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Earnings Inequality within and Between Levels of Responsibility in Engineering

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Responsibility is a scarce resource—we can't all be chiefs. This paper studies how responsibility was allocated among engineers between 1961 and 1986 using the *Current Population Survey* and a Bureau of Labor Statistics salary survey that classifies workers by level within their firm. The percentage of engineers assigned to low levels fell until 1976 and rose thereafter. This pattern follows the distribution of experience in the profession, as measured in the CPS. Overall earnings inequality rose during two periods, the early 1970s and 1980s. Inequality within levels, however, steadily fell after 1976, so the later and sharper increase in inequality reflects a widening gap between job levels. This suggest that firms are better able to assign workers responsibility when the profession is relatively young; the match between the supply and demand of responsibilty is better. Technological change biased against high level jobs does not appear to be a major factor in the changes since the mid 1970s.

JEL Classifications: J3,J4

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TABLE 6.
FIT OF THE SINGH-MADALA DISTRIBUTION
VERSUS AN UNRESTRICTED MULTINOMIAL MODEL (BY YEAR AND LEVEL)

	level I*				level II*				level III*				level IV*				level V*				level VI*			
year	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
61	2.74	2.71	20	1797	2.91	2.90	20	2674	2.95	2.92	20	1520	2.92	2.90	21	2408	2.93	2.90	21	1512	3.06	3.01	22	1111
62	2.75	2.72	19	1859	2.90	2.89	20	3937	2.90	2.87	20	1820	2.90	2.87	20	1616	2.88	2.86	20	3657	3.03	2.98	21	1037
63	2.78	2.75	20	1636	2.88	2.87	20	3230	2.87	2.83	20	1228	2.94	2.91	22	1745	2.86	2.85	20	4523	3.07	3.02	23	1132
64	2.78	2.75	20	1548	2.85	2.84	19	4260	2.85	2.82	20	1665	2.88	2.86	21	2326	2.84	2.82	20	2930	3.00	2.98	22	2496
65	2.80	2.77	21	1671	2.83	2.82	19	2800	2.83	2.80	19	1464	2.85	2.83	20	2923	2.79	2.78	18	5040	3.01	2.97	23	1116
66	2.82	2.79	22	1672	2.76	2.74	17	2204	2.79	2.76	19	1481	2.91	2.89	21	2085	2.90	2.89	21	4671	3.13	3.10	25	1925
67	2.80	2.78	22	2709	2.71	2.70	18	2788	2.76	2.73	18	1597	2.87	2.85	19	2246	2.97	2.95	22	2914	3.24	3.20	29	1903
68	2.81	2.79	22	2546	2.64	2.63	17	3017	2.69	2.67	17	1683	2.85	2.82	18	1699	2.97	2.95	22	3604	3.06	3.04	23	2695
69	2.74	2.72	21	2351	2.55	2.55	16	6836	2.67	2.67	17	9673	2.81	2.81	19	9148	3.02	3.02	24	7267	3.10	3.06	24	1605
70	2.68	2.66	20	2621	2.53	2.53	15	5482	2.72	2.71	17	4728	2.86	2.85	20	5438	3.04	3.02	24	3350	3.17	3.14	26	2158
71	2.67	2.65	21	2149	2.55	2.55	14	6503	2.73	2.73	18	20967	2.89	2.88	20	11010	3.09	3.09	25	10324	3.20	3.17	27	2141
72	2.71	2.68	21	1796	2.65	2.64	16	4389	2.75	2.75	18	9036	2.92	2.91	21	5111	3.12	3.11	25	4104	3.16	3.13	25	1851
73	2.75	2.72	24	2056	2.69	2.68	17	5907	2.84	2.83	19	14925	3.00	2.99	22	4505	3.13	3.11	24	3962	3.15	3.12	26	2663
74	2.79	2.76	23	1671	2.75	2.74	17	3846	2.87	2.86	20	10385	3.09	3.07	24	3348	3.11	3.09	23	2617	3.14	3.10	25	1528
75	2.80	2.77	20	1374	2.85	2.83	19	2339	2.97	2.96	22	7743	3.11	3.10	24	6051	3.06	3.03	22	1839	3.01	2.99	24	2773
76	2.88	2.85	23	2029	2.95	2.94	21	3728	3.05	3.04	23	8565	3.12	3.10	23	2451	3.06	3.03	22	1643	2.89	2.87	22	2174
77	2.92	2.90	22	2302	3.01	2.99	22	3975	3.05	3.04	22	7937	3.01	2.99	22	4037	2.99	2.95	21	1367	2.91	2.88	21	1527
78	3.00	2.98	25	3227	3.05	3.04	22	4124	2.98	2.98	21	8568	2.85	2.84	20	12137	2.74	2.74	19	7897	2.95	2.94	24	2851
79	3.06	3.04	26	4292	3.04	3.03	22	4212	2.88	2.88	20	13121	2.79	2.79	20	13266	2.79	2.78	18	6758	3.05	3.03	24	2260
80	3.14	3.12	29	4501	2.99	2.97	21	2880	2.82	2.81	20	9383	2.76	2.76	18	8597	2.93	2.92	21	6496	2.94	2.91	22	1750
81	3.17	3.15	30	5172	2.87	2.86	20	4129	2.78	2.77	18	8413	2.87	2.87	20	10247	3.00	2.99	22	6855	3.18	3.14	25	1509
82	3.13	3.12	29	6402	2.76	2.75	19	4806	2.86	2.85	19	19174	3.01	3.00	22	6698	3.08	3.07	23	6791	3.21	3.18	27	1909
83	3.06	3.05	29	4251	2.75	2.74	18	7963	2.89	2.89	20	7733	3.12	3.11	25	10863	3.11	3.10	24	5072	3.06	3.03	24	1959
84	3.02	3.00	27	3445	2.75	2.74	17	6475	2.94	2.93	21	5626	3.08	3.08	23	12998	3.20	3.19	27	5455	3.13	3.10	23	1840
85	2.56	2.55	19	2984	2.63	2.63	16	10926	2.82	2.81	19	5984	2.98	2.97	21	3682	3.06	3.05	23	4803	3.18	3.14	25	1445
86	2.63	2.62	24	3917	2.68	2.68	24	8265	2.88	2.87	28	7015	3.09	3.08	32	7514	3.15	3.13	31	3718	3.09	3.01	22	694

Summary of fit for the maximum likelihood estimates reported in Table 7.
(1) = value of the log-likelihood function at the parameter estimates, per obersavtion
(2) = value of the likelihood for an unrestricted multinomial model
(3) = number of income categories reported in the data. (3) - 4 equals the degrees of freedom for a likelihood ratio test for values in (1) and (2).
(4) = The sample size for which the likelihood ratio test rejects the Singh-Madala model at a .01 significance level.

I. Introduction

A number of recent studies have documented the dramatic rise in wage inequality in the U.S. over the last 30 years.[1] These changes are broad and fundamental, and it is clear that a variety of forces are behind them. There is a limit, however, to what can be learned from studying the whole labor market. The variables in the *Current Population Survey*, the main source of data in this literature, do not fully describe either workers or their jobs. Davis and Haltiwanger (1990) provide evidence that over the same period firms have restructured their labor force, but the overall impact that re-assigning workers within firms has on wage dispersion is not well understood.

This paper documents the aggregate relationship between salaries and rank within firms using data for a single occupation—engineering. Engineering was chosen because it is a large, well-defined profession in which responsibility varies greatly across jobs. The data come from two sources. The first is male engineers in the CPS for the years 1969 to 1991. The second source is a little-known survey conducted by the Bureau of Labor Statistics since 1961. The *Professional, Administrative, Technical and Clerical Pay Survey* (henceforth PATC) reports the distribution of monthly salaries for various white-collar occupations by level of responsibility. The next section and Appendix A describe the PATC survey in detail, but several features should be noted here:

- It surveys full time employment in large private plants and establishments, so it surveys jobs not individuals.
- It reports the size distribution of monthly salaries using several (50 or more) salary classes.
- It classifies jobs within plants by occupation and level of responsibility using the Federal Government's General Service classifications, commonly known as GS levels. The definitions of levels are specific to each occupation, and they gauge responsibility relative to other jobs in the same occupation. (A synopsis appears in Appendix A.)
- The survey remained virtually the same from 1961 through 1986, which is the last year used in this study.

Overall earnings inequality for engineering jobs rose during two periods, the early 1970s and 1980s. Before 1970 inequality was falling, although this pattern is sensitive to the definition of inequality. These two episodes of increased salary dispersion were distinct,

[1] For example, see Juhn, Murphy and Pierce (1989), Mincer (1991), Katz and Murphy (1992), Bound and Johnson (1992), and Murphy and Welch (1992).

