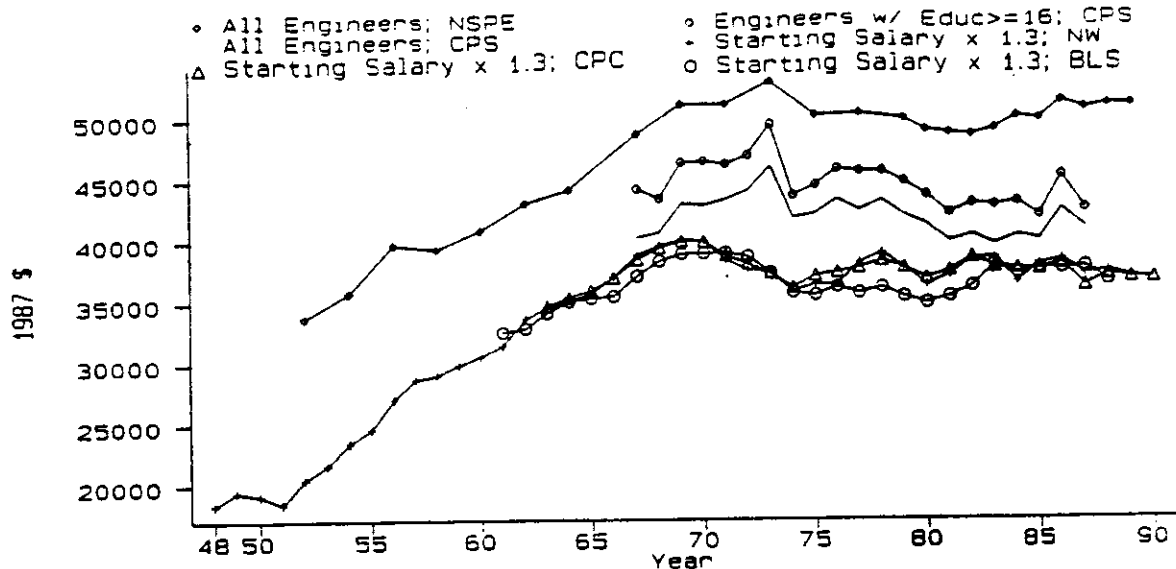
<Figure 2> Engineering Enrollments and Graduates



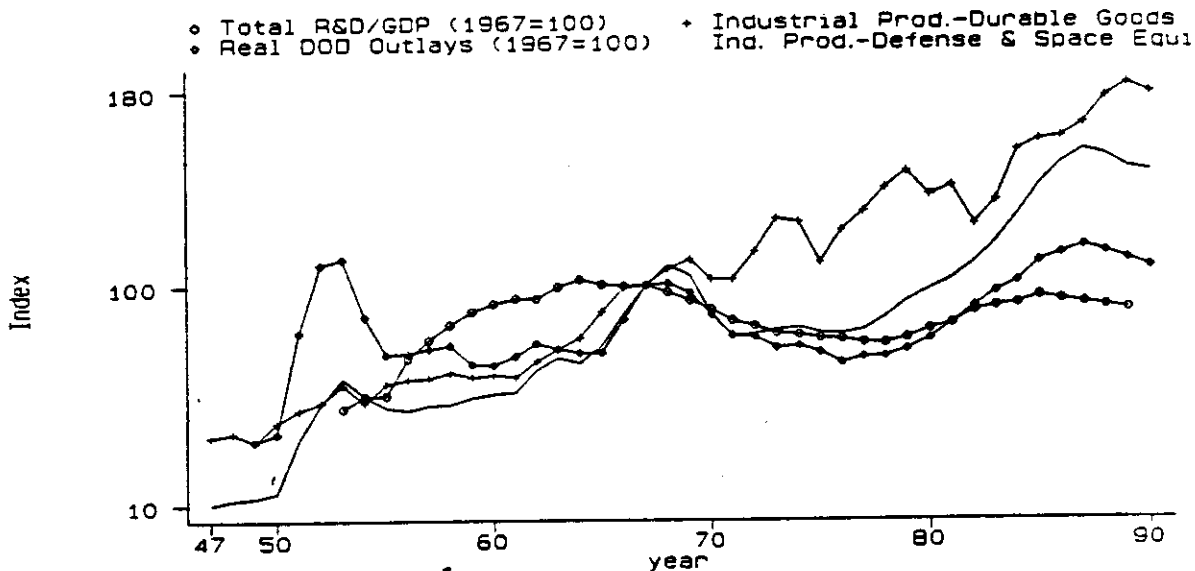
<Figure 3> Total Number of Engineering Degrees Conferred



