Draft

ACADEMIC LEARNING AND NATIONAL PRODUCTIVITY

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ACADEMIC LEARNING AND NATIONAL PRODUCTIVITY

"The fate of empires depends on the education of youth"
--Aristotle

Skill requirements clearly appear to be escalating. Occupations which require the worker to use or process information are growing rapidly. The need for greater ability to process information is also growing in blue collar occupations that have traditionally not been thought to make such demands. Increasing numbers of manufacturing workers are working in production cells in which every member of the team is expected to learn every job. Production workers are being given responsibilities--quality checking, statistical process control (SPC) record keeping, resetting machines shown by SPC to be straying from target dimensions, redesigning the layout of the machines in the production cell--that used to be the sole province of supervisors, specialized technicians and industrial engineers.

Concern about slackening productivity growth and deteriorating competitiveness has resulted, in many nations, in a new public focus on the quality and rigor of the elementary and secondary education received by the nation's front line workers. Higher order thinking and problem solving skills are believed to be in particularly short supply so much attention has been given to mathematics and science education because it is thought that these subjects are particularly relevant to their development.

The debate has been enlivened by the availability of comparative data on mathematics and science achievement of representative samples of secondary school students for many industrialized nations. At age 13 Swedish students are roughly comparable to students in most other industrialized nations in geometry, statistics and measurement but lag substantially behind other nations in arithmetic and algebra. By the end of secondary school the Swedish students who are taking advanced mathematics courses intended to prepare for college have caught up with other European students in similar courses. This group represented 13 percent of the age cohort in the US, 12 percent in Japan and Sweden, 15 percent in Finland and the 50 percent in Hungary. Figure 1 plots the percent correct on the Algebra section of the Second International Mathematics Study against proportion of the 18-year old population in the types of courses to which the international test was administered. In Algebra, Sweden's 60 percent

FIGURE 1

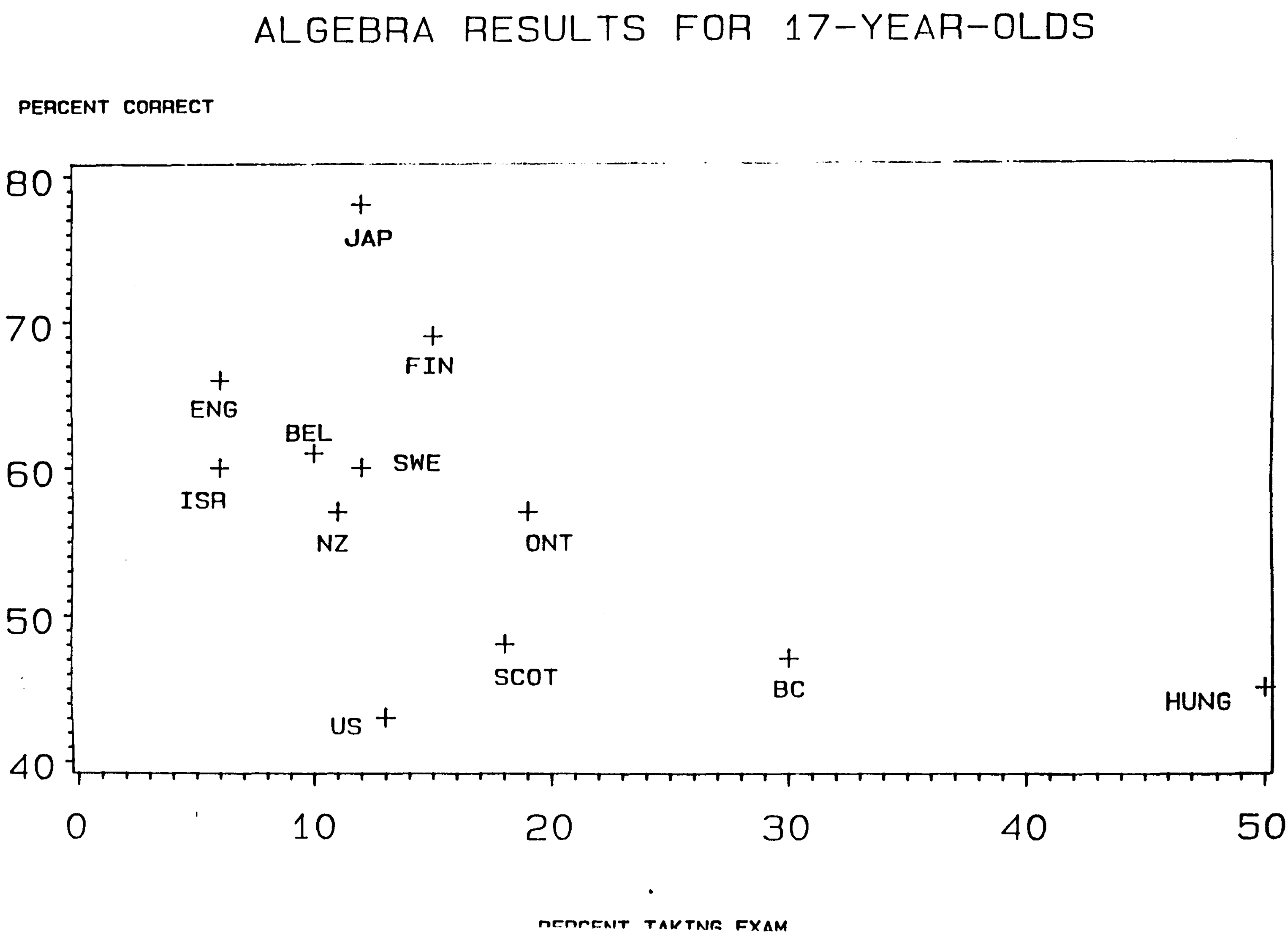

ALGEBRA RESULTS FOR 17-YEAR-OLDS
PERCENT CORRECT
80
70
60
50
40
0
10
20
30
40
50
JAP
FIN
ENG
BEL
SWE
ISR
NZ
ONT
SCOT
BC
HUNG
US
PERCENT TAKING EXAM

FIGURE 2

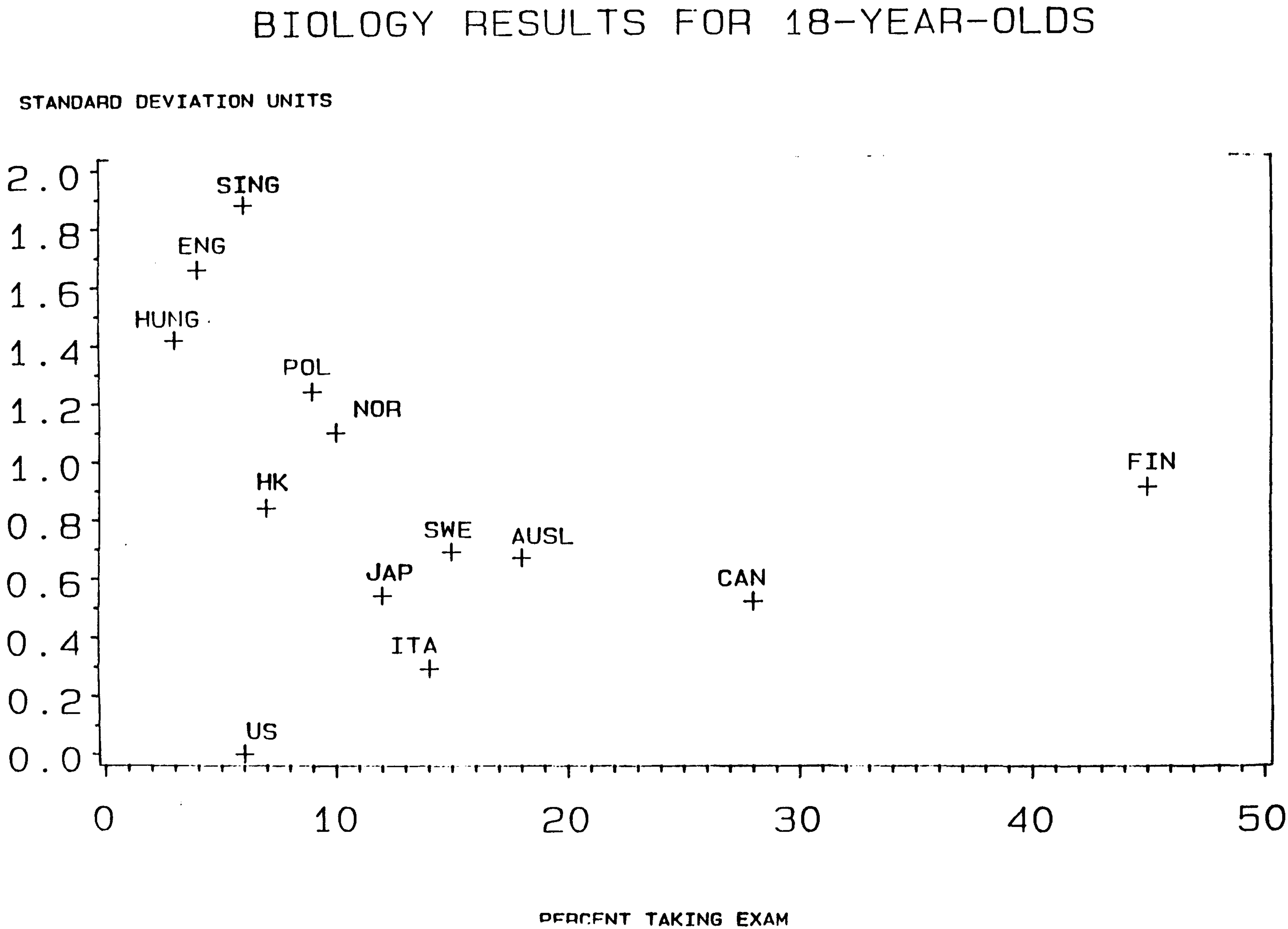

BIOLOGY RESULTS FOR 18-YEAR-OLDS
STANDARD DEVIATION UNITS
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
SING
ENG
HUNG
POL
NOR
HK
SWE
AUSL
JAP
CAN
ITA
US
FIN
0
10
20
30
40
50
PERCENT TAKING EXAM