TABLE 5.
Maximum Likelihood Estimates of the Singh-Maddala Distribution

level	I*			II*			III*			IV*			V*			VI*		
year	a1	a2	a3	a1	a2	a3	a1	a2	a3	a1	a2	a3	a1	a2	a3	a1	a2	a3
61	0.6381	10.87	1.06	0.0303	11.62	0.94	0.0131	10.95	0.88	0.0134	9.20	1.13	0.001	10.01	0.89	0.001	8.54	1.59
62	0.0303	11.62	0.94	0.0131	10.95	0.88	0.0134	9.20	1.13	0.001	10.01	0.89	0.001	8.54	1.59	0.449	11.13	1.09
63	0.0131	10.95	0.88	0.0134	9.20	1.13	0.001	10.01	0.89	0.001	8.54	1.59	0.449	11.13	1.09	0.0157	12.34	0.87
64	0.0134	9.20	1.13	0.001	10.01	0.89	0.001	8.54	1.59	0.449	11.13	1.09	0.0157	12.34	0.87	0.0117	10.62	1.03
65	0.001	10.01	0.89	0.001	8.54	1.59	0.449	11.13	1.09	0.0157	12.34	0.87	0.0117	10.62	1.03	0.0101	9.28	1.19
66	0.001	8.54	1.59	0.449	11.13	1.09	0.0157	12.34	0.87	0.0117	10.62	1.03	0.0101	9.28	1.19	0.0005	10.45	0.92
67	0.449	11.13	1.09	0.0157	12.34	0.87	0.0117	10.62	1.03	0.0101	9.28	1.19	0.0005	10.45	0.92	0.0003	9.34	1.34
68	0.0157	12.34	0.87	0.0117	10.62	1.03	0.0101	9.28	1.19	0.0005	10.45	0.92	0.0003	9.34	1.34	0.4113	10.59	1.29
69	0.0117	10.62	1.03	0.0101	9.28	1.19	0.0005	10.45	0.92	0.0003	9.34	1.34	0.4113	10.59	1.29	0.0098	12.35	0.92
70	0.0101	9.28	1.19	0.0005	10.45	0.92	0.0003	9.34	1.34	0.4113	10.59	1.29	0.0098	12.35	0.92	0.0076	10.70	1.00
71	0.0005	10.45	0.92	0.0003	9.34	1.34	0.4113	10.59	1.29	0.0098	12.35	0.92	0.0076	10.70	1.00	0.0113	8.72	1.44
72	0.0003	9.34	1.34	0.4113	10.59	1.29	0.0098	12.35	0.92	0.0076	10.70	1.00	0.0113	8.72	1.44	0.0002	10.80	1.00
73	0.4113	10.59	1.29	0.0098	12.35	0.92	0.0076	10.70	1.00	0.0113	8.72	1.44	0.0002	10.80	1.00	0	10.82	0.78
74	0.0098	12.35	0.92	0.0076	10.70	1.00	0.0113	8.72	1.44	0.0002	10.80	1.00	0	10.82	0.78	0.2471	11.08	1.24
75	0.0076	10.70	1.00	0.0113	8.72	1.44	0.0002	10.80	1.00	0	10.82	0.78	0.2471	11.08	1.24	0.0066	12.68	0.89
76	0.0113	8.72	1.44	0.0002	10.80	1.00	0	10.82	0.78	0.2471	11.08	1.24	0.0066	12.68	0.89	0.005	11.15	0.87
77	0.0002	10.80	1.00	0	10.82	0.78	0.2471	11.08	1.24	0.0066	12.68	0.89	0.005	11.15	0.87	0.0056	9.22	1.42
78	0	10.82	0.78	0.2471	11.08	1.24	0.0066	12.68	0.89	0.005	11.15	0.87	0.0056	9.22	1.42	0.0002	10.95	1.08
79	0.2471	11.08	1.24	0.0066	12.68	0.89	0.005	11.15	0.87	0.0056	9.22	1.42	0.0002	10.95	1.08	0	12.54	0.68
80	0.0066	12.68	0.89	0.005	11.15	0.87	0.0056	9.22	1.42	0.0002	10.95	1.08	0	12.54	0.68	0.2355	10.78	1.38
81	0.005	11.15	0.87	0.0056	9.22	1.42	0.0002	10.95	1.08	0	12.54	0.68	0.2355	10.78	1.38	0.0093	11.90	1.01
82	0.0056	9.22	1.42	0.0002	10.95	1.08	0	12.54	0.68	0.2355	10.78	1.38	0.0093	11.90	1.01	0.005	10.92	0.92
83	0.0002	10.95	1.08	0	12.54	0.68	0.2355	10.78	1.38	0.0093	11.90	1.01	0.005	10.92	0.92	0.0036	9.35	1.54
84	0	12.54	0.68	0.2355	10.78	1.38	0.0093	11.90	1.01	0.005	10.92	0.92	0.0036	9.35	1.54	0	11.96	1.00
85	0.2355	10.78	1.38	0.0093	11.90	1.01	0.005	10.92	0.92	0.0036	9.35	1.54	0	11.96	1.00	0	14.59	0.55
86	0.0093	11.90	1.01	0.005	10.92	0.92	0.0036	9.35	1.54	0	11.96	1.00	0	14.59	0.55	0.2198	11.00	1.30

Notes:
Estimates based on monthly salaries measured in constant 1982 thousands of dollars.
a1 is multiplied by 1000. A "0" signifies a value below 1E-7.

TABLE 4.
Male Engineers in the CPS

year	number of engineers in sample (1)	female engineers % (2)	Real Weekly Wages: average (3)	Real Weekly Wages: entropy (4)	Experience: mean (5)	Experience: st.dev. (6)	Experience: below 15 years % (7)	Experience: between 15 and 30 years % (8)	Experience: above 30 years % (9)
69	782				18.08	10.40	0.43	0.42	0.14
70	789				17.36	10.27	0.46	0.41	0.13
71	800				18.49	10.48	0.42	0.44	0.14
72	669				18.54	10.79	0.44	0.39	0.16
73	629				18.51	11.38	0.43	0.38	0.18
74	646				19.11	11.42	0.43	0.38	0.19
75	637				18.86	11.27	0.41	0.41	0.18
76	670		634.51	0.0031	18.79	11.33	0.44	0.36	0.19
77	789		660.70	0.0037	18.26	10.67	0.42	0.43	0.15
78	776	0.01	647.66	0.0038	19.01	11.11	0.42	0.39	0.19
79	827		636.62	0.0040	19.00	11.37	0.44	0.35	0.21
80	992		645.31	0.0041	18.68	11.46	0.45	0.35	0.20
81	963		643.96	0.0036	18.37	11.36	0.46	0.35	0.19
82	902	0.04	643.53	0.0040	18.55	11.17	0.44	0.37	0.18
83	881		651.93	0.0042	18.49	11.53	0.47	0.34	0.20
84	891	0.06	636.86	0.0045	17.29	11.33	0.51	0.31	0.18
85	899	0.06	660.75	0.0046	17.10	11.34	0.52	0.31	0.17
86	903	0.06	653.14	0.0043	17.12	11.06	0.50	0.35	0.15
87	872	0.07	681.01	0.0039	17.41	10.99	0.48	0.36	0.16
88	933	0.06	657.13	0.0042	17.05	11.05	0.49	0.36	0.15
89	829	0.07	663.99	0.0043	16.95	11.03	0.49	0.35	0.16
90	966	0.07	654.17	0.0042	17.44	10.51	0.46	0.39	0.15
91	935		673.55	0.0043	17.80	10.35	0.44	0.42	0.14

Notes:
Columns (1) and (3)-(9) from the March Current Population Survey.
See Appendix A for more details.
(1) = sample size for the experience statistics. Some not included in wage sample.
(2) = percentage of engineers that are women. Source: Statistical Abstract of the United States.
Experience = Age - Years of Education - 5.

however. In the early 1970s inequality both between and within levels of responsibility increased. In contrast, inequality within job levels fell after 1976. The sharper increase during the 1980s was driven exclusively by rising inequality between levels.

The share of employment within levels also goes through a cycle. Until the mid 1970s the proportion of jobs with high amounts of responsibility rose steadily, but since then the profession has become leaner. By 1986 employment in the upper and lower levels returned to their 1961 shares. The hierarchical structure in engineering flattened at the same time that observers noticed a general "downsizing" of firms (Tomasko 1987).