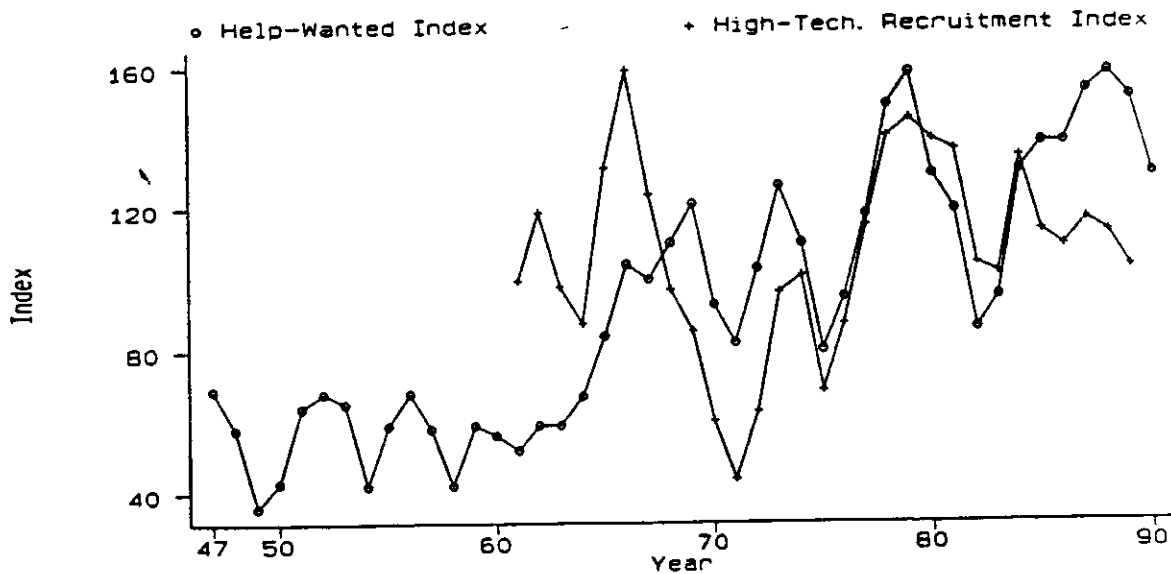
<Figure 4> Share of Engineering Degrees Conferred



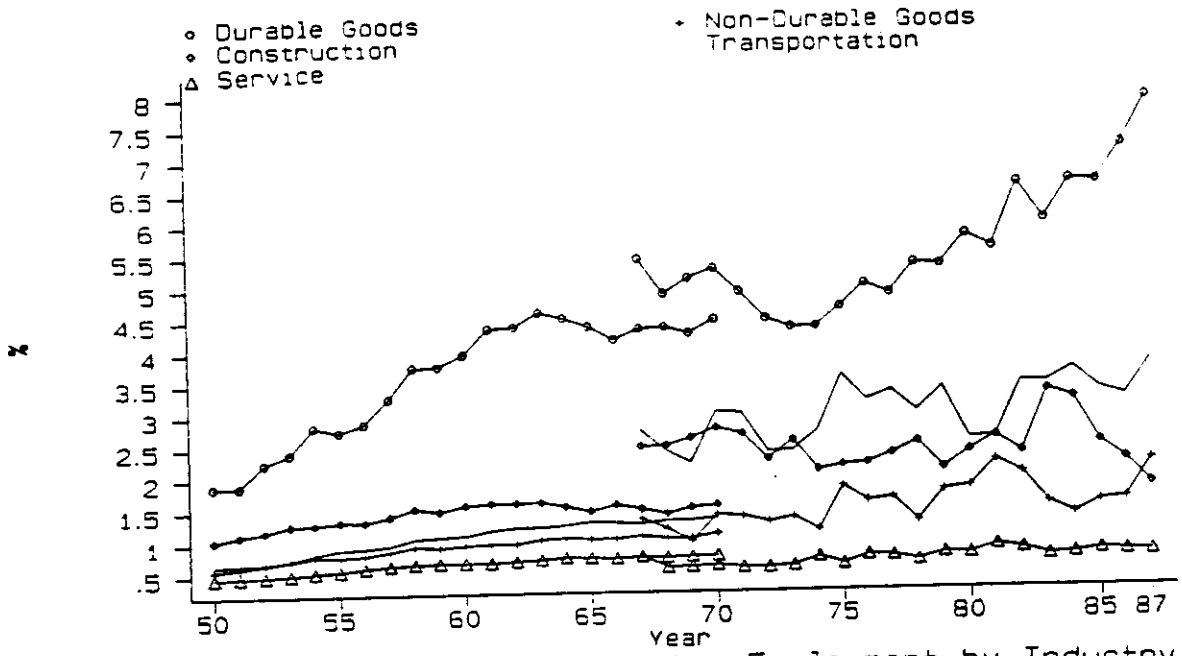