FIGURE 3

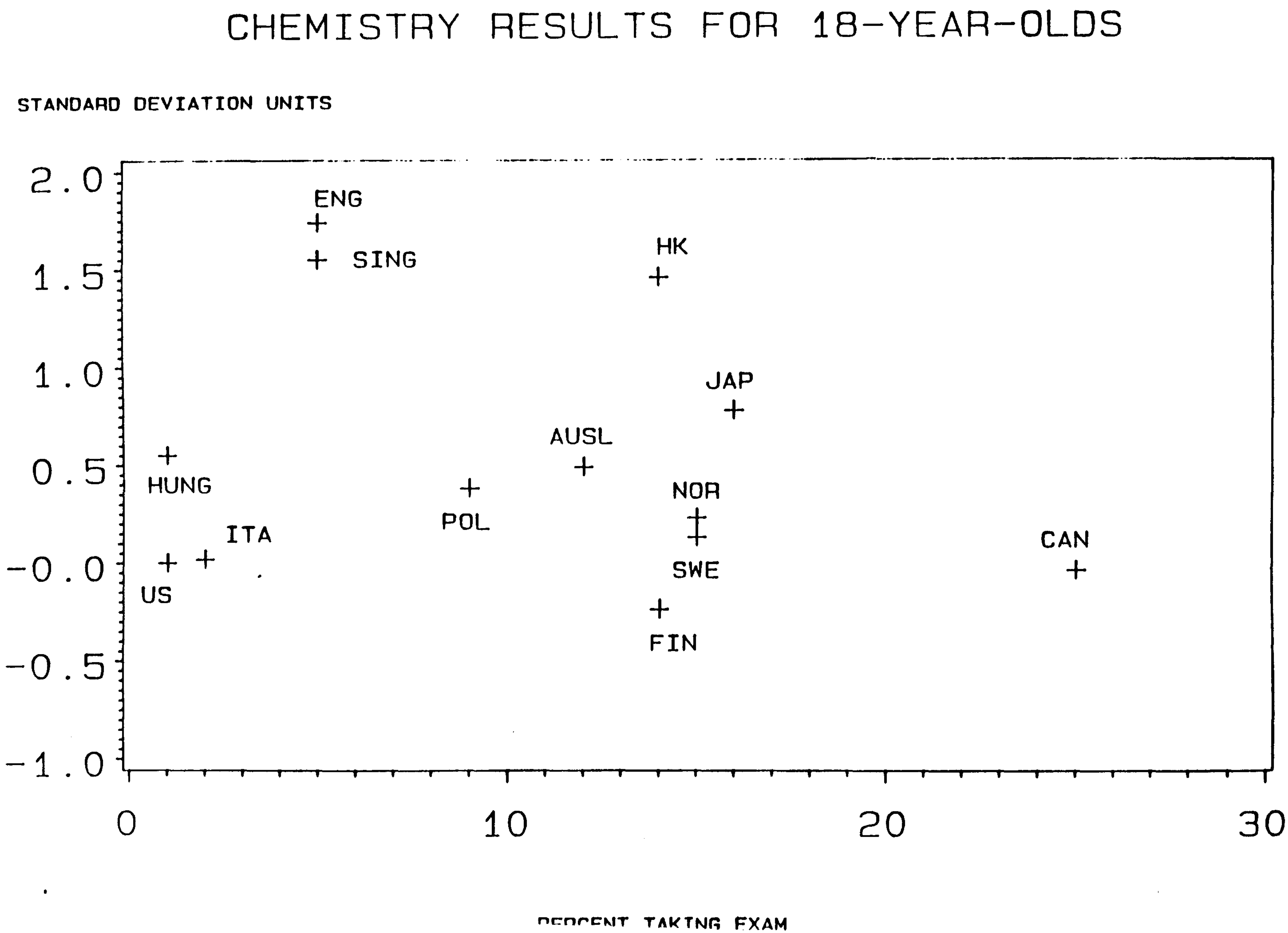
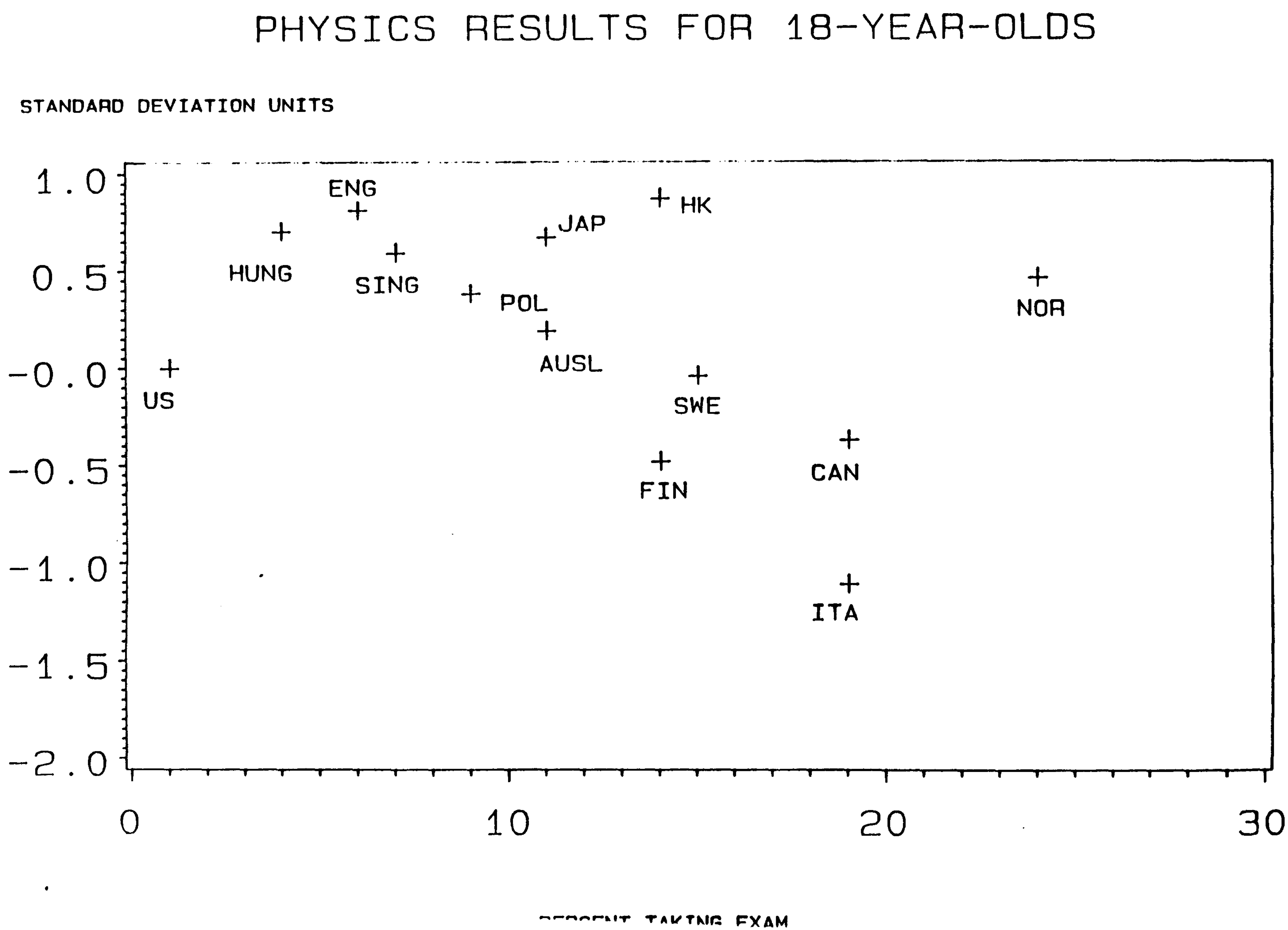

CHEMISTRY RESULTS FOR 18-YEAR-OLDS
STANDARD DEVIATION UNITS
2.0
1.5
1.0
0.5
-0.0
-0.5
-1.0
ENG
SING
HK
JAP
AUSL
HUNG
POL
NOR
ITA
CAN
US
SWE
FIN
0
10
20
30
PERCENT TAKING EXAM

FIGURE 4



PHYSICS RESULTS FOR 18-YEAR-OLDS
STANDARD DEVIATION UNITS
1.0
0.5
-0.0
-0.5
-1.0
-1.5
-2.0
ENG
HK
JAP
HUNG
SING
POL
NOR
AUSL
US
SWE
CAN
FIN
ITA
0
10
20
30

correct was in the middle of the pack; half way between the Japanese mean of 78 percent correct and the US mean of 43 percent correct. Finnish students got 69 percent correct (McKnight et al 1987).

The findings of the Second International Science Study place Sweden in the middle of the pack and the US at the bottom. For 15 year olds, the percent correct on the general science test was 72 for Hungary, 67 for Japan, 62 for Finland, 61 for Sweden, 60 for Norway and 55 for the US. Only a small share of an age cohort typically takes advanced science courses in the final year of secondary school. The IEA data suggests that the Swedish percentage, 15 percent in each of biology, chemistry and physics, is higher than that of most other countries. Normally, countries with large proportions of the age cohort in advanced courses, have lower mean scores and this accounts for Sweden's mean scores being slightly below the grand mean. The exceptions to this generalization are the standout performance of Norway in physics, Finland in biology and Hong Kong in chemistry and the dismal performance of the very select samples (1 percent of the age cohort in chemistry and physics) in America. The 6 % of American 17-18 year olds who are taking their second biology course knew considerably less than much less selective groups of students in Europe, Canada and Asia (International Association for the Evaluation of Educational Achievement, 1988).

Clearly, there is a large gap between the science and math competence of young people from different nations. Do such gaps have major consequences for a nation's standard of living? In the view of many, it does:

> If only to keep and improve on the slim competitive edge we still retain in world markets, we [Americans] must dedicate ourselves to the reform of our educational system....Learning is the indispensable investment required for success in the "information age" we are entering. (National Commission on Excellence in Education, p. 7).

Behind their call for higher standards and more class time devoted to core academic subjects--math, science, social science and language arts--is an assumption that most jobs require significant competency in these fields. There is, however, some controversy about these claims. Morris Shamos, an emeritus professor of physics at New York University, argues, for example, that "widespread scientific literacy is <u>not</u> essential to... prepare people for an increasingly technological society"(Education Week, Nov. 23 1988. p. 28). The purpose of this paper is to determine whether evidence from the labor market supports these claims?

The first section of the paper examines the effect of generalized academic competence on the wage rates of adults. In section two I examine which of the various competencies developed in secondary school has the largest impact on wage rates and earnings of young workers. The findings from this analysis appear on the surface to support Shamos and contradict the recommendations of many educational reformers. For young men in the United States, competence in mathematical reasoning, science and language arts does not increase wage rates or earnings in the first 8 years after graduating from high school. The competencies that pay off for young men are speed in doing simple computations (something that calculators do better than people) and technical competence (knowledge of mechanical principles, electronics, automobiles and shop tools), something that has been ignored by most of the reports recommending educational reform. For young women in the United States, the findings are that verbal and mathematical reasoning competence lower unemployment and increase earnings but only mathematical reasoning competence and computational speed increase female wage rates. Competence in science has no effect on earnings or wage rates and verbal ability has no effects on wage rates. While these results provide little support for the Excellence Commission's recommendations, they suggest an immediate explanation for the poor performance of American students in science and higher level mathematics--the absence of significant rewards for the competencies.

The reports recommending educational reform, however, make claims about the **productivity** effects not the **wage rate** effects of science, mathematics and language arts competency. Are these effects necessarily the same? The third section of the paper addresses this question and concludes that, when the specific competencies of students are not signaled to the labor market by a credential (as is the case for math and science achievement in US high schools), there is very little reason to expect the wage rate effects of specific competencies which are highly correlated with each other to be the same as their productivity effects.

The fourth and fifth section of the paper, therefore, tackle the productivity effects question more directly by analyzing data sets in which worker competencies have been correlated with their relative job performance in specific jobs. These analyses provide support for recommendations for better preparation in math and science, but they also reinforce the findings from the analysis of wage rates, earnings and unemployment regarding the important role of technical competence in blue collar, craft and technician jobs.

The sixth section of the paper examines the association for the period following World War 2 between rates of gain on tests assessing the general intellectual achievement of the population and aggregate rates of productivity growth for the nation. The association is quite strong and survives the introduction into the model of controls for the setback to economic growth resulting from World War 2.

The concluding section of the paper briefly reviews the evidence and concludes ceteris paribus that improvements in the academic achievement of the average worker can have substantial effects on a nation's productivity growth rate.

I. THE EFFECT OF GENERAL ACADEMIC ACHIEVEMENT ON WAGES OF ADULTS

The standard way to assess the impact of general academic achievement on the productivity of individual workers is to infer its effect by studying the relationship between general academic achievement and wage rates. Models must be estimated in which adult wage rates are predicted by a contemporaneous measure of general academic achievement while controlling for schooling and other worker characteristics such as experience. It is essential that the sample be representative of the nation and that academic achievement be measured long after the completion of schooling and as close as possible to the date of the wage rate observation. The difficulty, however, is that reliable academic achievement tests are time consuming and costly to administer. Consequently, data sets which measure both adult academic achievement and earnings for national probability samples are rare. There is only one American data set with these characteristics, the Panel Study of Income Dynamics (PSID). Unfortunately, the measure of academic achievement available in the PSID is a short form IQ test with 13 sentence completion questions (taken from the Lorge-Thorndike intelligence test) which has a KR-20 reliability of only .652. If not corrected for, measurement error will seriously attenuate estimated relationships between wage rates and such a short form IQ test.

Consequently, the true impact of general academic achievement (GAA) and years of schooling on wage rates must be estimated as part of a system of equations that includes a measurement model for academic achievement, years of schooling (SCH) and family background.[1] When such a model is estimated, the true effect of general academic achievement is calculated to be a 20.9 percent increase in earnings per population standard deviation change/difference in achievement. These results suggest that if the GIA of people with given levels of schooling either changes over historical time or differs across societies, these differences need to be explicitly included in any accounting of differences in labor quality across space or time.

1.2 Are Regression Estimates of The Economic Payoff to Knowledge and Skill Biased?

Will, however, improvements in performance on such tests resulting from a more rigorous, higher quality education have a similar effect on productivity? The absence of controls for the individual's genetic endowment in the above analysis might mean that .190 is an upward biased estimate of the true causal impact of test score gains generated by higher quality education. There are a number of reasons for believing that if such bias exists, it is limited in magnitude. First, while genetic endowment has probably influenced schooling and academic achievement as an adult, it appears to have no direct effect on wages in this data set, for adding the three background variables--fathers education, fathers occupation and number of siblings--with the highest correlation with genetic endowment did not decrease the coefficient on academic achievement. It was the addition of Born on a farm and Father foreign born which lowered the coefficient on academic achievement. Secondly, controlling for family background and genetic endowment by estimating within family models comparing brothers actually increases the effect of academic ability relative to cross section regressions of earnings on education and childhood IQ in Michael Olneck's (1977) Kalamazoo data.

The test used to characterize general academic achievement in this analysis purports to be an "aptitude" test. But, verbal and mathematical aptitude tests correlate almost as highly with broad spectrum achievement tests as alternate forms of the same test correlate with each other.[2] Numerous studies have found that school attendance raises scores on these aptitude tests (Lorge 1945; Husen 1951; Department of Labor 1970), and that taking a rigorous college prep curriculum increases the gains on these tests between sophomore and senior years of high school (Bishop 1985; Hotchkiss 1985). In recognition of the fact that aptitude test scores are significantly influenced by educational background, the College Board describes the SAT as a measure of "developed verbal and mathematical reasoning abilities (1987, p. 3)."

Adult vs Childhood GIA Tests: The final piece of evidence on this issue comes from examining the results of estimations where adult GIA tests compete with childhood IQ tests in predicting adult labor market success. It is sometimes argued that aptitude tests like the Lorge-Thorndike test really measure a stable "ability to learn" which is not substantially effected by educational experiences after the age of 10, and that it is this "ability to learn" not the content of the courses taken in secondary and tertiary education which helps workers who score well on these tests to get better, higher paying jobs. If this were true, we would expect childhood IQ tests to predict adult labor market success just as well as GIA tests taken as a young adult. In fact, however, when the two tests are simultaneously entered into a model, it is the adult test not the childhood test which has by far the biggest effect on labor market success (Husen, 1969). Evidence for this statement can be found in Tables 1 to 3. American data from the National Longitudinal Study of Youth (NLSY) was analyzed to determine whether 1985 wages and earnings is more influenced by a test taken in 1980 (the Armed Services Vocational Aptitude Battery) or by aptitude tests taken in the early 1970s. The results reported in Table 1 clearly imply that the later test had by far the most significant effect, implying that the learning that occurred during the interval between test administrations had a substantial impact on subsequent labor market outcomes.