Employment shares within levels reflect the change in the experience distribution, as measured in the CPS. While the share of jobs at a level does not match the share of engineers within a fixed range of experience, as the profession aged the share at low levels fell. Since 1976 the profession has become younger and lower ranks have been replenished. Both overall inequality and inequality between levels rise as the distribution of experience becomes more disperse, but the relationship between aggregate experience and within-level inequality is not obvious.

Workers acquire the ability to handle high responsibility mainly through experience, so the data on level assignments reflect the substitution between old and young workers within the firm. Traditionally, this substitution effect is found in the response of wage profiles to demographics,[2] and rank within firms is usually unobserved. In the PATC data we observe how, in aggregate, firms have adjusted to changes in both the demand and supply of responsibility.

Compression of wages between levels can be caused by bottlenecks in responsibility assignment, since the skill differential between workers at different levels falls. An increase in the relative supply of young workers forces firms to hold back capable engineers because not enough managers are available. Demand shifts can also cause this effect. For instance, cheaper computers may let a flatter hierarchy handle the same-scaled projects, lowering the demand for high responsibility jobs.

Since changes in the experience distribution and inequality between levels are correlated, changes over time are partly driven by supply. The wage grap grew between levels as the percentage of workers in high level jobs fell, so it appears that hierarchies did not flatten in response to "responsibility-saving" technological change. Technology change is still an important indirect cause of changes within engineering, because it helps determine

[2] For example Freeman (1979) and Welch (1979).

the entry of young workers into the profession.[3] The evidence then suggests that technology plays a secondary role, and has not been the dominant force behind changes in responsibility assignment.

To help understand the wage structure, the data must measure the concept of responsibility not only at a point in time but across a period of dramatic technological change. The next section describes the PATC survey in some detail, and argues that it is up to this task.

II. The PATC Measure of Responsibility

Since Adam Smith (1976 p.204) included it in his list of five causes for equilibrium wage differentials,[4] responsibilty has played an important role in labor market theories. Yet it eludes a simple and non-empty definition. Clearly responsiblity is an aggregate of many duties. It can be identified with rank in an organization or the number of workers an individual supervises, but these definitions only partially measure responsibility. They also make it difficult to compare responsibility across different sized firms.

To be more accurate, yet still specific, we can think of responsibility as a balance of two other abstract quantities: scale and scope. Scale defines the amount of resources, human and physical, which a worker controls. The human resources include the worker's skills and the skills of those she supervises. Scope, on the other hand, defines how much the worker can affect the product flowing from this capital.

For example, compare a truck driver's truck and a doctor's education. The two assets might represent similar amounts of capital, but the doctor clearly has more scope in using her capital. And within firms a manager tends to have greater scope than her subordinates. Scope, however, is not synonymous with management level and responsibility is not inherent within rank. An auditor may have a smaller staff but greater responsibility than a middle manager.

The long literature on hierarchies within firms provides theories of responsibility assignment that correspond to this view.[5] The literature's implications for aggregate distri-

[3] Freeman (1975), Siow (1984), Zarkin (1985) and Pearce (1990) study occupational choice as an investment.

[4] "Fourthly, the wages of labour vary accordingly to the small or great trust which must be reposed in the workmen," Smith (1976 p. 207)

[5] For example Tuck (1954), Mayer (1960), Lucas (1978), Rosen (1982) and Waldman

TABLE 3.
Fit of the Singh-Maddala Distribution
Versus an Unrestricted Multinomial Model

level	average likelihood ratio	average critical sample size	minimum critical sample size	maximum critical sample size
I*	0.015	2768	1374	6402
II*	0.008	4681	2204	10926
III*	0.009	7363	1228	20967
IV*	0.009	5929	1616	13266
V*	0.01	4583	1367	10324
VI*	0.023	1848	694	2851

Summary of 26 years of estimates.
See Table 6 in Appendix B for details.

TABLE 1.
Summary of Employment Shares By Level

level	average share	minimum share	maximum share
I*	0.37	0.31	0.44
II*	0.29	0.26	0.31
III*	0.20	0.16	0.22
IV*	0.10	0.08	0.11
V*	0.03	0.02	0.04
VI*	0.01	0.00	0.01

Source: The PATC Pay Survey, Bureau of Labor Statistics, 1961-86.

TABLE 2.
Simple Correlations Between Employment Shares

level	I*	II*	III*	IV*	V*
II*	-0.69				
III*	-0.76	0.11			
IV*	-0.92	0.47	0.75		
V*	-0.97	0.60	0.77	0.92	
VI*	-0.92	0.65	0.66	0.83	0.94

butions, however, have been limited. The PATC data confirm the basic predictions from the theory: overall earnings are skewed and earnings rise with responsiblity. The literature gives little guidance for interpreting changes over time or disentangling responsibility assignment from macro changes, such as increased international competition.

If it is useful to view responsibility as a mix of scope and scale, then the PATC survey is a good measure of responsibility within occupations and firms.[6] Since its inception the survey has been conducted by on-site interviews with personnel officers of large plants and establishments. The officer and the interviewer assign jobs to an occupation and a level of responsibilty. Within engineering the PATC survey uses eight levels, denoted I to VIII. The use of Roman numerals to denote levels is awkward, but it indicates a strength of the PATC survey: Responsiblity is not confused with job titles or with specific amounts of training or experience.

Jobs in the lowest three engineering levels receive close supervision. Jobs above level III usually entail supervising other engineers but may also involve carrying out large scale tasks independently. Because the distinctions among the lowest three levels are small compared to the others, throughout this paper levels I - III are combined. To avoid confusion with the orignial data, the result of combining levels I - III is denoted I*. The levels named IV through VIII in the PATC survey are then renamed II* through VI*, respectively. (In some of the figures levels IV* through VI* are also combined for convenience.)

The description of each level has remained identical over the life of the PATC survey. The descriptions are specific, but they are not tied to any technology, industry or organizational structure. A synopsis of the job descriptions appears in Appendix A, as do notes about the survey design. Although the job descriptions have not changed, the design of the survey has. Until 1986 these changes are insignificant for the engineering data, but after 1986 the survey was split into two biannual surveys. Rather than attempting to combine the distributions, only data through 1986 are used.

III. Task Assignment and Wage Distributions

(1984). Indeed, as used here, "scale" and "scope" are meant to parallel Rosen's use of "authority" and "control".

[6] There is a clear tradeoff between aggregate measures of job content and disaggregate measures such as those found in the *Dictionary of Occupational Titles*. See, for example, Howell and Wolff (1991). Within a group of similarly trained technical workers such as engineers, aggregate measures that reflect relative rank within the firm are probably preferable than lists of specific skills used on the job.

Summary of the Data

The percentage of engineers assigned to each level is summarized in Table 1 and Figure 1.1. Once the first three levels are combined to form I*, the employment shares form a pyramid. That is, in each year more engineers work in I* than II* and so on. Employment at level I* steadily fell until the mid 1970s and then rose until 1986. In the 1960s, the share of engineers in the other levels rose in response, although the top three levels grew faster than the middle levels. In a sense, the profession became increasingly top heavy. Between 1976 and 1986 the previous pattern was reversed as employment shifted back into the lowest level. The negative correlations in Table 2 confirm that employment at level I* moves counter to higher levels. Finally, note that total employment of engineers grew steadily except during the sluggish 1970s (Figure 1.2).[7]

Besides reporting employment by level, the PATC survey reports salary distributions by reporting the percentage of engineers whose monthly salaries fall into one of roughly 50 intervals. When the percentage at the upper and lower tails drops below 1% of total employment in the level, the intervals beyond that point are combined. The tail categories therefore differ across levels.