<Figure 5> Real Earnings of Engineers



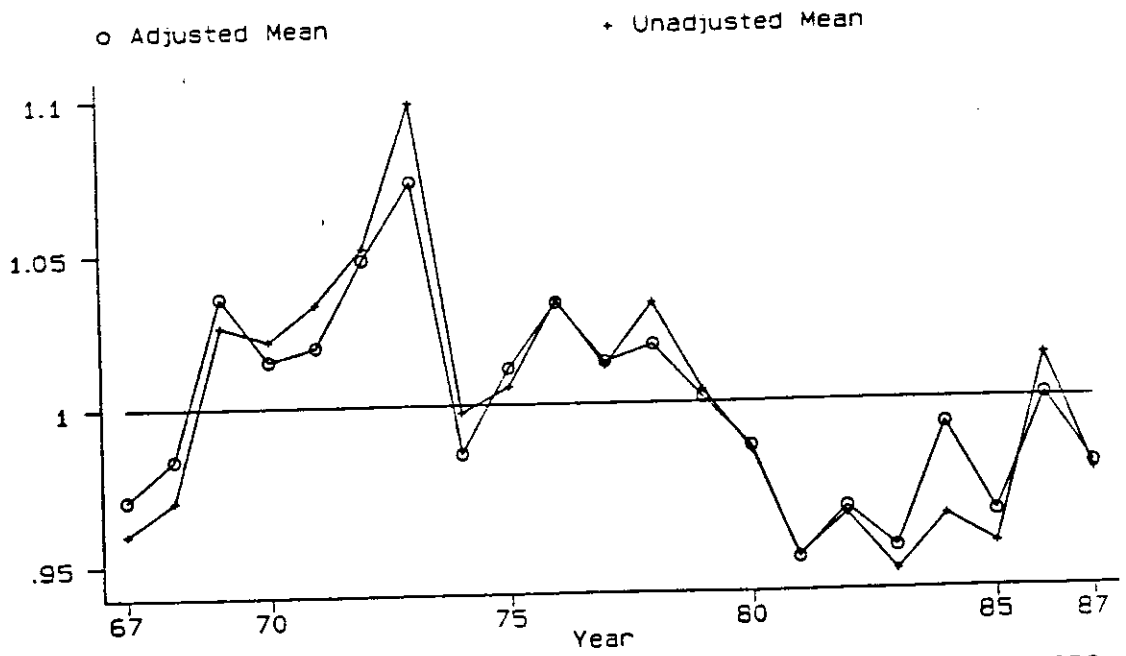
<Figure 6> Indices of Demand Shifters



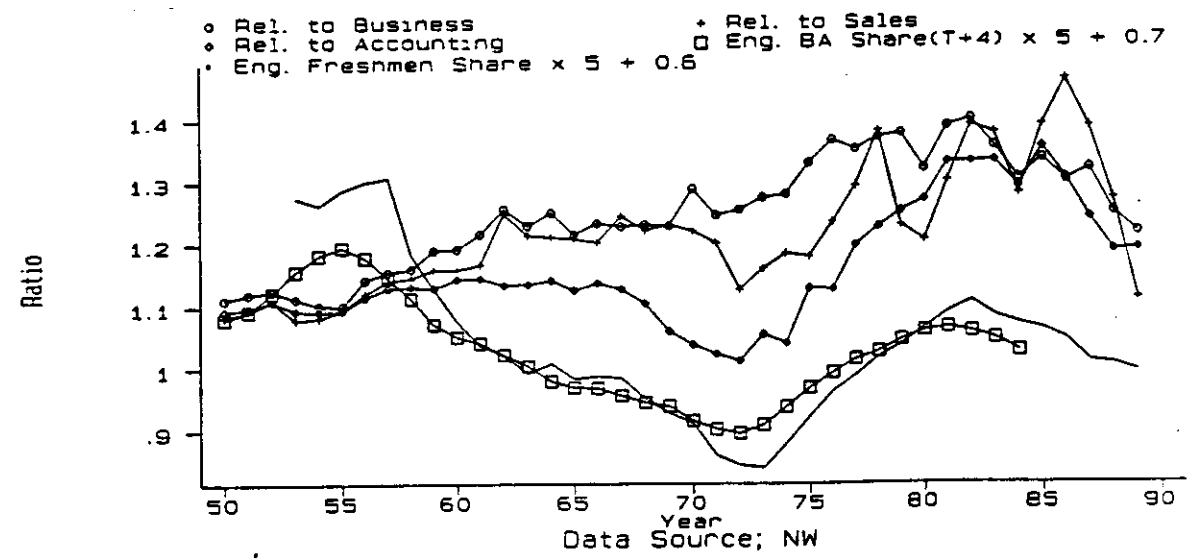