Tuijnman's (1989) analysis of occupational attainment in the Malmo Longitudinal Study is reproduced in Table 2. The path coefficients on the test taken at age 20 has significant positive effects on earnings, while the childhood test often has a negative effects when the adult test is included in the model. Table 3 reports the results from a similar model predicting earnings rather than occupation. [3] The estimated effect of the IQ tests on earnings in the Malmo data is much smaller than the effects obtained in NLSY data. This could be reflecting the general compression of wage differentials in Sweden, the inclusion of technical competence and speed of numerical computation in the ASVAB test battery, or possibly a shift over time in the relative importance of the competencies assessed by these tests. But, here again, the adult test has much stronger effects on earnings than the childhood test.

These findings suggest that the associations between scores on employment aptitude and IQ tests on the one hand and productivity and labor market success on the other arise because the tests measure developed abilities that contribute to productivity. This suggests that an increase in the incidence of these developed abilities in the working population will increase national output. Left unresolved, however, is the relative importance of different types of developed abilities. It is to this issue I now turn.

II. WHICH COMPETENCIES ARE REWARDED IN THE AMERICAN LABOR MARKET ?

Which of the various subjects typically taught in secondary schools yield the largest economic return. This issue was addressed by estimating models predicting wage rates and earnings of young adults in the U.S. as a function of competence in the academic fields of mathematics, science and language arts and in the trade/technical arena while controlling for years of schooling, school attendance, ethnicity, age, work experience, marital status and characteristics of the local labor market.

2.1 The Data

The Youth Cohort of National Longitudinal Survey (NLS) is a good data for analyzing this issue because it contains subtest scores on the Armed Services Vocational Aptitude Battery (ASVAB), a three hour battery of tests used by the armed forces for selecting recruits and assigning them to occupational specialties. The primary purpose of the ASVAB is to predict the success of new recruits in training and their subsequent performance in their occupational specialty.[4] Even though the ASVAB was developed as an "aptitude" test, the current view of testing professionals is that:

> Achievement and aptitude tests are not fundamentally different....Tests at one end of the aptitude-achievement continuum can be distinguished from tests at the other end primarily in terms of purpose. For example, a test for mechanical aptitude would be included in a battery of tests for selecting among applicants for pilot training since knowledge of mechanical principles has been found to be related to success in flying. A similar test would be given at the end of a course in mechanics as an achievement test intended to measure what was learned in the course (National Academy of Sciences Committee on Ability Testing 1982 p.27)."

The ASVAB test battery is made up of 10 subtests: Mechanical Comprehension, Auto and Shop Knowledge, Electronics Knowledge, Clerical Checking (Coding Speed), Numerical Operations (a speeded test of simple arithmetic), Arithmetic Reasoning, Mathematics Knowledge (covering the high school math curriculum), General Science, Word Knowledge and Paragraph Comprehension. (See Bishop 1990 for sample questions.)

Two dimensions of mathematical achievement are measured: the speed of doing simple mathematical computations is measured by a three minute 50 problem arithmetic computation subtest which will be referred to as computational speed. Mathematical reasoning ability is measured by a composite of the mathematics knowledge and arithmetic reasoning subtests. Science achievement is indexed by the ASVAB's General Science subtest. This test focuses on science definitions and has minimal coverage of higher level scientific reasoning. Verbal achievement is measured by a composite made up of the word knowledge and paragraph comprehension subtests.

The universe of skills and knowledge sampled by the mechanical comprehension, auto and shop information and electronics subtests of the ASVAB roughly corresponds to the vocational fields of trades and industry and technical so these subtests are aggregated into a single composite which is interpreted as an indicator of competence in the "technical" arena.[5]

Competencies that are unique to clerical and retail sales jobs do not appear to be measured by the ASVAB. The ASVAB does contain a seven minute 84 item clerical checking subtest which was intended to predict performance in clerical jobs but validity studies of clerical jobs in the military have found that it does not add to the validity of composites based on verbal, arithmetic reasoning and mathematics knowledge subtests (Wise, McHenry, Rossmeissl and Oppler, 1987). The clerical checking subtest is included in the analysis but it should not be viewed as a valid predictor of clerical competency. These seven test composites have all been normalized to have zero mean and unit variance.[6]

All of these competencies are highly correlated with years of schooling. When these composites are regressed on age, ethnicity, proportion of 1980 spent in school, region, work experience, occupation of parents and schooling, the coefficients on years of high school range between .19 for math and .28 for verbal for males and range from .12 for technical and .24 for verbal and clerical speed for females. Greater work experience significantly increased the clerical speed of women but did not have positive effects on any of the other competencies.

2.2 Results

Two measures of labor market success were studied: the log of the hourly wage rate in the current or most recent job taken from the 1983 through 1986 interviews and the log of yearly earnings for calender years 1984 and 1985 when they exceed $500.[7] The sample was limited to those who were not in the military in 1979. At the time of the 1986 interview the NLS Youth ranged from 21 to 28 years of age. An extensive set of controls was included in the estimating equations.[8]

The labor market consequences of the competencies that a young person develops early in life were examined by regressing log wage rates and log earnings on ASVAB subtest scores, years of schooling, and the background variables listed above. Holding academic competencies in 1980 constant, female high school dropouts with 10 years of schooling earned 10 percent less than high school graduates and college graduates earned 42 percent more. Male high school drop outs earned 21 percent less than high school graduates and college graduates earned 35 percent more. The effects of our measures of academic and technical achievement are summarized in Figures 5 and 6 (see Bishop 1988 for a more complete description of the results).

The results for young men were as follows--<u>high level academic competencies do not have positive effects on wage rates and earnings</u>. The mathematics reasoning, verbal and science composites all had negative effects on wage rates and earnings. Speed in arithmetic computation has substantial positive effects on labor market success of young men. This competency, however, is a lower order skill that is not (and should not be) a focus of high school mathematics (National Council of Teachers of Mathematics 1989).

For young women, speed in arithmetic computation and mathematical reasoning ability both have substantial effects on wage rates and earnings. Verbal competence had somewhat more modest positive effects on wages and earnings. <u>Science test scores had no effect on wage rates and earnings.</u>

For young men, the ASVAB technical subtests measuring electronics knowledge and mechanical, auto and shop information had large and significant positive effects on wage rates and earnings. These subtests had essentially no effect on the labor market success of young women.

The clerical checking subtest had weak positive effects on wage rates of young women and large significant effects on their earnings. For young men, doing well on the clerical checking subtest appears to increase earnings very modestly but it has no effect on wage rates.

This pattern of results is not unique to this data set. Similar results were obtained in

Willis and Rosen's (1979) analysis of the earnings of those who chose not to attend college in the NBER-Thorndike data, Kang and Bishop's (1986) analysis of High School and Beyond seniors and Bishop, Blakemore and Low's (1985) analysis of both Class of 1972 and High School and Beyond data.[9]

In summary, in the United States, when years of schooling are held constant, achievement in science has no effect on wage rates, earnings or unemployment of young men and women. Achievement in mathematical reasoning has no effect on the wage rates and earnings of young men and only very modest effects on the wage rates of young women. Verbal competency has no effect on the wage rates on young men and women and no effect on the earnings of young men. These results suggest an immediate explanation for the poor performance of American students in science and higher level mathematics. For the 80 percent of youth who are not planning to pursue a career in medicine, science or engineering, there are no immediate labor market rewards for developing these competencies. For the great bulk of students, therefore, the incentives to devote time and energy to the often difficult task of learning these subjects are very weak.

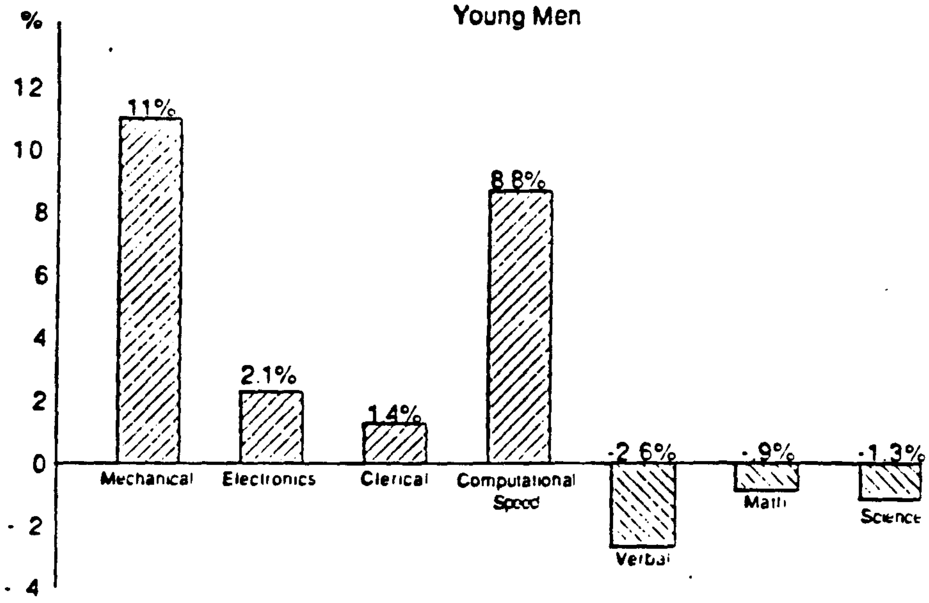
Do these findings also imply that if a way could be found to recruit a high quality engineering and scientific elite (possibly by recruiting scientists and engineers from abroad or early identification of mathematically and scientifically talented youth), there would be little need to worry about the poor math and science preparation of most American youth. It is to this question I now turn.

III. IS THERE REASON TO EXPECT WAGE EFFECTS OF SPECIFIC COMPETENCIES TO BE THE SAME AS THEIR PRODUCTIVITY EFFECTS?

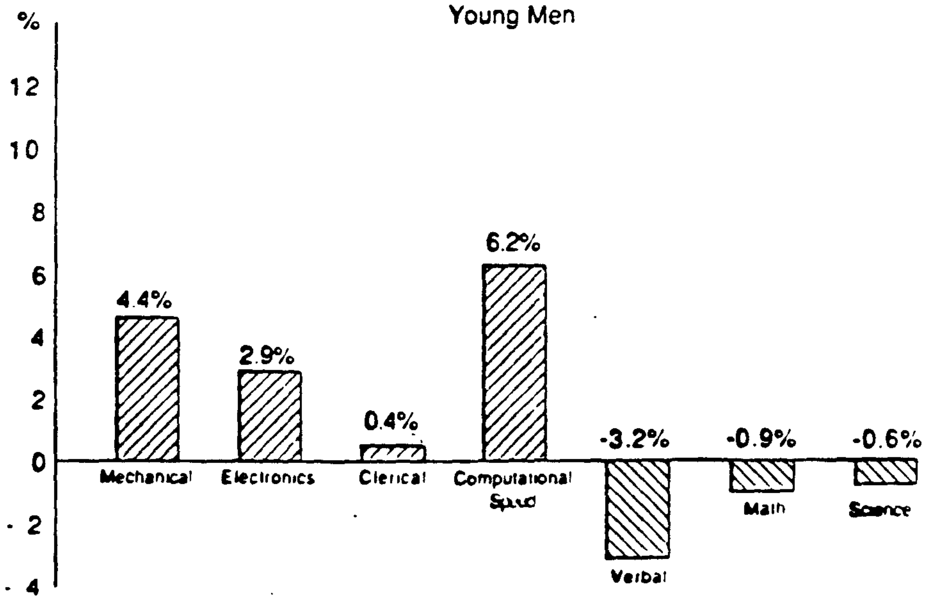
Are the productivity effects of achievement in science, mathematical reasoning and English essentially zero in the types of jobs occupied by most young workers? Speed in simple arithmetic computations has large effects on the wage rates of both sexes and technical competence has large effects on wage rates of young men. Do these competencies have comparable effects on productivity?