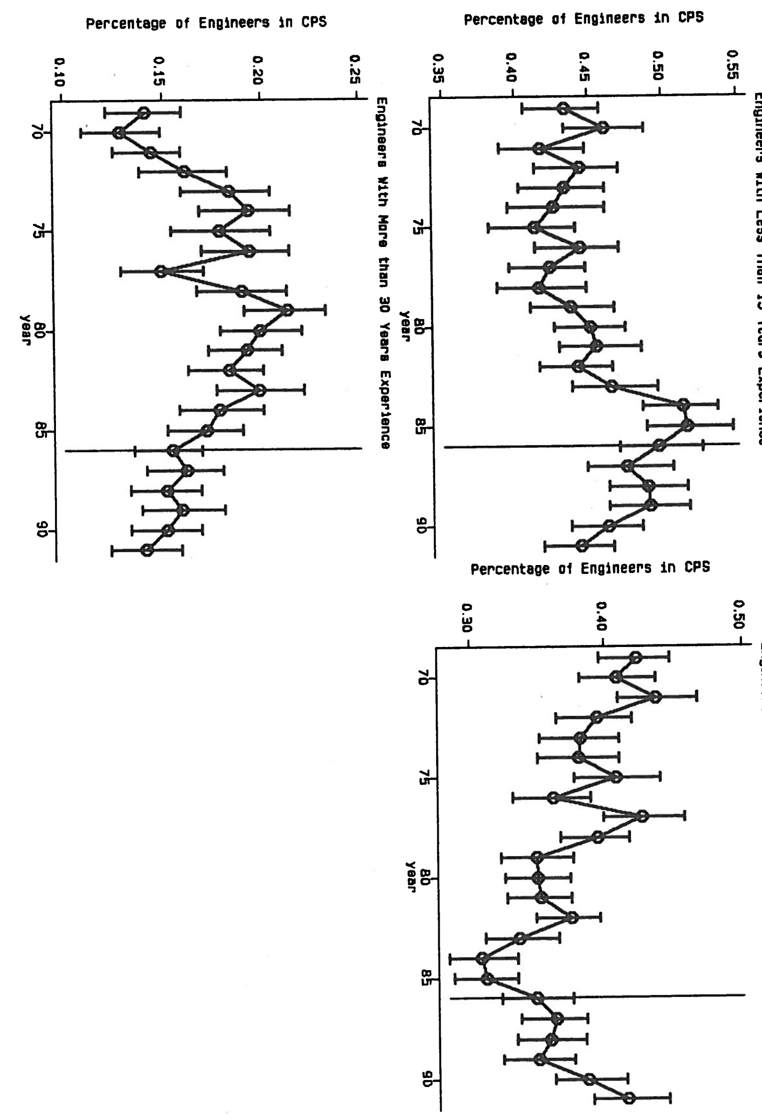
To make the form of the data clear, Figure 3 shows the densities of real salaries by levels for 1986. Each point in the graph lies above the midpoint of a salary interval, converted to 1982 dollars. The height of the point is the pecentage of engineers in the interval divided by its width. Only the inside salary categories for each level are shown, because the midpoints of the tail categories are unknown. The share of employment in the level is roughly the area under its density in Figure 3.

Figure 4 shows that the overall shapes of the salary distributions have not changed a great deal. (The graphs are made by smoothing the data in the same form as Figure 3.) The shifts out of and then back into level I* can be seen by the size of its curve relative to the others. Shifts in the relative locations of distributions can also be discerned in Figure 4, but Figure 5 illustrates this better.

Figure 5 shows that median wages followed the pattern of total employment in Figure 1.2. Median wages rose steadily in all levels during the 1960s and 1980s, but they stagnated in the 1970s. Wage growth in the 1980s was fastest in the top three levels, IV* to VI*,

[7] Although changes in the survey's coverage occurred in 1966 and 1986, employment figures do not jump in these years. This is because the changes only lowered the minimum establishment size, and engineers are concentrated in large establishments.

Figure 9. Experience Distribution and 90% Confidence Intervals



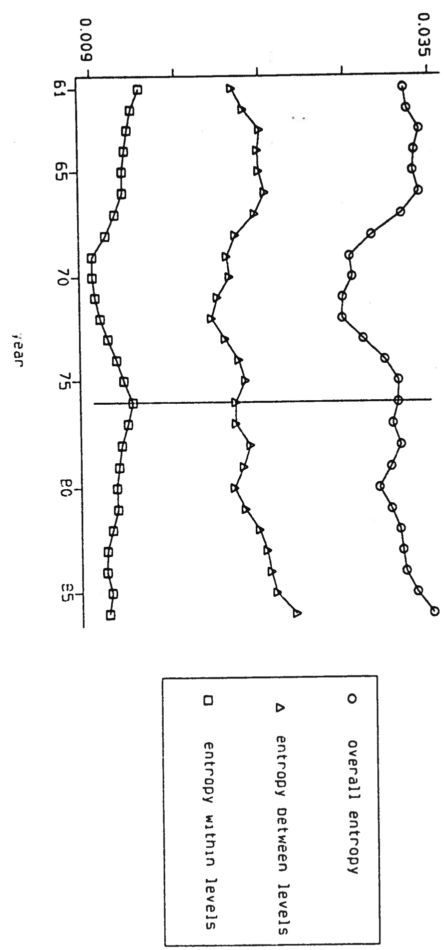


Figure 8.
Earnings Inequality Within and Between Levels

leading to an increased gap between earnings at different levels. The top of the capped lines between medians is the 75^{th} percentile of the salary distribution of the lower level. The bottom of the line is the 25^{th} percentile of the upper level. A longer line in a year indicates more overlap between the middle 50% of adjacent distributions. In years where no capped line appears, there is no overlap. The salary distributions for level I* and II* are closer than between higher levels, so the uncapped lines represent the overlap of the 90^{th} and 10^{th} percentiles of these distributions. The overlap between levels is large in the early 1960s. It shrinks and then expands in the early 1970s. By the 1980s salary distributions within upper levels were very distinct.

Because the data in the PATC survey are grouped by income class, to measure changes in inequality it is necessary to infer more about the salary distributions. To this end, the Singh-Maddala distribution was estimated on the empirical salary distribution for each level and year. Singh-Maddala is a three-parameter distribution that fits income distribution data well and compares favorably to four-parameter families that are more difficult to estimate.[8]

The Singh-Madala distribution and density take the form:

$$F(x; a_1, a_2, a_3) = 1 - \frac{1}{(1 + a_1 x^{a_2})^{a_3}}$$

$$f(x; a_1, a_2, a_3) = \frac{a_1 a_2 a_3 x^{a_2 - 1}}{(1 + a_1 x^{a_2})^{a_3 - 1}}$$

where x is income and each a_i is a positive parameter. The parameter a_1 scales the distribution but does not affect unitless values such as the Gini coefficient. The moments and Gini coefficient of the Singh-Madala family have closed forms, so besides providing a good fit it is easy and reliable to estimate separately for 6 levels and 26 years.

The maximum likelihood estimates are reported in full in Table 5 of Appendix B. The parameters themselves lack an economic interpretation. More important is whether the Singh-Maddala distribution describes the data well enough to trust results based on the parameter estimates. Since the data are grouped by income, the most general, and least informative, model is a simple multinomial distribution over income categories. If the Singh-Maddala distribution compares favorably to the multinomial then using a more flexible but more difficult distribution is unlikely to change the conclusions.

[8] See Singh-Madala (1976) and Macdonald (1984). Beach and Davidson (1982) develop a distribution-free approach to estimating the Lorenz curve. Without micro data, however, it requires interpolating the distribution for points between salary intervals, which amounts to fitting a curve.

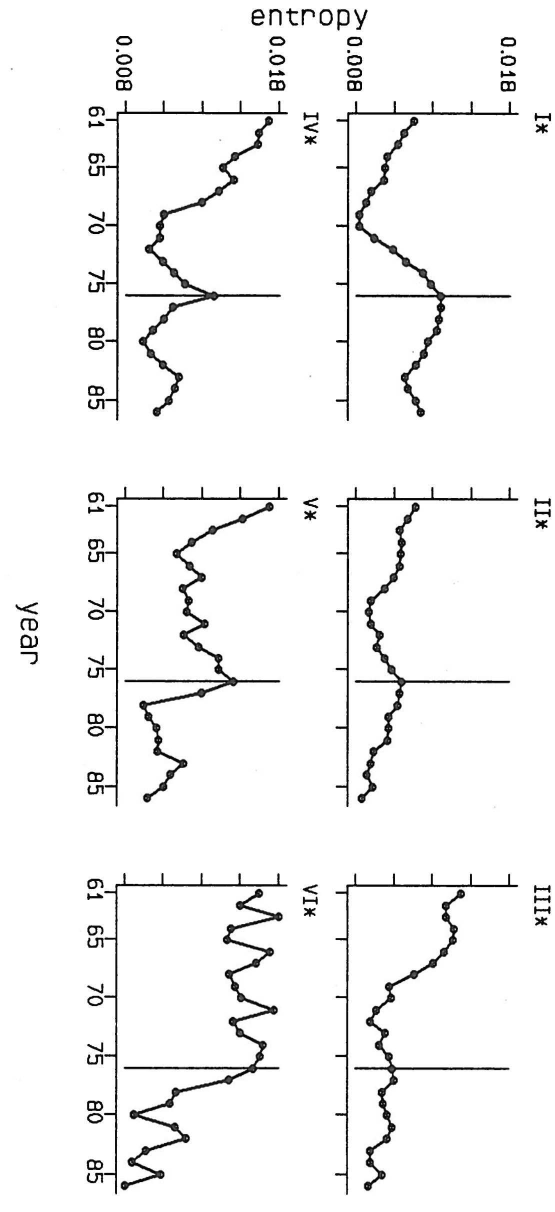


Figure 7. Earnings Inequality Within Levels of Responsibility

The Singh-Maddala distribution does do well, but assessing the fit is not straight forward. The problem lies in the fact that the PATC survey is based upon a stratified sample of firms rather than jobs or workers. So the number of engineers sampled is not known. The employment levels shown in Figure 1.2 are estimates for the whole population of jobs, and because the sample is stratified the actual number of jobs contacted in each category is not proportionate to the reported levels. Nonetheless, the sample of engineering jobs actually surveyed is large, at least 50,000 in each year.[9]

One way to measure fit when the cell probabilities are known but the sample size is not is to compute the minimum sample size that causes a likelihood ratio test to reject the Singh-Madala distribution in favor of the multinomial when using, say, a .01 significance level. This critical sample size is summarized in Table 4 and fully reported in Table 6. The sizes are fairly large; for all levels the average is above 1000 across years. In 1971 and level III*, for instance, the fit is so close that the discrepancies would cause rejection of Singh-Maddala only if based on a sample of 20,967 or more. In only one case—level VI* in 1986—does the value fall below 1000. The fit is best in the middle levels and worse in level I* and level VI*.