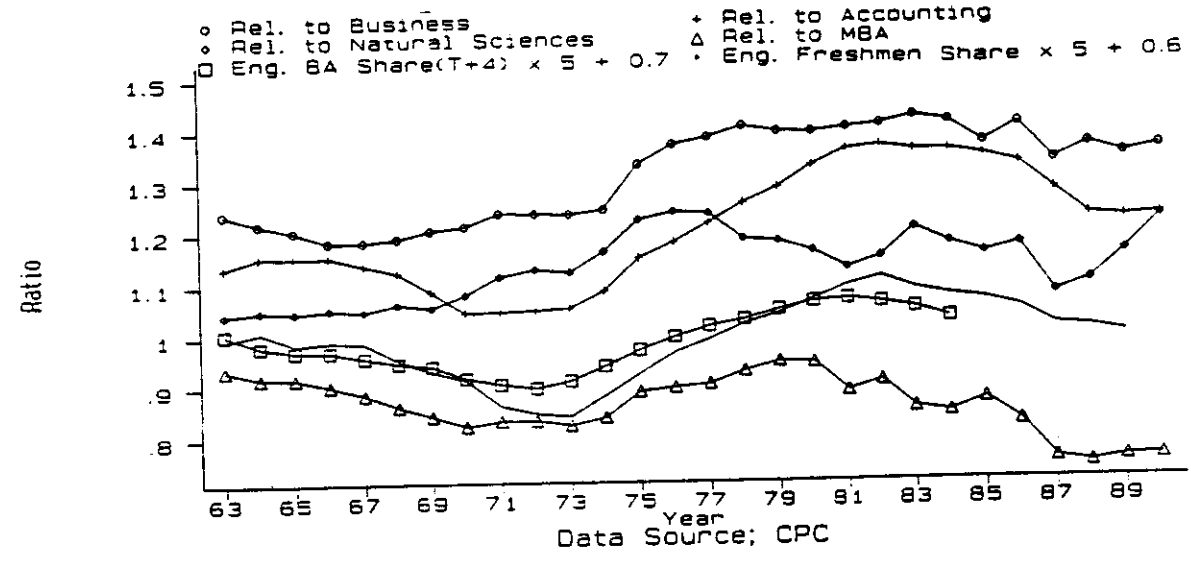
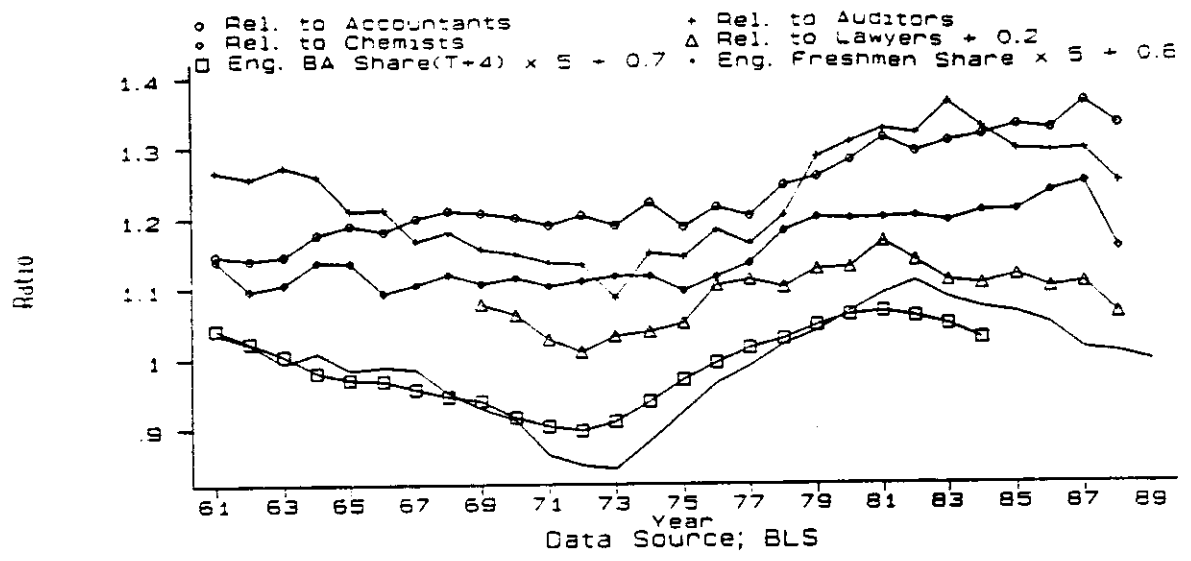
<Figure 7> Help-Wanted Indices



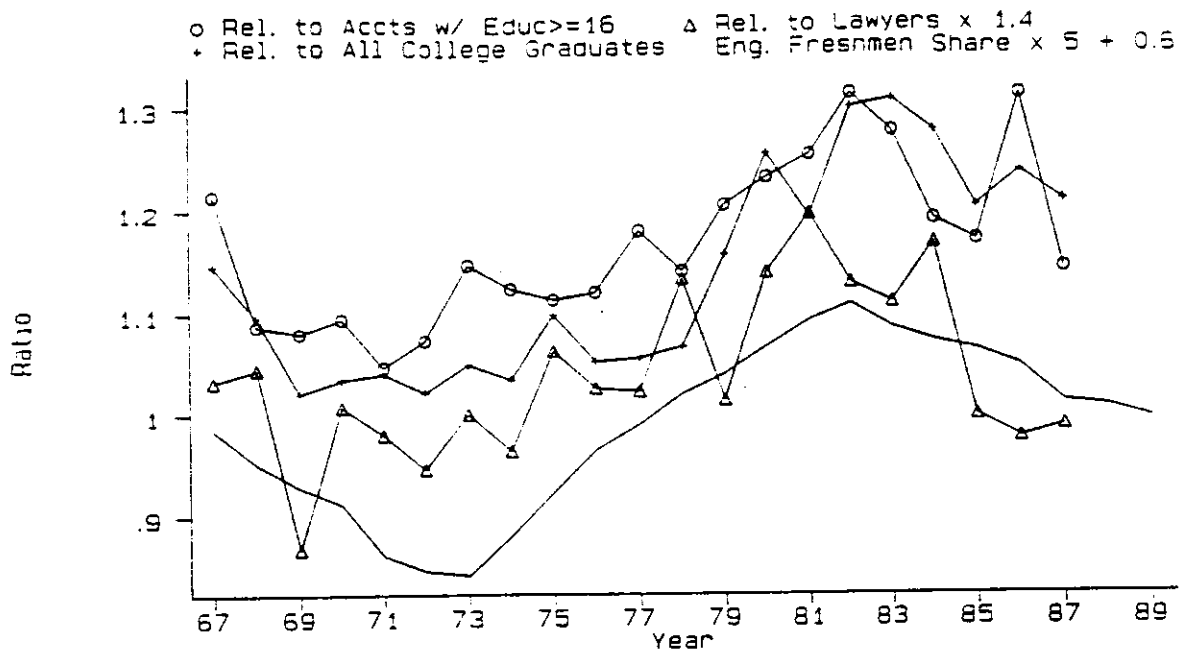
<Figure 8> Proportion of Engineering