One approach to these questions is to ask employers directly about the nature of the tasks performed by entry level workers. When the owners of small and medium sized business in the United States were asked how frequently the employee most recently hired by their firm needed to "use knowledge gained of chemistry, physics or biology" in their job, 74

Effect of Competencies
on Earnings, 1984-1985
Young Men

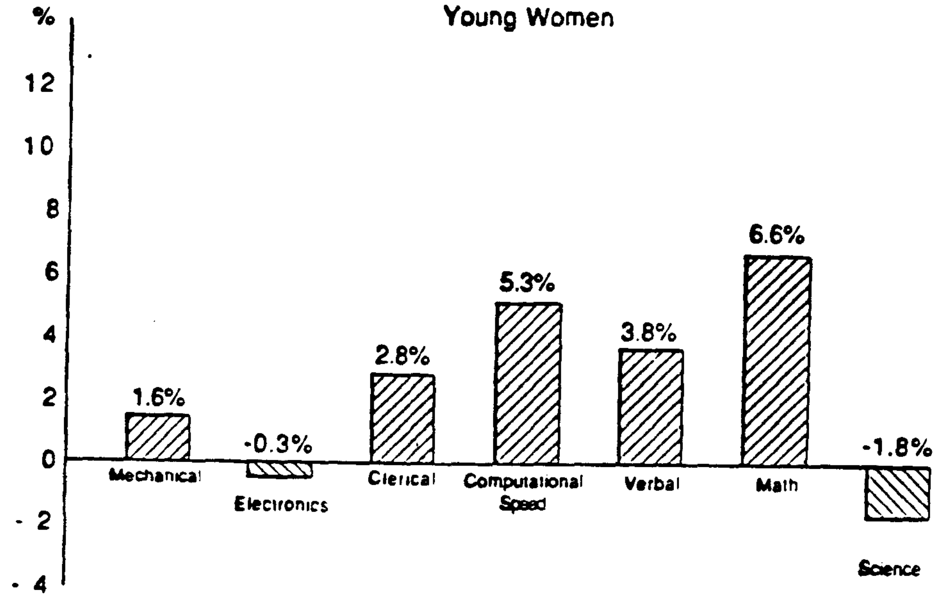


Effect of Competencies
on Wage Rates, 1983-1986
Young Men

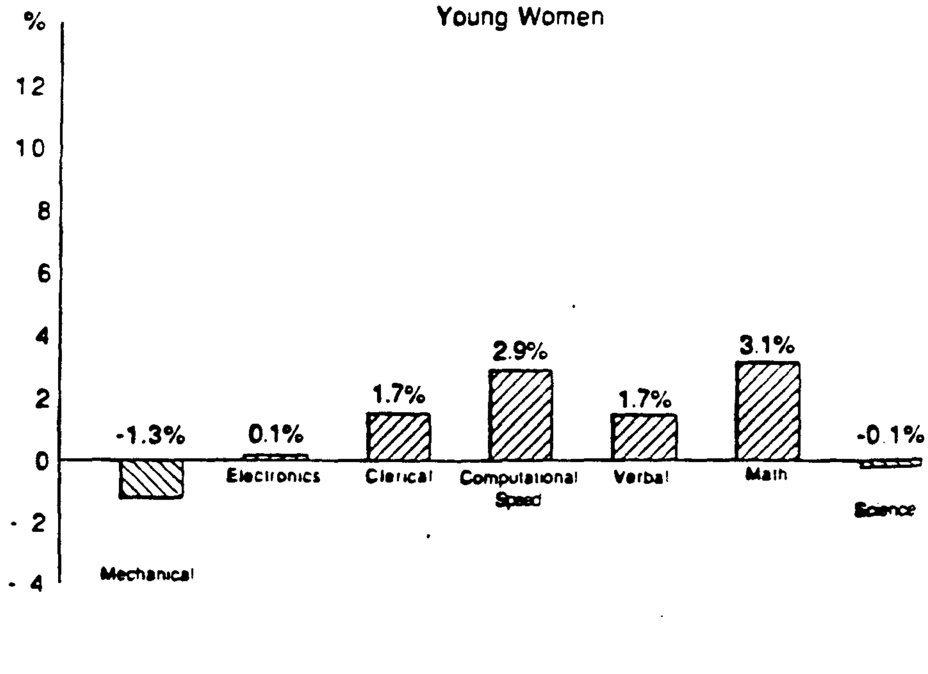


Source: Analysis of NLS Youth data. The figure reports the effect of a one population standard deviation increase in Armed Services Vocational Aptitude Battery subtest while controlling for schooling, school attendance, age, work experience, region, SMSA residence and ethnicity.

Effect of Competencies
on Earnings, 1984-1985
Young Women



Effect of Competencies
on Wage Rates, 1983-1986
Young Women



Source: Analysis of NLS Youth data. The figure reports the effect of a one population standard deviation increase in Armed Services Vocational Aptitude Battery subtest while controlling for schooling, school attendance, age, work experience, region, SMSA residence and ethnicity.

percent reported that such knowledge was never required and only 12 percent reported such knowledge was used at least once a week.[10] Asked how frequently the new employee had to "use algebra, trigonometry or calculus", 68 percent reported that such skills were never required by the job and only 12 percent reported they were used at least once a week.

The skills used by entry level workers at small and medium sized firms, however, are not decisive evidence regarding employer needs for three reasons. First, the low levels of scientific and mathematical competence in the work force available to small and medium sized firms may have forced them to put off technological innovations such as statistical process control that require such skills and to simplify the functions that are performed by workers who lack technical training. If better educated workers were available, entry level workers might be given greater responsibility and become more productive. Second, the study just quoted does not tell us what is happening at large firms or in the jobs occupied by long tenure employees at small firms. The CEOs of many large technologically progressive companies such as Motorola and Xerox are insisting that their factory jobs now require workers who are much better prepared in math and science than ever before. Third, employers may not realize how the knowledge and skills developed in high school science and mathematics classes contribute to productivity in their jobs. Not knowing which employee possesses which academic skill, they would have no way of learning from experience which scientific and mathematical skills are helpful in doing a particular job. Science and mathematics are thought to teach thinking, reasoning and learning skills applicable outside the classroom and the laboratory. If these skills are indeed successfully developed by these courses, productivity might benefit even when there are no visible connections between job tasks and course content.

A second approach to estimating the effect of a trait on productivity, one favored by economists, has been to infer its effect by studying its effect on wage rates. Such an approach is not justified in this case. In the United States academic achievements in high school-- particularly the fine details of achievement in a particular domain like science, mathematical reasoning or reading ability--are not well signaled to the labor market. When competencies which are highly correlated with each other are poorly signaled to the labor market, American employers have a difficult time figuring out which competencies they need and an even more difficult time finding high school graduates with the particular constellations of academic abilities they may believe they need. As a result, the relationship between their wage offers and the imperfect signals of worker competencies available to them is unlikely to reflect the true relationship between productivity and these competencies.

The Signaling Failure in the United States

In Canada, Australia, Japan, and Europe, educational systems administer achievement exams which are closely tied to the secondary school curriculum. Students generally take between 3 and 9 different examinations. These are not pass/fail minimum competency exams. On the Baccalaureate, for example, there are four different levels of pass: Tre's Bien, Bien, Assez Bien and a regular pass (Noah and Eckstein 1988). Grades on these exams are requested on job applications and typically included on one's resume. Exhibit 1 reproduces a resume used by an Irish secondary school graduate applying for a clerical job. Exhibit 2 is the first page of an application filed by a 28 year old university graduate seeking a managerial job. While employers report they pay less attention to exam grades when hiring workers who have been out of school many years, it is nevertheless significant that the information remains on one's resume long after graduation from secondary school.

In Japan, clerical, service and blue collar jobs at the best firms are available only to those who are recommended by their high school. The most prestigious firms have long term arrangements with particular high schools to which they delegate the responsibility of selecting the new hire(s) for the firm. The criteria by which the high school is to make its selection is, by mutual agreement, grades and exam results. In addition, most employers administer their own battery of selection tests prior to hiring. The number of graduates that a high school is able to place in this way depends on its reputation and the company's past experience with graduates from the school. Schools know that they must be forthright in their recommendations because if they fail just once to make an honest recommendation, the relationship will be lost and their students will no longer be able to get jobs at that firm (Rosenbaum and Kariya 1987).

The hiring environment for clerical, service and blue collar jobs is very different in the US. American employers generally lack objective information on applicant accomplishments, skills, and productivity. Tests are available for measuring competencies, but EEOC guidelines resulted in a drastic reduction in their use after 1971. A 1987 survey of 2014 small-and medium-sized employers who were members of the National Federation of Independent

Business found that aptitude test scores had been obtained in only 2.9 % of the hiring decisions studied (Bishop and Griffin, forthcoming).

Other potential sources of information on effort and achievement in American high school are transcripts and referrals from teachers who know the applicant. Both are under-used. In the NFIB survey, when someone with 12 or fewer years of schooling was hired, the new hire had been referred or recommended by vocational teachers only in 5.2 % of the cases and referred by someone else in the high school in only 2.7 %. Transcripts had been obtained prior to the selection decision for only 14.2 % of the hires of people with 12 or fewer years of schooling. Transcripts are not obtained because differing grading standards in different schools and courses make them difficult to interpret, because many high schools are not responding to requests for the information and because there are generally long delays before the transcripts arrive.

The only information about school experiences requested by most American employers is years of schooling, diplomas and certificates obtained, and area of specialization. Hiring decisions are based on easily observable characteristics which are imperfect signals of the competencies the employer cannot observe directly. As a result, hiring selections and starting wage rates are often not influenced by even very gross indicators of academic achievement such as GPA, AFQT or SAT scores (Bishop 1987b). Given the limited information available to employers prior to hiring, it is not realistic to expect their decisions to reflect in a refined manner the specific combinations of academic competencies that students bring to the market.

But after a worker has been at a firm a while, the employer presumably learns more about the individual's capabilities and is able to observe performance on the job. Workers assigned to the same job often produce very different levels of output (Hunter, Schmidt and Judiesch 1988). Why, one might ask, are the most productive workers (those with just the right mix of specific competencies) not given large wage increases reflecting their higher productivity? The reason appears to be that workers and employers prefer employment contracts which offer only modest adjustments of relative wages in response to perceived differences in relative productivity. There are a number of good reasons for this preference: the unreliability of the feasible measures of individual productivity (Hashimoto and Yu, 1980), The unwillingness of workers to risk that their wage may be reduced if their supervisor decides they are not doing a good job (Stiglitz, 1974), the absence of any real danger that

NAME:

ADDRESS:

Exhibit 1

Resume of Irish Secondary School Graduate

DATE OF BIRTH: AGE:

NATIONALITY:

TELEPHONE NO:

EDUCATIONAL DETAILS

Primary School

Post Primary

Secretarial Course

Office Procedures Course

EXAMINATIONS

Intermediate Certificate 198

SUBJECTS		
	English	B - L.C.
	Irish	C - L.C.
	Maths	B - L.C.
	Science	C
	Geography	C
	History	C
	Home Economics	D

Leaving Certificate 198

SUBJECTS		
	English	D - L.C.
	Irish	C - L.C.
	Maths	C - L.C.
	Biology	C - H.C.
	Geography	C - L.C.
	French	D - L.C.
	Home Economics	B - L.C.

Exhibit

APPLICATION FOR AN APPOINTMENT HANDLED BY MVP

16, Highfield Road, Edgbaston, Birmingham, B15 3DU Tel: 021 455 9765/0559
United Kingdom

3

Appointment applied for DISTRIBUTION PROJECTS MANAGER (B & Q) Ref.No.

PERSONAL DETAILS: (block capitals)

Surname [illegible] Title MR Forenames MERVYN JOHN

Address 7, CAERNARVON GARDENS, [illegible]

Postal Code [illegible] Tel.No.Home [illegible] Work

Marital Status M Children/Dependants (with ages) 1 x 4 YRS, 1 x 1 YR.

Age 33 Date of Birth 5.8.55 Nationality BRITISH Place of Birth ILFRACOMBE,

State of health OK Height 6' Weight 13

Any disabilities/recurrent medical problems? — Regd.disabled

Driving Licences CAR Car Owner ✓ Company Car

Endorsements, convictions, accidents, etc NONE

Leisure activities and offices held in clubs and societies CYCLING/WALKING

EDUCATION:
Secondary Education

From	To	School	Exams Taken (inc. grades)	Other ac
1966	1972	BARNSTAPLE GRAMMAR	'O' LEVEL:- ENG. LANG. (2), MATHS (1) FRENCH (2) GEOGRAPHY (1), STATISTICS (3), CHEMISTRY (3), ADDL. MATHS (6), HISTORY (6), PHYSICS (6) 'A' LEVEL:- CHEMISTRY (E), PHYSICS (E), MATHS (O)	MIDDLE SCHO CAPTAIN

Further Education

From	To	College/University	Course & results (inc.class/grades)	Other a
1972	1973	UNIVERSITY of BRADFORD	APPLIED CHEMISTRY - LEFT AFTER 1 YEAR - DOMESTIC REASONS	

Other training and qualifications (inc. in-company and external courses, etc.)

From	To	Establishment	Training/Qualifications
1979		FARNLEY COLLEGE, LEEDS	CERTIFICATE OF PROFESSIONAL COMPETENCE (TRANSPORT OP,
1983	1984	BRADFORD COLLEGE	INSTITUTE OF INDUSTRIAL MANAGEMENT CERT.
1984	1989	IN-COMPANY	NUMEROUS MANAGEMENT COURSES.

Membership of professional bodies

one's best employees will be raided because the skills of these top performers can be fully used only within the firm (Bishop, 1987a), the desire to encourage cooperation among coworkers (Lazear 1986) and union preferences for pay structures which limit the power of supervisors. In addition, compensation for better than average job performance may be non-pecuniary -- praise from one's supervisor, more relaxed supervision, or a high rank in the firm's social hierarchy (R. Frank, 1984).

A study of how individual wage rates varied with initial job performance found that when people hired for the same or very similar jobs are compared, someone who is 20 % more productive than average is typically paid only 1.6 % more. After a year at a firm, better producers received only a 4% higher wage at nonunion firms with about 20 employees, and they had no wage advantage at unionized establishments with more than 100 employees or at nonunion establishments with more than 400 employees (Bishop, 1987a). Over time there is some tendency for those with high test scores to be promoted more rapidly and to be employed more continuously (Wise 1975). Since, however, worker productivity cannot be measured accurately and cannot be signaled reliably to other employers, this sorting process is slow and only partially effective. Consequently, when men and women under the age of 30 are studied, the wage rate effects of specific competencies may not correspond to their true effects on productivity and, therefore, direct evidence on productivity effects of specific competencies is required before conclusions may be drawn. We turn now to an examination of direct evidence on the effects of academic and technical competencies on the job performance. Research on the determinants of job performance in the US military is examined in section 3. Research on the determinants of job performance in the civilian sector is examined in section 4.