At first these sample sizes look small quite small to a true sample of 50,000 or more. However, all the estimates are conditional on employment in a level and the sample in each level is a fraction of the overall sample. Because employment is quite small in the upper levels (see Table 1), the lower critical sample sizes here are not a serious indication of a bad fit. Finally, Figure 5 shows how good the fit is for the best and worst cases. The larger discrepancy in the worst case is due to raggedness in the data (see Figure 2) caused by a smaller sample size at upper levels and rounding in the original PATC tables.

Aggregate and Within-Level Earnings Inequality

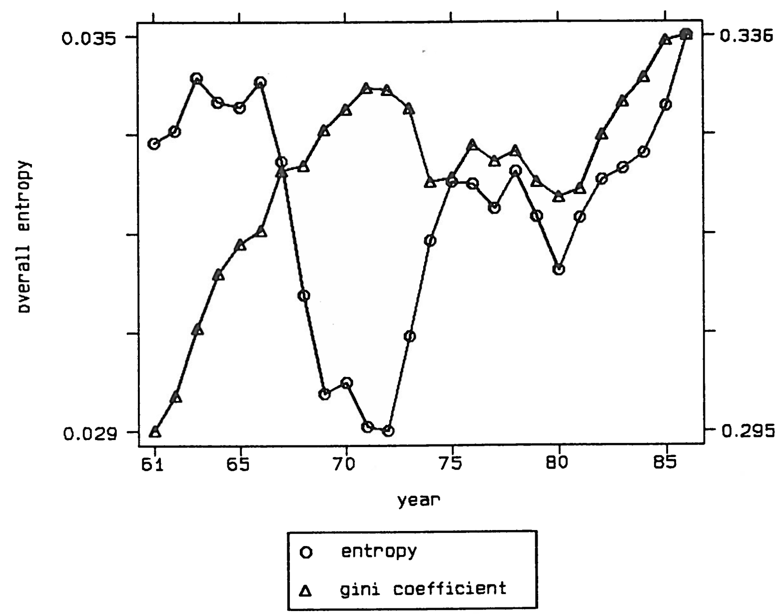
The estimates are used to construct the aggregate salary distribution, the mixture or pooling of distributions within hierarchy levels (see Appendix B for details). These estimates are then used to compute measures of earnings inequality within engineering in each year.

The two most common measures of earnings inequality are the Gini coefficient and

[9] Officials at the BLS suggested in conversations that firms employing roughly one in three workers are contacted each year. Compared to the levels of employment, the figure of 50,000 in the text is conservative.

Figure 6.

Measures of Overall Earnings Inequality



the family of generalized entropy measures.[10] The values for the aggregate distribution are shown in Figure 6. Greater entropy or a larger Gini coefficient correspond to more unequal sharing of total earnings. The rankings of different distributions can disagree, and they do disagree during the 1960s, as Figure 6 indicates. Entropy was falling during this time, while the Gini coefficient rose. This disagreement can oocur when the middle and tail sections of the distribution behave differently, because the entropy measures place more emphasis on the tail behavior than the Gini coefficient. Apparently the tails were becoming more egalitarian, and this is suggested by Figure 3 in which the distribution at level VI* appears to be pulled up by its peak between 1961 and 1970. The two measures of inequality agree past 1974. From this year on both values stabilize, drop slightly in the late 1970s, and then rise sharply in the 1980s.

Unlike the Gini coefficient, entropy can be decomposed by sub-groups, which will be done by responsibility levels. It turns out that within levels the two measures agree qualitatively over the whole period 1961 to 1986. Only entropy will be discussed from this point on.

Figure 7 shows the path of entropy within each level of responsibility. In contrast to the aggregate values in Figure 6, inequality did not rise within levels during the 1980s. Indeed, inequality within levels has tended to decline since 1961. Except for level I*, entropy in all levels is at or near its minimum by 1986. Most levels, except VI*, saw their greatest declines during the 1960s. The cycle in inequality is longer than the business cycle. And while median wages (Figure 4) seem to suffer for six years from the 1974 oil shock, wage dispersion continues an earlier trend for two more years and then drops even during the sharp rise in real wage levels during the 1980s.

Inequality in level I*, which includes new and non-manager engineers, behaves somewhat differently than in upper levels. Here entropy fell then rose sharply until 1976, fell again, and finally rose slightly in the 1980s. For most levels the year 1976 seems to be a year of change. This corresponds in Figure 1 to the point at which level I* employment begins to recover. Within lower levels, increases in entropy stalled and reversed, while in level VI* entropy suddenly dropped.

Within-group entropy contributes directly to aggregate entropy, so the discrepancy in their behavior is caused by two additional factors: changes in the gaps between earnings

[10] The entropy measures depend upon a parameter that can range between 0 and 1. The choice of the parameter has little effects for this data, so only values for the parameter set to .5 are reported. See Appendix B and the sources cited there for a fuller discusion.

and the share of employment at different levels. Figure 8 shows how within- and between-inequality differed. Changes in entropy between levels contributed to all changes in overall entropy. In particular, Figure 8 confirms what Figure 4 hinted at: inequality between levels rose sharply in the 1980s. During the early 1960s the drop in within-level inequality occurred while the overall value held steady. Since 1976 within-level entropy has fallen, so the rise in inequality during the early 1970s was fueled by both within- and between-inequality. The rise in the 1980s, on the other hand, was fueled exclusively by a widening gap between responsibility levels.

Entropy and employment within levels do not relate in any obvious way. Inequality fell in all levels before 1970 and after 1976, periods in which employment shares within levels moved in opposite directions. If employment in level I* fell before 1976 simply because workers were being promoted out of it more quickly, then earnings differentials within the level should have fallen, and at least the primary effect should have been a drop in wage dispersion. The patterns so far suggest that many of the changes relate to demographic shifts within engineering.

The Experience Distribution in Engineering

Table 4 summarizes the information on male engineers appearing in the CPS from 1969 to 1991. (Appendix A describes the sample.) Since only men were available, column (2) shows for certain years the overall percentage of female engineers in the U.S. Although the growth of young women entering the profession alters the overall experience distribution, their numbers in the profession are still relatively small. Including them would only accentuate the shift toward an inexperienced stock of workers.