Employment by Industry



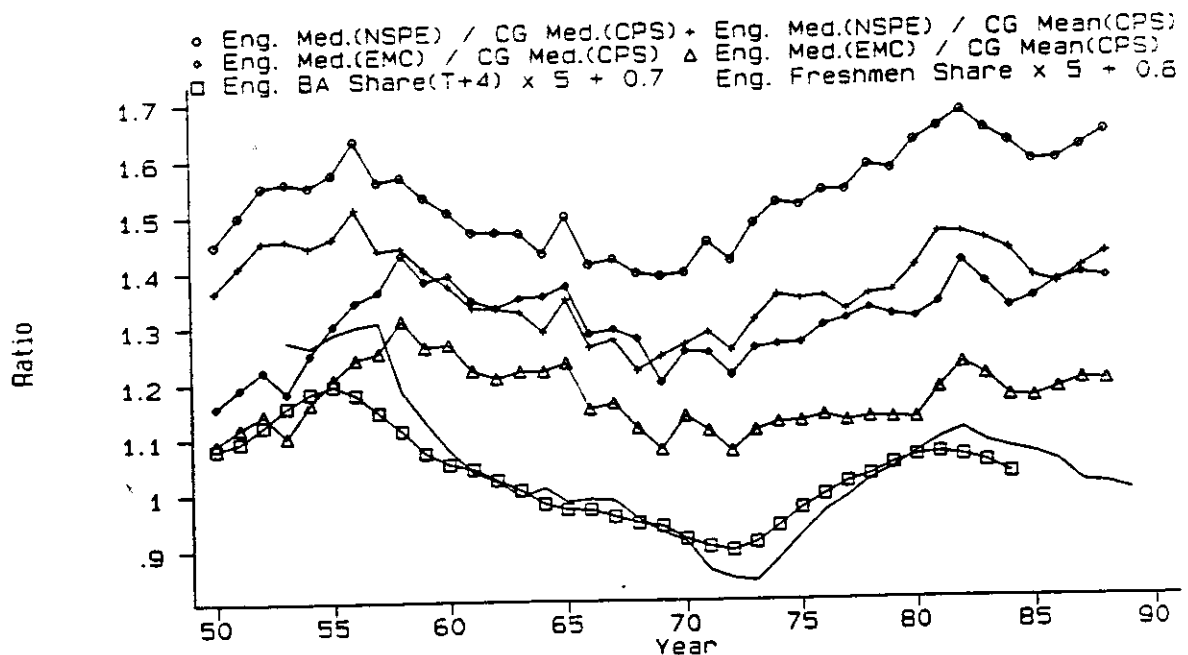
<Figure 9> Adjusted and Unadjusted Average Earnings of Engineers; CPS



<Figure 10> Relative Starting