IV. THE IMPACT OF ACADEMIC AND GENERIC TECHNICAL COMPETENCIES ON THE JOB PERFORMANCE IN THE AMERICAN MILITARY

The theoretical arguments of the previous section will now be put to an empirical test. Direct estimates of the relative importance of different competencies are obtained by estimating models in which measures of job performance in the military are regressed on all 9 subtest scores of the ASVAB battery. These direct measures of the productivity effects of the competencies measured by the ASVAB, will then be compared to the wage and earnings effects of ASVAB subtests presented in section 1. Is technical competence an important determinant of job performance as well as wages? Do verbal skills and scientific competencies which have no effects on wage rates, nevertheless, have significant positive effects on job performance? The wages and earnings of young men were influenced by computational speed not mathematical reasoning ability. Is this the case for job performance as well?

The ASVAB is one of the most thoroughly researched selection and classification batteries in existence, so there is a wealth of evidence on how its subtests effect job performance in a great variety of jobs. The test battery was developed by the US armed forces for use within the military, so military recruits have been the subject of almost all of this research. Eighty percent of the jobs held by enlisted personnel in the military have civilian counterparts, so the research on the validity of the ASVAB in military settings generalizes quite well to large portions of the civilian sector (US Department of Defense, 1984). The civilian occupations that are not represented in the ASVAB research are professional, manager, farmer, sales representative, and sales clerk. Since most of the soldiers studied were young and male, generalizing to other populations must be done with care. This is not a problem in this study, however, for the desired comparisons are with other young males, those in the NLS.

4.1 Studies of Training Success

Most of the validity research has involved correlating scores on ASVAB tests taken prior to induction with final grades in occupationally specific training courses (generally measured at least 4 months after induction). Since recruits are selected into the army and into the various specialties by a nonrandom process, mechanisms have been developed to correct for selection effects--what I/O psychologists call restriction of range (Thorndike 1949; Lord and Novick 1968; Dunbar and Linn 1986). These selection models assume that selection into a particular MOS is based on ASVAB subtest scores (and in some cases measures of the recruit's occupational interests). For the military environment, this appears to be a reasonable specification of the selection process for attrition is low and selection is indeed explicitly on observable test scores. This ability to model the selection process is an advantage that validity research in the military has over research in the civilian sector.[4]

A reanalysis was conducted of data from two large scale studies of Marine recruits (Sims and Hiatt 1981 reprinted in Hunter, Crossen and Friedman 1985; Maier and Truss 1985). These studies were selected because they used versions of the ASVAB that were quite similar to the one administered to the NLS Youth Cohort. Correlation matrices which had been corrected (for restriction of range and selection effects) were obtained from the appendices of these studies and LISREL was employed to estimate models in which training grades were regressed on the full set of ASVAB subtests. The standardized regression coefficients from this analysis are reported in table 4.

The results were similar to the wage and earnings regressions in only one respect: technical competency as indexed by the mechanical, auto-shop and electronics subtests had major effects on success in training for occupations involving the maintenance or use of complicated equipment. <u>In all other respects, however, the results contrast sharply with the wage rate regressions for young males.</u> The math knowledge and arithmetic reasoning subtests have much larger effects on training success than the computational speed test. Both the science and verbal subtests have strong positive impacts on success in training. It appears that the higher level academic competencies measured by the ASVAB have much larger positive effects on success in training programs than on wage rates of young men in the civilian sector.

4.2 Reanalysis of Maier and Grafton's Data on Job Performance

In the reanalysis we reported above, training success was measured by a paper and pencil test. There is a danger that validity coefficients may be biased by common methods bias. It would be desireable to check these findings in a data set in which ASVAB subtest scores predict a hands-on measure of job performance. Maier and Grafton's (1981) study of ASVAB 6/7's ability to predict the hands-on Skill Qualification Test (SQTs) provides such a data set. Maier and Grafton described the hands-on SQTs they used in their study as follows:

> SQTs are designed to assess performance of critical job tasks. They are criterion referenced in the sense that test content is based explicitly on job requirements and the meaning of the test scores is established by expert judgment prior to administration of the test rather than on the basis of score distributions obtained from administration. The content of SQTs is a carefully selected sample from the domain of critical tasks in a specialty. Tasks are selected because they are especially critical, such as a

> particular weapon system, or because there is a known training deficiency. The focus on training deficiencies means that relatively few on the job can perform the tasks, and the pass rate for these tasks therefore is expected to be low. Since only critical tasks in a specialty are included in SQTs, and then only the more difficult tasks tend to be selected for testing, a reasonable inference is that performance on the SQTs should be a useful indicator of proficiency on the entire domain of critical tasks in the specialty; that is, workers who are proficient on tasks included in an SQT are also proficient on other tasks in the specialty. The list of tasks in the SQT and the measure themselves are carefully reviewed by job experts and tried out on samples of representative job incumbents prior to operational administration (pp. 4-5).

A more extensive discussion of the procedures for developing SQTs is available in a handbook (Osborn et al, 1977). A thorough discussion of their rationale is provided in Maier and Hirshfeld (1978).

Regressions were estimated using LISREL for nine major categories of Military Occupational Specialties (MOS): Skilled Technical, Skilled Electronic, General Maintenance, Mechanical Maintenance, Clerical, Missile Battery and Food Service Operators, Unskilled Electronic, Combat and Field Artillery. Except for combat and field artillery, these MOSs have close counterparts in the civilian sector. The independent variables were the 10 ASVAB 6/7 subtest scores which had counterparts in the ASVAB 8A battery used in the analysis of NLS Youth. The standardized regression coefficients from this analysis are reported in Table 5. These coefficients are an estimate of the effect of a one population standard deviation improvement in a test score on the hands-on job performance criterion measured in standard deviation units. Since the ASVAB subtests measure competencies with error and this error has not been corrected for, these results provide lower bound estimates of the effects of the true competencies on true job performance.

The effects of the four "technical" subtests--mechanical comprehension, auto information, shop information and electronics information--are presented in the first four columns of the table. As one might anticipate, these subtests had no effect on job performance in clerical jobs. However, they had very substantial effects on job performance in all the other occupations. The impact of a one population standard deviation increase in all four of these subtests is an increase in the SQT of .415 SD in skilled technical jobs, of .475 SD in skilled electronics jobs, of .316 SD in general maintenance jobs, of .473 SD in mechanical maintenance jobs, of .450 SD for missile battery operators and food service workers, of .170 SD in unskilled electronics jobs, of .345 SD in combat occupations and .270

SD in field artillery. The technical subtests appear to have larger effects on hands-on job performance than on training grades suggesting a common methods bias in validation studies which employ training grades as the criterion. The proportionate change in productivity that results is somewhere between 25 and 40 percent of these numbers.[10] If we assume the SD of true productivity averages 30 percent of the mean wage in these jobs, the impact of a simultaneous one SD increase in all four technical subtests is 11.5 percent of the wage (or about $2875 per year) averaging across the six non-clerical non-combat occupations. The present discounted value of such a learning gain is about $50,000 (using a 5 percent real rate of discount). This is consistent with the wage rate findings presented earlier. These results imply that broad **technical literacy** is essential for workers who use and/or maintain equipment that is similar in complexity to that employed in the military. The attention to detail subtest (which is similar to the clerical checking subtest in ASVAB 8A) has no effect on performance in clerical jobs and small effects on performance in skilled electronic, general maintenance, combat arms and field artillery.

The results for the academic subtests, however, contrast sharply with the wage rate regressions for young males. With the sole exception of the mechanical maintenance MOS cluster, the two mathematical reasoning subtests have much larger effects on SQTs than on wage rates. **The Math Knowledge subtest assessing algebra and geometry is responsible for most of this effect.** A one standard deviation increase in competence in algebra and geometry raises predicted job performance by .121 SD in skilled technical jobs, .261 SD in skilled electronic jobs, .44 SD in general maintenance jobs, .206 SD in clerical jobs, .106 SD for missile battery operators and food service jobs, .139 in combat arms and .230 in artillery. The arithmetic reasoning test was significant in 7 of the MOS clusters and had large positive effects on performance in clerical (.24 SD), missile battery and food service (.11 SD), and field artillery (.186 SD) jobs. Assuming that the standard deviation of true productivity is 30 percent of the wage, the impact of a simultaneous one SD increase in both mathematics reasoning subtests is 6.4 percent averaging across all seven non-combat occupations. The effects of the two tests of mathematical reasoning on job performance are substantial and unlike the wage rate findings much larger than the effects of computational speed. Nevertheless, they are somewhat smaller than those obtained in the models predicting training success suggesting again the possibility of methods bias.

Science knowledge which had small negative effects on wage rates, now has positive effects on hands-on measures of job performance in eight of the MOS clusters, significantly so in 4 clusters and in pooled data. A one standard deviation (SD) increase in science knowledge raises job performance by .057 SD in skilled technical jobs, .072 SD in skilled electronics jobs, .134 SD in general maintenance and construction jobs, .096 SD in mechanical maintenance jobs, .064 SD in clerical jobs, .076 SD in missile battery operator and food service jobs and .070 in combat arms. Word knowledge has significant effects on job performance in the skilled technical, general maintenance and clerical jobs and in combat arms. While statistically significant, the effects of these two competencies appear to be rather modest. Assuming that the standard deviation of true productivity is 30 percent of the wage, the effect of a one SD increase in test scores is 2 percent of the wage for science and 1.9 percent for word knowledge averaged across the seven noncombat occupations.

Differences in science or verbal competency of one population SD are quite large. In these subjects, one population SD is about the magnitude of the difference between young people with 14 years of schooling and those who left school after the 9th grade. Consequently, a productivity increase of about 2 percent per population SD on the test may appear to be only a modest return. This may be due to the inadequacies of the 11 minute long ASVAB subtests used to assess these competencies. General Science had only 24 items and Word knowledge only 35. This biases down the estimated effects of science and word knowledge on job performance. Clearly, there is a need for new research to determine whether broader and more reliable measures of verbal capacity, scientific knowledge and understanding and the ability to solve problems have more substantial effects on job performance in non-technical jobs than these ASVAB subtests.

On the other hand, however, a 2 percent increase in productivity should not be dismissed as unimportant. It is about $500 per worker per year and has a present discounted value of about $8700. (using a 5 percent real rate of interest and a 40 year working life).

4.3 Analysis of Project A Data on Core Technical Proficiency

Still more evidence on what truly determines job performance comes from Project A, a massive study (total costs of more than $100,000,000) that is developing improved methods for selecting and classifying army personnel. Wise, McHenry, Rossmeissl and Oppler (1987) have estimated ASVAB validities for 19 very diverse jobs using Core Technical Proficiency, a MOS specific job performance measures, as the criterion. These ratings are about 50 percent based on hands-on work sample tests (the hands-on SQT) and 50 percent based on paper and pencil job knowledge exams. The ratings were obtained after the recruit had been in the army for 2 to 3 years. The study was designed to select the three or four ASVAB subtests which could be used as the aptitude composite for that MOS cluster.

Table 6 reports the names of the three or four subtests which in combination did the best job of predicting Core Technical Proficiency. As before, the technical subtests are important predictors of Core Technical Proficiency in all the nonclerical occupations. For the academic subtests the results are very different from the wage rate regressions but similar to the results of the reanalysis of Maier and Grafton's validity data for hands-on work samples. Computational speed is only a weak determinant of job performance. Competence in science, language arts and mathematical reasoning has very large effects on job performance.

4.4 Analysis of Project A Data on Other Performance Measures

Most of the ASVAB validity studies have studied MOS specific measures of performance which reflect the soldier's ability to do the job not their willingness to do it on a regular basis or under adverse conditions. Do the results change when other dimensions of job performance are studied? The Project A data set again provides an opportunity to address this issue. Besides the Core Technical Proficiency construct already analyzed, Project A offers three other performance constructs which have some applicability to civilian jobs: General Soldiering Proficiency, Effort and Leadership and Maintaining Personal Discipline. General Soldiering Proficiency assesses skills that all soldiers must have (eg. use of basic weapons, first aid, map reading, use of a gas mask) and is measured much the same way as Core Technical Proficiency by a combination of job knowledge tests and hands-on performance tests. These two constructs are designed to measure the <u>can do</u> element of job performance.

The other two constructs attempt to measure the <u>will do</u> element of job performance. John P. Campbell (1986) described the constructs and their measurement as follows:

> <u>Peer Leadership, Effort, and Self Development</u>: Reflects the degree to which the individual exerts effort over the full range of job tasks, perseveres under adverse or dangerous conditions, and demonstrates leadership and support of peers. That is, can

> the individual be counted on to carry out assigned tasks, even under adverse conditions, to exercise good judgement, and to be generally dependable and proficient? Five scales from the Army-wide BARS rating form (Technical Knowledge/Skill, Leadership, Effort, Self-development, and Maintaining Assigned Equipment), the expected combat performance rating, and the total number of commendations and awards received by the individual were summed for this factor.
>
> Maintaining Personal Discipline: Reflects the degree to which the individual adheres to Army regulations and traditions, exercises personal self-control, demonstrates responsibility in day-to-day behavior, and does not create disciplinary problems. Scores on this factor are composed of three Army-wide Bars scales (Following regulations, Self-Control, and Integrity) and two indices from the administrative records (number of disciplinary actions and promotion rate). (p. 150)

It had been planned to obtain information on commendations, awards, promotions, and disciplinary actions from administrative records. However, the cost of this approach was extremely high so "everyone crossed their fingers and we collected eight archival performance indicators via a self report questionnaire....Field tests on a sample of 500 people showed considerable agreement between self-report and archival records"(Campbell, 1986, p 144).