Figure 9 shows the change in three segments of the experience distribution: below fifteen years, between fifteen and thirty, and above thirty years. The 90% confidence intervals are also shown. The share of young workers fell slightly in the early 1970s and then started to rise significantly in 1976. In 1985, this baby-boom in engineering had peaked as early entrants started to hit mid-career. Prior to that, the share of engineers between fifteen and thirty years experience fell continuously from 1969. At the other end of the spectrum, the number of older engineers rose until 1980, at which time the retirement of the post-war cohorts and the influx of the baby-boom began.[11]

[11] There is some evidence (Dalton and Thompson 1971) that engineers peak in performance by age 45, or approximately 25 years experience. Coincidentally, Dalton and Thompson's study appeared in the year when the post-War cohort reached its professional

FIGURE 5.
Fitted and Actual Distributions

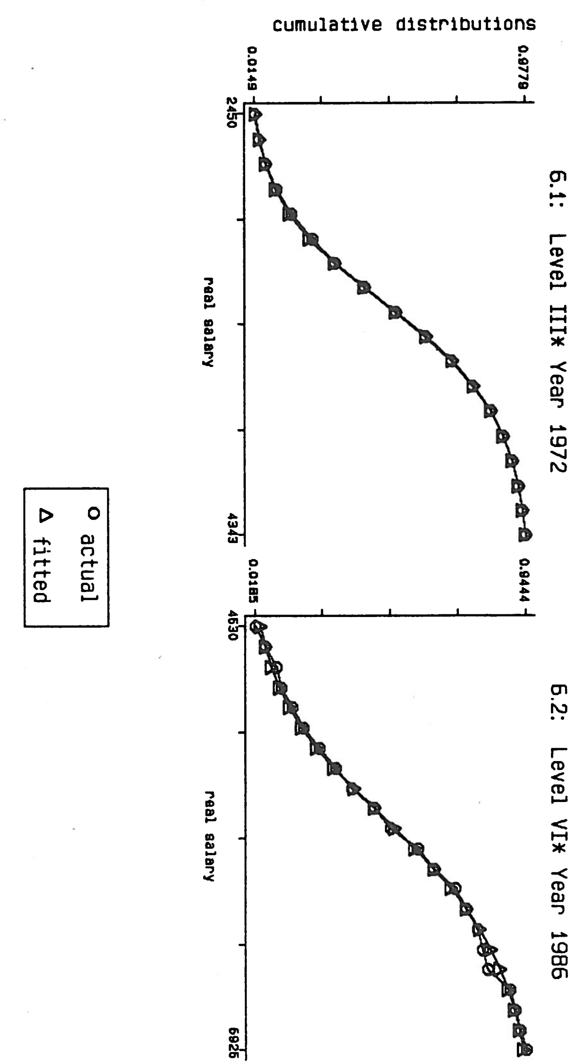


FIGURE 4.
Median Wages and Percentile Overlap

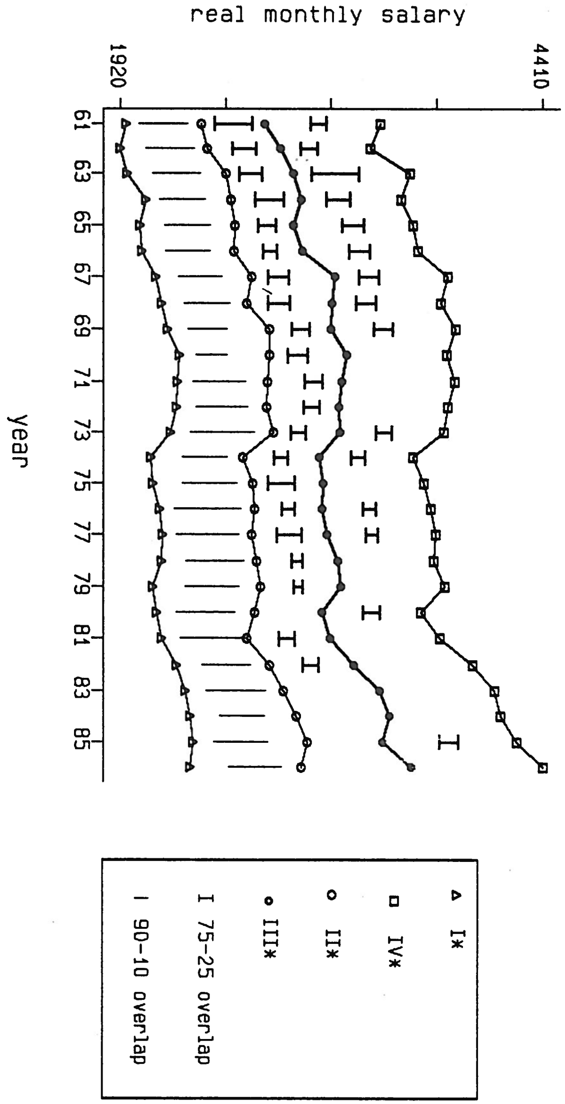


Table 4 reports entropy in the weekly salaries for full-time engineers in the CPS since 1976. The data before 1976 behave quite differently, most probably because of the imputation method used before 1976 (Lilliard and Welch 1986). The entropy measure is calculated using only records without allocated earnings. Since 1976 the data suggest that overall inequality within the profession was on the rise, and perhaps reached a peak in the mid 1980s.

The connection between experience and employment shares within levels is clear. Around 1976, both level I* employment and the share of inexperienced engineers start to rise. Employment in level VI* drops off rapidly after 1980, corresponding roughly with the drop in high experienced engineers. The link between experience and overall earnings inequality is also fairly clear. From 1970 the number of engineers with extreme (high or low) experience rose as did overall inequality. Later the increase was more at the low end, and this seems to have had a greater effect on inequality. The link to within-level earnings inequality, however, is not so clear. For instance, the drop in dispersion at most levels in the early 1970s occurs when the experience distribution is only changing gradually.

Interpretation

The co-movement of wage dispersion and the experience distribution can be reconiled with a simple model in which the skill to handle highly responsible jobs is accumulated primarily through experience. The supply of low-skill engineers was near its nadir in the early 1970s. This created pressure for firms to hold engineers back in level I* until the upswing six years later. This bottlneck in assignment increased the skill differential of those placed in level I*. After 1976, the bottleneck subsided and inequality within levels fell again. The fact that it started to fall in all levels (Figure 7) suggests that the new experience distribution allowed firms to better sort workers between levels, creating less within-level inequality and more between.

These patterns rule out one type of technological change as being the dominant force. Advances in computing and trends in management philosophy both encourage team production, in which decisions are made nearer the base of an organization. This creates a bias against high responsibility jobs. Projects that previously required large hierarchies can and are encouraged to be be done with flatter, more egalitarian structures. Engineering should be very responsive to such changes, since it relies on computing power and

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maturity and the baby-boom cohort began its professional infancy.

deals with tasks varying greatly in size and complexity. While the share of employment in upper ranks has fallen since 1976, relative earnings in those ranks rose. Thus the shift in supply, caused by the drop in highly experienced engineers, appears to dominate this type of technology bias, although the impact of this bias may not have been felt before 1986.

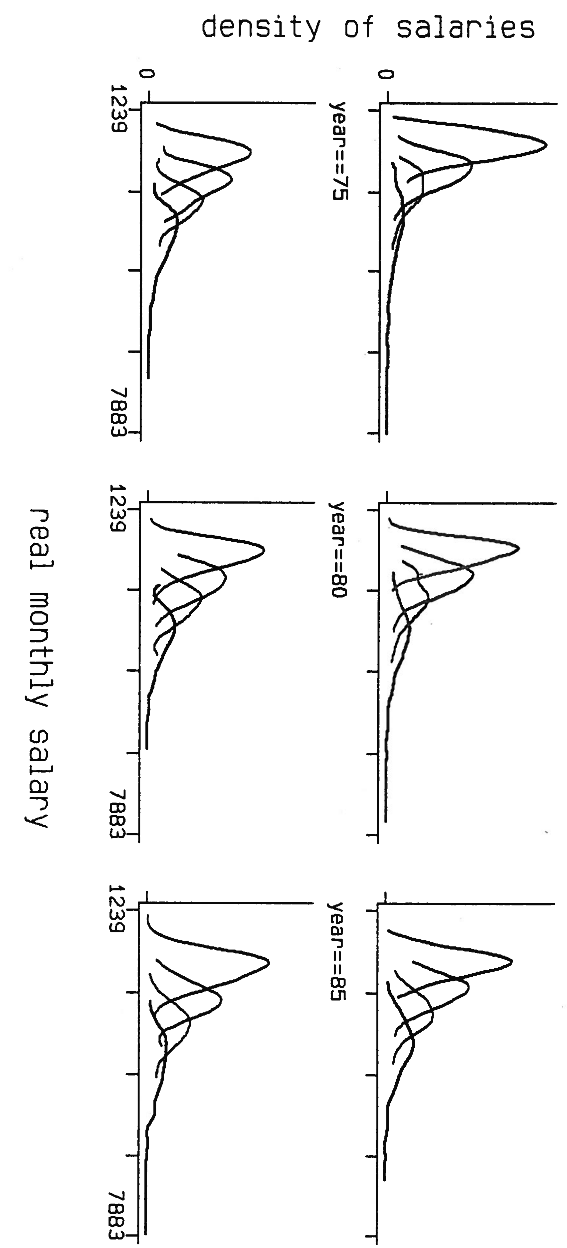
The unique way in which the PATC survey documents aggregate changes in firm organization leads to several open questions. For instance, Freeman (1977) has put forth the active labor market idea: young workers should feel more sharply the effects of labor demand conditions. The same principle may operate for firms. If experienced workers are in short supply, growing firms may be slower to adopt large vertical hierarchies. Firms with stable control structures may find it more costly to respond since they have explicit and implicit contracts with workers. To what extent are changes in rank assignment due to firms actually re-organizing versus new firms adapting to current conditions? More generally, accounting for theories of the firm may refine current explanations for changes in the wage structure that focus on labor supply and labor demand factors.