Salaries of Engineers



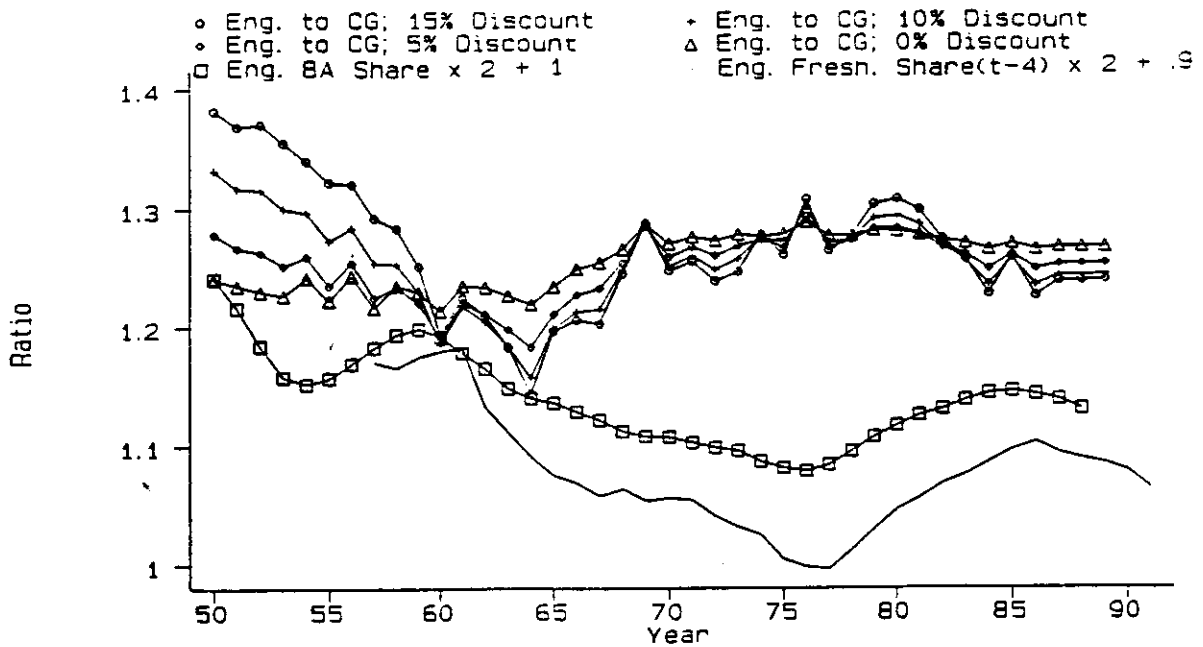
<Figure 11> Relative Earnings of Engineers with Educ ≥ 16; CPS



<Figure 12> Ratio of Earnings; Engineers to College Graduates



<Figure 13> Relative Life-Time Earnings of Engineers: Synthetic Cohort



<Figure 14> Relative Life-Time Earnings of Engineers; Actual Cohort