These two constructs are related to each other (they correlate .59) but are clearly quite distinct from the two "can do" constructs. Correlations with Core Technical Proficiency are only .28 for Effort and Leadership and .19 for Personal Discipline. The "can do" constructs are based on ratings made by the same person, so they share some common measurement error. Campbell, consequently, constructs residualized "can do" performance constructs by subtracting a ratings method factor from the raw score. With the ratings methods effect removed, Core Technical Proficiency (raw) has a correlation of .465 with Effort and Leadership (residual) and .225 with Personal Discipline (residual). In the view of the Project A team, soldiers must have both qualities--the technical competence to do their job and the willingness to do it under stressful circumstances.

Table 7 presents the results of using ASVAB test scores to predict General Soldiering Proficiency (raw), Effort and Leadership (both raw and residualized) and Personal Discipline (raw) (Campbell, 1986, Table 10). The correlation matrices were corrected for range restriction as described by Dunbar and Linn (1986). In this analysis the 9 ASVAB subtests have been reduced to four composites: Technical, Speed (Numerical Operations and Clerical Checking), Quantitative (Arithmetic Reasoning and Mathematics Knowledge) and Verbal/Science. For General Soldiering Proficiency, the results are quite similar to the results obtained predicting Hands-on SQTs and Core Technical Proficiency. The technical and quantitative composites have the largest effects, and the verbal/science composite has a substantial effect. Speed has almost no effect. As before, the pattern of coefficients is very different from the wage regression for young men.

The pattern is different for the "will do" performance constructs. The technical composite had large positive effects on both measures of Effort and Leadership. The quantitative composite had a modest positive effect on Maintaining Personal Discipline and the residualized Effort and Leadership. Speed had a modest positive effect on Effort and Leadership. The verbal/science composite had no effect on the residualized Effort and Leadership and a small negative effect on raw score measures of both constructs. The coefficient pattern for the raw score "will do" performance constructs looks rather similar to the male wage and earnings regressions. This is an interesting result that needs to be investigated in other data sets. It should be treated with caution, however, for four reasons: the information on commendations, awards, promotions and disciplinary actions was self reported, a ratings method effect was clearly visible in the data, other researchers have expressed skepticism about the validity of military ratings (Vineberg and Joyner 1982), and there appears to be major differences between the civilian and military sectors in the effect of academic achievement tests on supervisory ratings (with the effects much larger in the civilian sector)(Hunter 1986).

In any case, even if one adopts the Project A position that ratings are a valid measure of the "will do" component of job performance, this in no way implies that the "can do" elements are subsidiary or unimportant. Consequently, the findings reviewed above that science, verbal and mathematical reasoning capability predict hands-on SQTs, Core Technical Proficiency and General Soldiering Proficiency in the military appear to provide some support the claim that improved math, science and language arts education will add to the productivity of the work force.

Eighty percent of the jobs held by enlisted personnel in the military have civilian counterparts so the research on the validity of the ASVAB in military settings just presented should generalize quite well to major segments of the civilian economy (US Department of Defense, 1984). Nevertheless, it would be useful to examine civilian data on the effect of technical competence on job performance. It is to the analysis of civilian data we now turn.

V. THE IMPACT OF ACADEMIC AND TECHNICAL COMPETENCE ON JOB PERFORMANCE IN THE CIVILIAN SECTOR

5.1 Ghiselli's Review of Validation Research Prior to 1973

Over the last 50 years, industrial psychologists have conducted hundreds of studies, involving many hundreds of thousands of workers, on the relationship between supervisory assessments of job performance and various predictors of performance. In 1973 Edwin Ghiselli published a compilation of the results of this research organized by type of test and occupation. Table 8 presents a summary of the raw validity coefficients (correlation coefficients uncorrected for measurement error and restriction of range) for six types of tests: mechanical comprehension tests, "intelligence" tests, arithmetic tests, spatial relations tests, perceptual accuracy tests and psychomotor ability tests. As pointed out earlier, mechanical comprehension tests assess material that is covered in physics courses and applied technology courses such as auto mechanics and carpentry. The intelligence tests used in this research were paper and pencil tests assessing verbal and mathematical competency.

Intelligence tests were the best predictors of the performance of foreman. For craft occupations and semi-skilled industrial jobs, the mechanical comprehension tests are more valid predictors of job performance than any other test category. For protective occupations, mechanical comprehension tests and intelligence tests had equal validity. For clerical jobs, the best predictors of job performance were tests of intelligence, arithmetic and perceptual accuracy. These results are consistent with the analysis of job performance in the military data reported in Table 5.

It would appear that measures of mathematical, verbal and generic technical competence all have substantial effects on performance in technical and blue collar jobs. What about paper and pencil occupational competency tests for specific occupations? How well do they correlate with job performance.

5.2 The Relationship between Occupational Competency Tests and Job Performance

Meta-analyses of the hundreds of studies of the validity of occupational competency tests have found that content valid occupational competency tests are highly valid predictors of job performance. Dunnette's (1972) meta-analysis of 262 studies of occupational competency tests found that their average correlation with supervisory ratings was .51. This correlation was higher than the correlation of any other predictor studied including cognitive ability tests (.45), psychomotor tests (.35), interviews (.16) and biographical inventories (.34). Vineberg and Joyner's (1982) meta-analysis of military studies found that grades in training school (which were based on paper and pencil tests of occupational competency) had a higher correlation (.27) with global performance ratings by immediate supervisors than any other predictor. The correlations for the other predictors were .21 for ASVAB ability composites, .14 for years of schooling, .20 for biographical inventory and .13 for interest. Hunter's (1982) meta-analysis found that content valid job knowledge tests had a correlation of .48 with supervisory ratings and an even higher correlation of .78 with a work sample measure of job performance, the Skill Qualification Test. Consequently, for training program graduates who are employed in the occupation for which their competency was assessed, scores on these competency exams are highly valid predictors of job performance and promotion probabilities.

5.3 Analysis of GATB Validation Studies

More recent data on what predicts job performance is available from the US Employment Service's program for revalidating the General Aptitude Test Battery (GATB). This data set contains data on job performance, the 9 GATB "aptitudes" and background data on 36,614 individuals in 159 different occupations. Professional, managerial and high level sales occupations were not studied but the sample is quite representative of the 71,132,000 workers in the rest of the occupational distribution. It ranges from drafters and laboratory testers to hotel clerks and knitting-machine operators.

Since a major purpose of these validation studies was to examine the effects of race and ethnicity on the validity of the GATB, the firms that were selected tended to have an integrated workforce in that occupation. Firms that used aptitude tests similar to the GATB for selecting new hires for the job being studied were excluded. The employment service officials who conducted these studies report that this last requirement did not result in the exclusion of many firms. A total of 3052 employers participated.

The workers in the study were given the GATB test battery and asked to supply information on their age, education, plant experience and total experience. Plant experience was defined as years working in that occupation for the current employer. Total experience was defined as years working in the occupation for all employers. The dependent variable was an average of two ratings (generally two weeks apart) supplied by the worker's immediate supervisor. The Standard Descriptive Rating Scale obtains supervisory ratings of 5 aspects of job performance (quantity, quality, accuracy, job knowledge and job versatility) as well as an "all around" performance rating (See Appendix A). Some studies employed rating scales specifically designed for that occupation and in one case a work sample was one of the job performance measures. None of the studies used ticket earnings from a piece rate pay system as the criterion. Studies which used course grades or tests of job knowledge as a criterion were excluded. Firms with only one employee in the job classification were excluded, as were individuals whose reported work experience was inconsistent with their age.

The mathematical achievement index (N) was an average of normalized scores on the same arithmetic reasoning test and on a numerical computations test. These two Verbal ability was assessed by a vocabulary test. Perceptual Speed was the sum of the P and Q aptitudes of the GATB divided by 36.72 to put it in a population SD metric. Psychomotor Ability was the sum of the K, F and M aptitudes of the GATB divided by 51.54 to put it in a population SD metric. The GATB does not contain tests assessing knowledge of electronics, mechanical comprehension, auto mechanics or shop knowledge.

Because wage rates, average productivity levels and the standards used to rate employees vary from plant to plant, mean differences in ratings across establishments have no real meaning. Therefore, normalized ratings deviations were predicted by deviations from the job/establishment's mean for gender, race, Hispanic, age, age squared, plant experience, plant experience squared, total occupational experience, total occupational experience squared, schooling and test composites.[11]

It should be recognized that the validity literature in general and this model in particular do not yield unbiased estimates of the true structural relationships prevailing in the full population (Brown 1978; Mueser and Maloney 1987). Validity studies based on examining which job incumbents are most productive are subject to bias for three reasons: omitted variables, the selection process that determines which new hires were retained by the firm and the selection process by which members of the population were hired for the job.

While the model used in this study is a more complete specifications of the background determinants of job performance than is typically found in the validity literature, it lacks controls for important characteristics of the worker which effect worker productivity. Examples of things left out of the model are occupationally specific schooling, grades in relevant subjects in school, reputation of the school, the amount and quality of on-the-job training, performance in previous jobs, character traits like reliability and need to achieve, physical strength and a desire to work in the occupation. Exclusion of these variables from the model causes bias in the coefficients of included variables.

The second problem arises from the fact that job performance outcomes have been used to select the sample used in the analyses. Since incompetent workers were fired or induced to quit and high performing workers were probably promoted to jobs of a higher classification, the job incumbents used in this study were a restricted sample of the people originally hired for a job. The systematic nature of attrition from the job substantially reduces the variance of job performance and biases coefficients of estimated job performance models toward zero.[12]

The third source of problems is selection effects introduced by the selection that precedes the hiring decision. If hiring selections were based entirely on X variables included in the model, unstandardized coefficients such as ß^ would be unbiased and correction formulas would be available for calculating standardized coefficients and validities. Unfortunately, however, incidental selection based on unobservables such as interview performance and recommendations is very probable (Thorndike 1949; Olson and Becker 1983; Mueser and Maloney 1987). In a selected sample like accepted job applicants, one cannot argue that these omitted unobservable variables are uncorrelated with the included variables that were used to make initial hiring decisions and, therefore, that coefficients on included variables are unbiased. When someone with 10 years of formal schooling is hired for a job that normally requires 12 years of schooling, there is probably a reason for that decision. The employer saw something positive in that job applicant (maybe the applicant received a particularly strong recommendation from previous employers) that led to the decision to make an exception to the rule that new hires should have 12 years of schooling. The analyst is unaware of the positive recommendations, does not include them in the job performance model and, as a result, the coefficient on schooling is biased toward zero. This phenomenon also causes the estimated effects of other worker traits used to select workers for the job such as previous relevant work experience to be biased toward zero. Consequently, the results presented below should not be viewed as estimates of the structural effect of schooling and previous work experience on worker productivity.

The test score results are not similarly biased, however, because **very few firms use cognitive tests to select workers and those that do were not included in the sample of firms studied specifically to avoid this source of bias.**[13]

Results: The results of estimating the model are presented in Table 9. Mathematical achievement was clearly the most important determinant of job performance for all occupational categories except operatives. The effect of mathematical achievement on the performance of operatives was highly significant but only about one-half to two-thirds of the size of the other occupations. Verbal ability had no effect on job performance in craft and operative jobs and in clerical and service jobs its impact is roughly 40 percent of the mathematical achievement's effect.

Spatial ability had significant positive effects on performance only for craft occupations. Perceptual speed had small effects on job performance, but the coefficients are nevertheless significant in all but technical occupations (where the sample is quite small). Psychomotor skills were significantly related to performance in all occupations but in the better paid and more complex jobs the magnitude of the effect was only about one-third of that of verbal and mathematical achievement together.

The effect of psychomotor skills was larger in the two least skilled occupations--operatives and service except police and fire. For operatives the impact of psychomotor skills was roughly comparable to the impacts of mathematical and verbal achievement. These results are consistent with previous studies of these and other data sets (Hunter 1983). Models were estimated containing squared terms for academic achievement and psychomotor skills but these additions did not produce significant reductions in the residual variance. When test scores are controlled, years of schooling had very small and sometimes negative effects on job performance.[14]

The effects of occupational experience and tenure are also quite substantial for all occupations. The negative coefficients on the square terms for occupational experience and tenure imply they are subject to diminishing returns. For workers who have no previous experience in the field, the expected gain in job performance is about 12-13 percent of a standard deviation in the first year and about 8-9 percent of an SD in the fifth year. The effect of tenure on job performance stops rising and starts to decline somewhere between 16 and 24 years of tenure. Increases in occupational experience lose their positive effect on performance even later--at 37 years for operatives, at over 55 years for craft workers and high skill clerical workers and at 19-31 years for other occupations. Except for technicians, age has large curvilinear effects on job performance as well. Holding tenure and occupational experience constant, age had a significant positive effect on job performance in all except technical occupations. In these occupations, twenty year olds with no experience at all in the field were 7.2 to 10.3 percent of an SD more productive than 18 year olds with no experience in the field. Thirty year olds with no occupational experience were 4.7 to 7.4 percent more of an SD more productive than 28 year olds with no experience in the field.

The substantial effects of age and previous occupational experience on job performance are consistent with current hiring practices which give great weight to these job qualifications. These results suggest that a job applicant who has age and relevant work experience in his favor but low test scores may nevertheless be preferable to a young applicant who has high test scores but no relevant work experience. This is particularly likely to be the case if turnover rates are high for the productivity benefits of age and previous relevant work experience are large initially but diminish with time on the job.