IV. Conclusion

Responsiblity is a scarce resource — we can't all be chiefs. And a major role of firms is to organize interaction between workers at different ranks. It is not surprising then that the distribution of experience within an occupation affects the value and assignment of responsiblity. The PATC data on job rank confirm that this effect is real, and that much remains to be known about the aggregate implications of job placement within firms.

If past trends are any guide the rise in inequality in engineering may have slowed in the late 1980s. The baby boom entered mid-career and the post-war cohort began to retire, compressing the experience distribution. This should narrow the wage gaps between ranks since worker skills are less varied. Indeed, the wage data on engineers from the CPS (Table 4) suggest that inequality leveled off after 1985. On the other hand, since the supply of relatively inexperienced workers is falling, firms may find it more difficult to allocate responsibility to workers efficiently, in turn leading to greater inequality within job ranks.

FIGURE 3.
WAGE DISTRIBUTIONS BY LEVEL AND YEAR



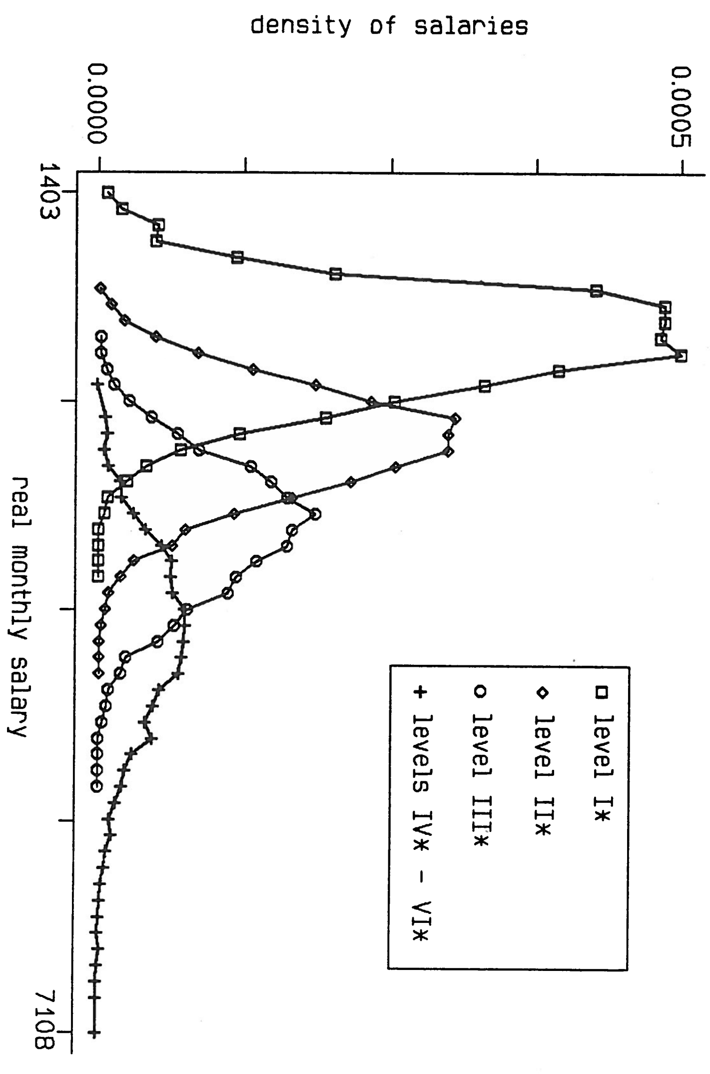


FIGURE 2.
WAGE DISTRIBUTIONS FOR 1986

Appendix A. Details of the Data

PATC Survey

Below are summaries of the definitions of levels for engineers in the PATC survey. Full job descriptions appear in an Appendix to the survey each year. In most cases below the wording in the survey is used.

Level I Performs routine tasks and receives close supervision.

Level II Performs routine tasks and applies standard techniques. Assignments are screened for unusual problms. May supervise technicians or draftsmen.

Level III Evaluates and applies standard techniques. Receives instruction on objectives. May supervise technicians or draftsmen.

Level IV Plans and conducts work requiring judgment and adaptation of techniques. Receives general guidance. May supervise a few engineers or technicians.

Level V •Supervises work substantially at level IV; or

•Carries out complex or novel assignments independently; or

•Develops and evaluates plans for projects carried out by others.

Level VI •Supervises large number of projects or responsible for entire engineering program of a company which is of limited complexity; or

•Conceives and conducts research in areas of considerable scope; or

•Serves as technical specialist for organization. Keeps abreast of new methods for purpose of recommending changes.

If a manager, then plans, organizes and supervises work of staff of engineers and technicians.

Level VII •Responsible for important segment of engineering program of company with extensive requirements or of entire program of a company, requires several subordinate teams;or

•Recognized leader and authority in the company in broad area, selects research problems to further the company's objectives.

If a manager, then directs several subordinate supervisors.

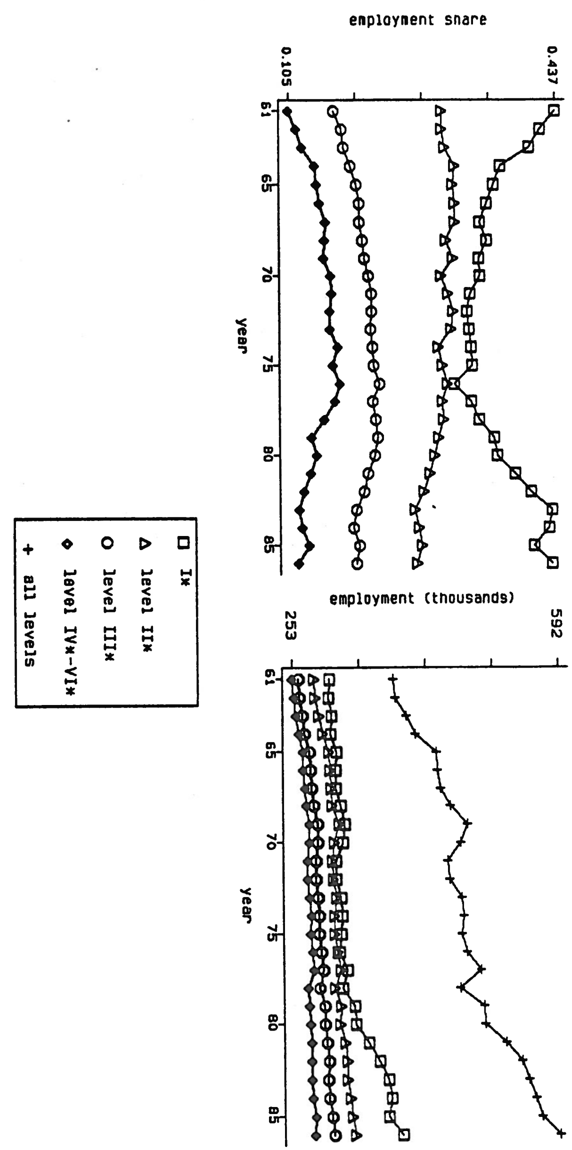
Level VIII •Responsible for important segment of extensive engineering program of a company or the entire program of moderate scope; or

•Formulates and guides the attack on problems of exceptional difficulty; or

•Supervises several subordinates whose positions are comparable to VII or some individual researchers at level VIII.

Level III is the typical entry level for a person with a B.A. Level VI is the entry level for a Ph.d., but no level requires a certain amount of education.

Figure 1.
Employment in Engineering By Level



Excluded from the survey are:

(1) Engineers in charge of programs so extensive and complex that one or more subordinate supervisory engineers are performing at level VIII.

(2) Individuals whose decisions have direct and substantial effect on setting policy for the organization (beyond engineering programs).

(3) Individual researchers recognized as national or international authorities.

The universe for the PATC survey consists of establishments in the continental U.S. and above a minimum total size of employment. Utilities and firms in the service sector are included, but educational and government institutions are not. The minimum size depends on industry, and it has remained nearly constant between 1962 and 1986. Prior to 1966 the minimum establishment size was 250 employees in all industries. In 1966 the minimum was lowered to 100 in transportation, communication, public utilities, and wholesale trade and was lowered to 50 in services and FIRE. In 1986 the minimum was lowered to 50 in all industries. These changes appear to have had little impact on the distributions for engineers because their employment is concentrated in much larger plants. For instance, in 1970 roughly 60% of engineers in the survey worked in establishments with more than 2500 workers.