VI. EDUCATIONAL ACHIEVEMENT AND THE GROWTH OF NATIONS

The evidence just presented suggests that verbal, mathematical and scientific competence has larger effects on a worker's productivity than on his or her wage rate. in these subjects, it appears, learning generates externalities--public benefits which do not accrue to the learner. If true, we would expect group differences in mean academic achievement to have larger effects on the average productivity of a group of cooperating workers than individual differences in academic achievement have on individual wage rates. National rates of productivity growth should, therefore, be more responsive to rates of change in average academic achievement, than cross section wage regressions would imply.

Economists have always had a difficult time explaining why some countries grow faster than others. Access to natural resources and a high savings rate are clearly important but large discrepancies between growth rates remain when these factors are controlled (Christensen, Cummings and Jorgenson 1980). The high productivity growth rates of Japan and continental Europe since 1950 have sometimes been attributed to a convergence phenomenon. According to the convergence hypothesis countries that have lower productivity at the start of a period tend to grow faster because they are adopting already proven technologies rather than having to discover and refine completely new technologies. When, however, 1950-80 growth rates are plotted against 1950 per capita output for all 72 countries for which data are available, there does not appear to be any systematic tendency for the countries with low initial productivity levels to grow more rapidly (Baumol 1986).

High mean levels of schooling appear to be one of the factors that explain why some low income countries grow rapidly and others do not (Hicks 1980, Wheeler 1980, Easterlin 1981, Marris 1982). But among the more advanced countries, rates of change of mean years of schooling are negatively correlated with gains in total factor productivity (Christensen, Cummings and Jorgenson 1980).

Are the countries where learning is progressing most rapidly also the countries where worker productivity is improving most rapidly? To address this question we need measures of the rate at which educational outcomes are improving. The average number of years spent in school is not an educational outcome. It is an educational input. It is possible to spend many years in school and learn very little.

What we need is internationally comparable data on trends in test scores. To calculate such trends the same test (or equated tests) must have been administered decades apart to large representative samples of the population. Data of this type can be obtained from two sources: general academic ability exams administered to military recruits in countries which have universal military service and from standardization studies for the WISC and the WAIS IQ tests (Flynn 1987). Such data is available for 10 western countries: Australia, Belgium, Canada, France, Germany, Japan, Netherlands, Norway, the United States and the United Kingdom.

The mean IQ of the young adult population substantially increased during the postwar period in both Europe and Japan. Table 10 reports the findings of the studies for which there can be no debate about the representativeness of the populations tested. In every country for which data was available (including the countries with weaker studies), there were major gains on IQ tests during the post war period. The findings for France, Netherlands, Norway and Belgium are especially strong. In these countries unchanged tests were given to all male 18 year olds entering their universal military training obligation. In just 25 years, for example, the IQ scores of French 18 year olds rose 25 points on the Ravens, a "culture reduced" test of abstract problem solving ability, and 9.4 points on a more conventional test of verbal and mathematical intelligence. In general, test score gains were smaller on math and verbal tests than on tests of abstract problem solving ability and the performance components of Wechsler IQ tests.

Let us begin by looking at how gains in test scores relate to gains in years of schooling. In figure 7 we have rates of gain on general academic ability tests per decade on the horizontal axis plotted against gains in mean years of schooling of adults (translated into a worker productivity metric) on the vertical axis. Quite clearly when one compares industrialized societies, there is no tendency for the countries with rapid increases in mean years of schooling to also have more rapid gains on tests given to adults and to students nearing the completion of their schooling. This result suggests that changes in mean years of schooling may be a very imperfect indicator of gains in real academic achievement. Since it is additional skills and knowledge, not additional years of schooling, which is presumed to cause increased worker productivity, it is the gains in skills and knowledge which must be measured and then related to productivity growth, not gains in mean years of schooling.

Now let us return to the question we began with. Figure 8 plots yearly percentage growth in labor productivity between 1960 and 1984 against gains on general academic ability tests. Clearly there is a strong positive relationship between productivity growth and the growth of general human capital as indexed by increased scores on IQ tests. Similarly there is a strong positive relationship between manufacturing productivity growth and gains on IQ tests (see Figure 9), between real wage growth in manufacturing and IQ test gains (see Figure 10) and between growth of per capita income and IQ test gains (see Figure 11).

These comparisons probably exaggerate the causal effect of test score gains on national productivity. The countries such as Japan, Germany, Belgium, France and Netherlands that had above average rates of gain in test scores during the postwar period tended to be the countries who suffered the most during World War 2. The war destroyed much of the nations physical capital and disrupted schooling of the young. The rapid postwar growth of these nations has quite correctly been characterized as a return to their pre-war position in the industrialized world. Table 11 presents the results of cross section regressions which examine the impact of gains in general human capital while statistically controlling for the effects of World War 2. Including controls for the devastation of the war, somewhat reduces the magnitude of the relationship between test score growth and productivity growth but the effect of IQ growth on productivity growth remains highly significant and substantively important. Causation may also operate in the opposite direction--better living standards may cause higher levels of academic achievement even if it does not cause young people to stay in school longer.

We have not, however, yet controlled for other determinants of productivity growth such as growth of capital per worker. Total factor productivity growth effectively provides such a control. It is defined by subtracting the effects of the growth of capital from labor productivity growth. Figure 12 plots total factor productivity growth for the period 1955 to 1973 against IQ growth. The slope of the relationship is somewhat reduced but a positive and significant relationship remains. When total factor productivity growth in manufacturing is examined, we also find a significant positive relationship with IQ growth (see Figure 13). Both of these relationships survive introduction of controls for the devastation of World War 2 (see Table 12).

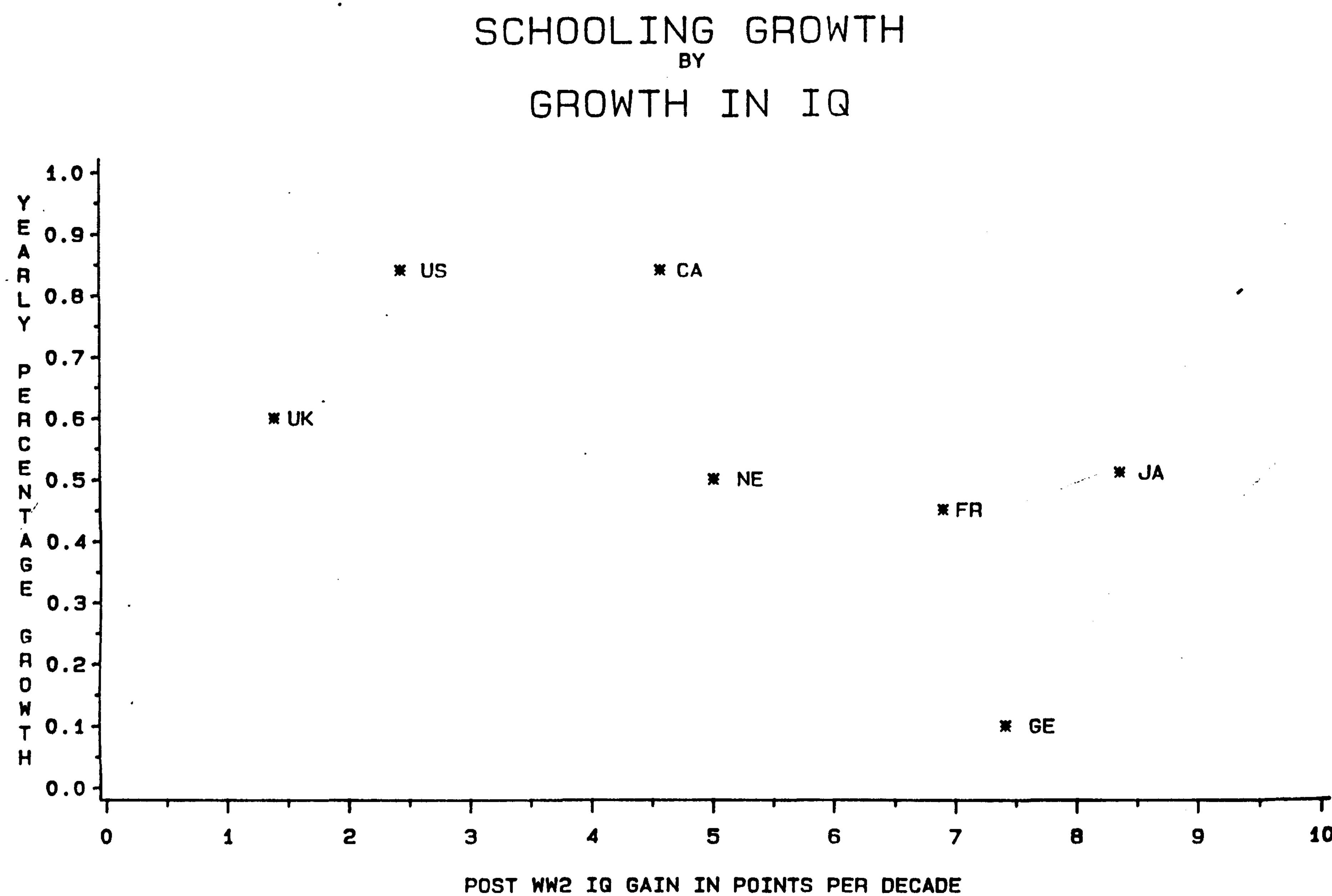
I think it is fair to conclude from this evidence that gains in IQ and by inference in general academic achievement have profound effects on competitiveness and productivity growth. US productivity growth has lagged behind that of other nations in the postwar period and slower rates of improvement in human capital may be one of the reasons for the contrast.

VII. IMPACT OF IMPROVEMENTS IN ACADEMIC PERFORMANCE ON AMERICAN PRODUCTIVITY GROWTH

Evidence has been presented that the effect of general intellectual achievement on wage rates and productivity is quite large. This, in turn, implies that the 1.25 grade level equivalent decline in the test scores of American secondary school graduates between 1967 and 1980 signalled a significant deterioration in the quality of young entrants into the American work force. The decline of student test scores was unprecedented for prior to 1967, student test scores had been rising steadily for more than 50 years. Bishop (1989) has recently developed an index of the quality of the US work force that incorporates the effects of improvements in academic achievement at given levels of schooling as well as increases in years of schooling. Jorgenson, Gollop and Fraumeni estimate that increases in years of schooling raised labor quality in the US by .725 percent per year between 1948 and 1973. Our estimates imply that improvements in academic achievement at given amounts of schooling contributed an additional .212 percent per year to the growth of the quality of labor during this period. The test score decline reduced this contribution to .16 percent per year between 1973 and 1980, and .085 percent per year in the 1980s. If the test scores of high school graduates had continued to grow at the rate that prevailed between 1942 and 1967, labor quality would now be 2.9 percent higher. The social cost in terms of foregone GNP is now 86 billion dollars annually. Even with rapid improvements in the quality of elementary and secondary education, the labor quality shortfall grows to 5.5 percent in 2000 and 6.7 percent in 2010.[16] If academic learning creates externalities, as argued above, the social costs of deteriorating school quality are even greater.

It would appear that the education enterprise has historically been an important source of economic growth. When the academic achievement of students completing their schooling declines substantially, the economic costs are large and last for generations. Consequently, the potential benefits of major improvements in the academic achievement of students would also appear to be substantial.

Figure 7



FLYNN; CHRISTENSEN, CUMMINGS, AND JORGENSEN.

ENDNOTES

1. The model estimated was:

$$lnWEARN = a_o + a_1GAA + a_2SCH + a_3AGE + a_4NOWHITE + \underline{a_5TRUEBG} + u_1$$

$$TEST = GAA + u_2$$

$$YRED = SCH + u_3$$

$$\underline{MEASBG} = \underline{c}*\underline{TRUEBG} + \underline{u_4}$$

<u>MEASBG</u> is a vector of imperfectly measured characteristics of the individual's true family background: <u>TRUEBG</u> = [fathers education, father's occupation (Duncan index), number of siblings, father foreign born, born on a farm, born in the South]. GIA, SCH and the elements of <u>TRUEBG</u> are latent variables with measurement errors (u_2, u_3 and $\underline{u_4}$) which are uncorrelated with each other and with equation error (u_1). Var(GAA) is normalized to 1, Var(GAA)/Var(TEST) = .652 and Var(SCH)/Var(YRED) = .915. For the three dummy variables (Father foreign born, Born on a farm, and Born in the South), reliability is assumed to be .903 and c_i is assumed equal to be .95. For the other three background variables, c_i is assumed to be 1 and the reliabilities are assumed to be .702 for Fathers education, .735 for Father's occupation and .927 for Number of siblings (Christopher Jencks et. al., 1979, table A2.14). The results of estimating such a model predicting the log of weekly earnings in 1971 PSID data on male household heads 25 to 64 years old are:

$$(1)\ lnWEARN = \underset{(6.26)}{.190GAA} + \underset{(6.24)}{.0576SCH} + \underset{(2.92)}{.004AGE} - \underset{(1.25)}{.06NOWHITE} + \underset{(.45)}{.005FAED} - \underset{(1.44)}{.0028FAOCC}$$