The survey covers workers employed during the month of the interview rather than the whole year. Interview dates occurred within four month periods centered in March for years before 1969 and after 1971. In the years 1969-1971 the average date was June.

The Current Population Survey

The CPS sample is drawn from the March tape. It includes males between the ages of 16-64 not in the armed forces who worked 40 or more weeks during the previous year and who report their occupation as engineer. The derived occupation code for engineers is used in all years except until 1982, when marine and naval architects included with engineers were dropped.

The weekly wage is the sum of yearly wage and self-employment income divided by the number of weeks worked, expressed in 1982 dollars. Out of 18,980 observations meeting these criteria, a total of 199 had topcoded self-employment or wage income. Earnings for these records were multiplied by 1.3. Records with allocated earnings flags were dropped.

University, Department of Economics Discussion Paper, 505, November.

Murphy, Kevin M. and Finis Welch 1992. "Wage Differentials in the 1980s: The Role of International Trade," *Quarterly Journal of Economics*, 107, 1, 285-326.

Pearce, Wayne B. 1990. "Occupational Choice: The Market for Lawyers," Ph.D. thesis, University of Chicago.

Rosen, Sherwin 1982. "Authority, control and the distribution of earnings," *Bell Journal of Economics*, 311-323.

Singh, S. K. and G. S. Madala 1976. "A Function for the Size Distribution of Incomes," *Econometrica*, 42, 1115-1127.

Siow, Alyosius 1984. "Occupational Choice Under Uncertainty," *Econometrica*, 52, 631-645.

Smith Adam 1976. *The Wealth of Nations*, Penguin.

Tamasko, Robert 1987. *Downsizing: Reshaping the Corporation of the Future*, New York, AMACOM.

Tuck, R.H. *An Essay on the Economic Theory of Rank*, Oxford: Blackwell 1954.

United States Deparment of Labor. *National Professional, Adminstrative, Technical and Clerical Pay Survey*, 1961-1986. Washington D.C.

Waldman, Michael 1984. "Worker Allocation, Hierarchies and the Wage Distribution," *Review of Economic Studies*, 51, 95-109.

Welch, Finis 1979. "Effects of Cohort Size on Earnings: The Baby Boom Babies' Financial Bust," *Journal of Political Economy*, 87, 5, S65-S97.

Zarkin, Gary 1985. "Occupational Choice: An Application to the Market for Public School Teachers," *Quarterly Journal of Economics*, 99, 409-446.

Appendix B. Statistical Appendix

Tables 6 and 7 fully report the maximum likelihood estimates of the Singh-Maddala parameters and the fit of the estimates. This appendix also gives the formulas for the inequality measures used in the text. See Macdonald (1984) and Jenkins (1991) for more details.

The Gini coefficient is the area between the Lorenz curve and the cumulative distribution for a perfectly equal distribution of earnings, or the case when x% of the population receives x% of total earnings. For the Singh-Madala distribution, the Gini coefficient has a closed form in the Γ function:

$$\gamma^{SM} = 1 - \frac{\Gamma(a_2)\Gamma(2a_3 - \frac{1}{a_2})}{\Gamma(a_3 - \frac{1}{a_2})\Gamma(2a_3)}$$

Entropy within a distribution is defined using fractional moments of the distribution:

$$E_\alpha = \frac{1}{\alpha^2 - \alpha}\int \left[\left(\frac{y}{\mu}\right)^\alpha - 1\right] f(y)dy,$$

where μ is the mean of the distribution, $f(y)$ is the density of earnings, and α is a parameter that can take on values between 0 and 1. As α goes to 0, the E_α approaches the coefficient of variation, and as α goes to 1, E_α approaches Teil's measure of inequality. For the Singh-Maddala distribution, E_α can be written as

$$E_\alpha = \frac{1}{\alpha^2 - \alpha}\left[a_1^{-\alpha/a_2}\frac{\Gamma(1+\alpha/a_2)\Gamma(a_3 - \alpha/a_2)}{\mu^\alpha\Gamma(a_3)} - 1\right].$$

As stated in the text, the value of α had little effect on the values of E_α for the PATC data. Values used in the paper are for $\alpha = .5$, and from now on the subscript α shall be dropped.

Entropy across all levels of responsibility can easily be calculated using entropy within levels and the shares of employment. That is, let π_{it} be the share of employment at level i in year t and let $\hat{a}_j^{it}$ be the maximum likelihood estimate of a_i in level j and year t. Also, let μ_{it} denote the estimated mean wage in level i year t and let μ_t denote the overall mean. Then if E^{it} denotes entropy in level i year t, aggregate entropy in year t is given by:

$$E^t = -\frac{1}{4}\sum_{i=I*}^{VI*}\pi_{it}\sqrt{\frac{\mu_{it}}{\mu_t}}\left[E^{it}+1\right] + \frac{1}{4}.$$

No such decomposition exists for the Gini coefficient. The aggregate Gini coefficient must be computed numerically from the estimates for each level. To this end the aggregate earnings distribution, as a mixture of the distributions at each level, must be defined. The aggregate distribution of earnings in year t is

$$G_t(x) = \sum_{i=I*}^{VI*}\pi_{it}F(x;\hat{a}_1^{it},\hat{a}_2^{it},\hat{a}_3^{it})$$

and the density is

$$g_t(x) = \sum_{i=I*}^{VI*}\pi_{it}f(x;\hat{a}_1^{it},\hat{a}_2^{it},\hat{a}_3^{it}).$$

In turn, let $\Phi_t(x)$ denote the share of total earnings made by engineers making less than x:

$$\Phi_t(x) = \frac{1}{\mu_t}\int_0^x g_t(y)dy.$$

Then the aggregate Gini coefficient in year t is:

$$\gamma_t = \int_0^1 \left[z - \Phi_t(G_t^{-1}(z))\right] dz$$

G_t must be inverted numerically. Computation of G_t^{-1} and the maximum likelihood estimates was done in Gauss386, using its BFGS routine. The numerical integration required to compute γ^t used Romberg's method. No problems in reaching convergence were encountered.

References

Beach, Charles and Russell Davidson 1982. "Unrestricted Statistical Inference with Lorenz Curves and Income Shares" *Review of Economic Studies*, 50, October, 723-55.

Bound, J. and George Johnson 1992. "Changes in the Structure of Wages in the 1980's: An Evaluation of Alternative Explanations," *American Economic Review*, forthcoming.

Dalton, Gene W. and Paul H. Thompson 1971. "Accelerating Obsolescence of Older Engineers," *Harvard Business Review*, September-October, 57-67.

Davis, Steve J. and Haltiwanger, John 1990. "Wage Dispersion between and within U.S. Manufacturing Plants, 1963-86," *Brookings Papers on Economic Activity Microeconomics Annual*, 115-200.

Freeman, Richard 1975. "Supply and Salary Adjustments to the Changing Science Manpower Market: Physics 1948-1973," *American Economic Review*, 65, 27-39.

—— 1976. "The Decilne in the Economic Rewards to College Education," *Review of Economics and Statistics*, 59, February, 18-29.

—— 1979. "The Effect of Demographic Factors on Age-Earnings Profles," *Journal of Human Resources*, 14, 3, 289-317.

Howell, David R. and Edward N. Wolff 1991. "Trends in the Growth and Distribution of Skills in the U.S. Workplace, 1960-85," *Industrial and Labor Relations Review*, 44, 3, 486-502.

Jenkins, Stephen 1991. "The Measurement of Income Inequality," in *Economic Inequality and Poverty: International Perspectives*, Lars Osberg (ed) Sharpe: New York.

Juhn, Chinhui, Kevin Murphy and Brooks Pierce 1990. "Wage Inequality and the Rise in Return to Skill," mimeo, University of Chicago, January.

Katz, Lawrence and Kevin M. Murphy 1992. "Changes in Relative Wages, 1963-1987: Supply and Demand Factors," *Quarterly Journal of Economics*, 107, 1, 35-78.

Lillard, Lee and James P. Smith and Finis Welch 1986. "What Do We Really Know about Wages? The Importance of Nonreporting and Census Imputation," *Journal of Political Economy*, 94, 3, 489-506.

Lucas, Robert E. "On the Size Distribution of Business Firms," *Bell Journal of Economics* 9, 2 (Autumn).

McDonald, James B. 1984. "Some Generalized Functions for the Size Distribution of Income," *Econometrica*, 52, 3, 647-663.

Mayer, Thomas 1960. "The Distributions of Ability and Earnings," *Reveiw of Economics and Statistics* 42, 2.

Mincer, Jacob 1990. "Human Capital, Technology, and the Wage Structure," Columbia