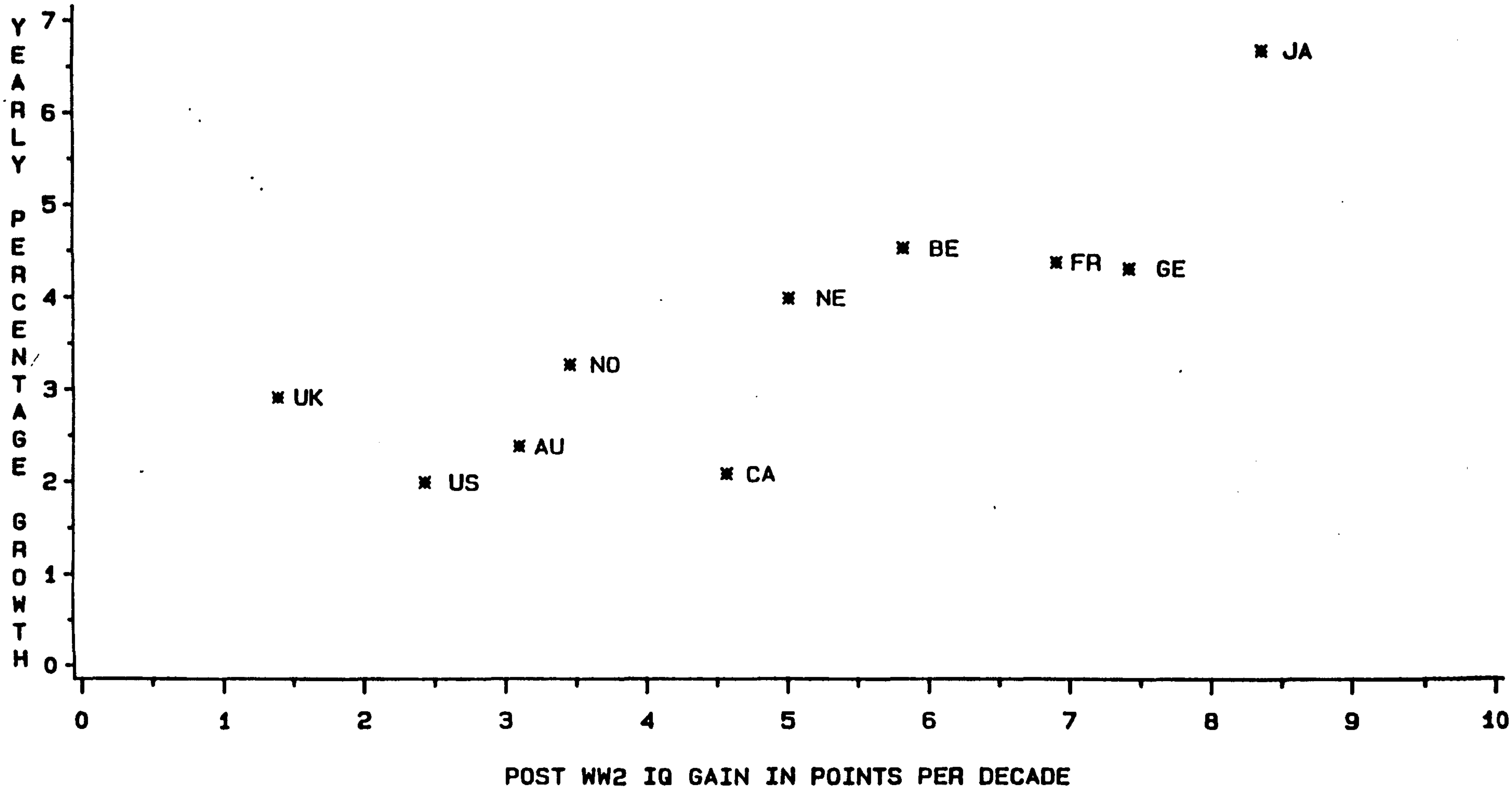
$$- \underset{(.03)}{.0002SIBS} + \underset{(1.74)}{.076FAFOR} - \underset{(3.58)}{.152BORNFARM} - \underset{(.25)}{.009BORNSOUTH} + a_o \quad R^2=.268 \quad N=1774$$

T statistics are in parenthesis below the coefficient. Except for BORNFARM, none of the indicators of family background have a significant direct effect on weekly earnings. The addition of these variables to the model causes a small (7 percent) reduction in the coefficient on academic achievement. If there is no correction for errors in measurement the coefficient on academic achievement (GIA) is .109 and the coefficient on schooling is .0596. Thus, correcting for measurement error increases the estimated effect of academic achievement by 74 percent and reduces the direct effect of years of schooling very slightly.

2. For example, reliabilities for the College Board's afternoon Scholastic Achievement Tests are .90 for English Literature and .87 for Math I and for the morning Scholastic Aptitude Tests are .91-.92. The correlation between Math I and the Math SAT is .83 and the correlation between English Literature and the Verbal SAT is .84 (College Board 1984, 1987). In contrast, the correlation between math and verbal SATs is .66. There are good reasons for high correlations between past achievement in a subject and scores on aptitude tests designed to predict future achievement in the subject. Past achievement aids learning because the tools (e.g. reading and mathematics) and concepts taught early in the curriculum are often essential for learning the material that comes later. Furthermore, aptitude tests are validated on later achievement levels, not on rates of change of achievement. Consequently, many of the items that are included are similar to the items that appear on achievement tests.

Figure 8

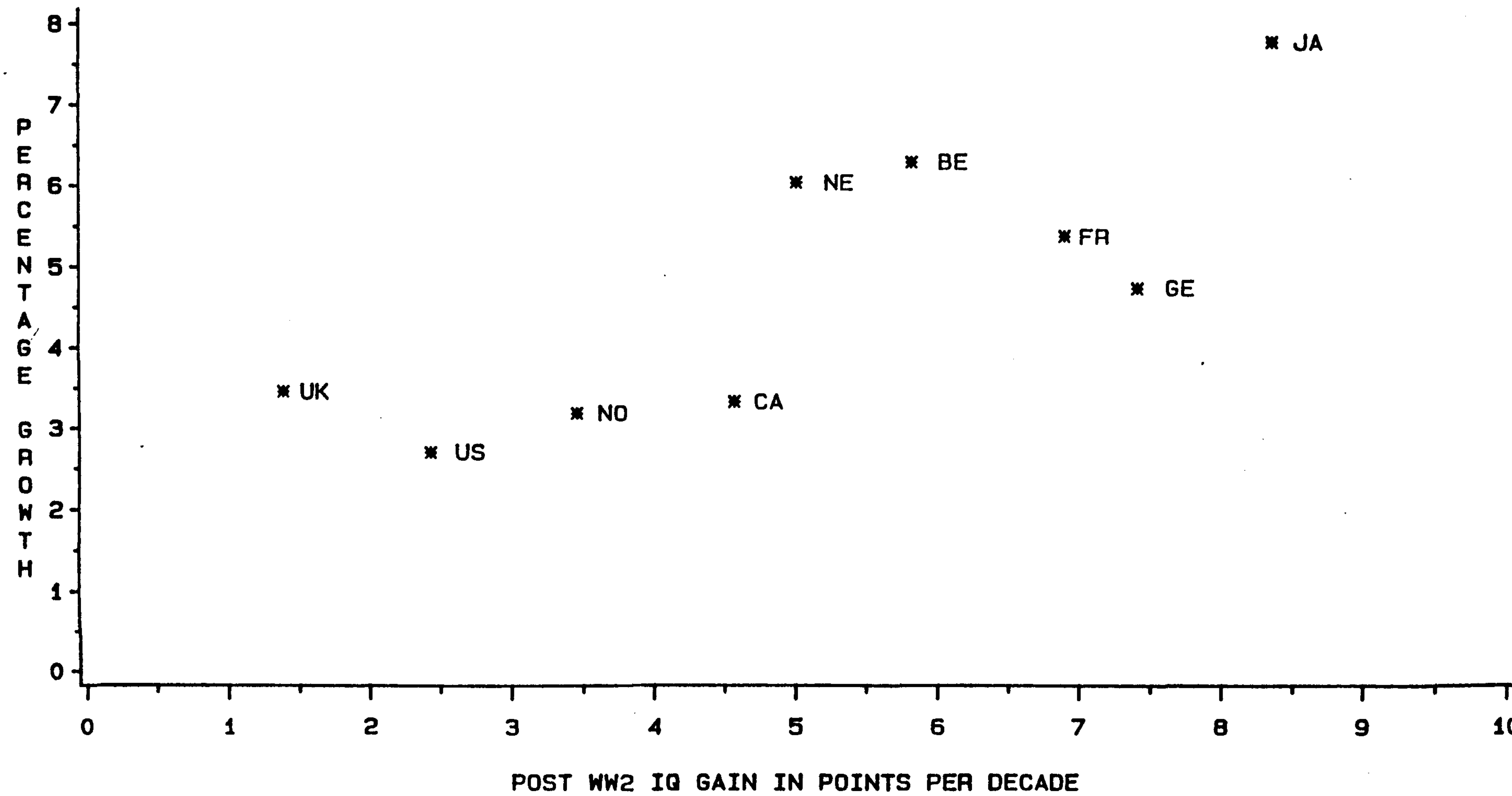
LABOR PRODUCTIVITY GROWTH PER HOUR 1960-1984 BY GROWTH IN IQ



SOURCES: FLYNN; MADDISON; OECD (1).

Figure 9

MANUFACTURING LABOR PRODUCTIVITY GROWTH
PER HOUR 1960-1985
BY
GROWTH IN IQ



SOURCES: FLYNN; BLS.

Figure 10

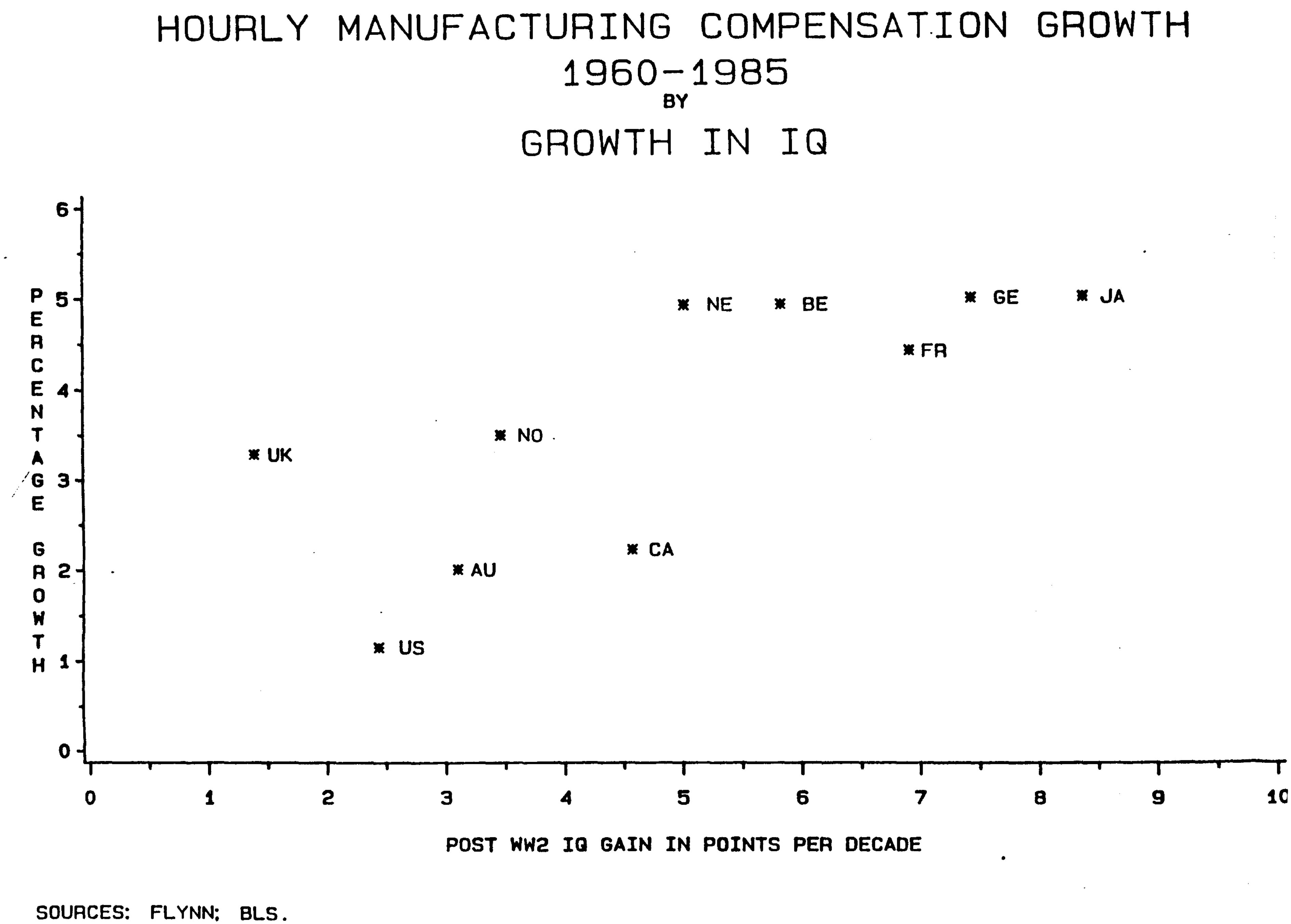

HOURLY MANUFACTURING COMPENSATION GROWTH
1960-1985
BY
GROWTH IN IQ
PERCENTAGE GROWTH
0
1
2
3
4
5
6
NE
BE
GE
JA
FR
NO
UK
CA
AU
US
0
1
2
3
4
5
6
7
8
9
10
POST WW2 IQ GAIN IN POINTS PER DECADE
SOURCES: FLYNN; BLS.

Figure 11

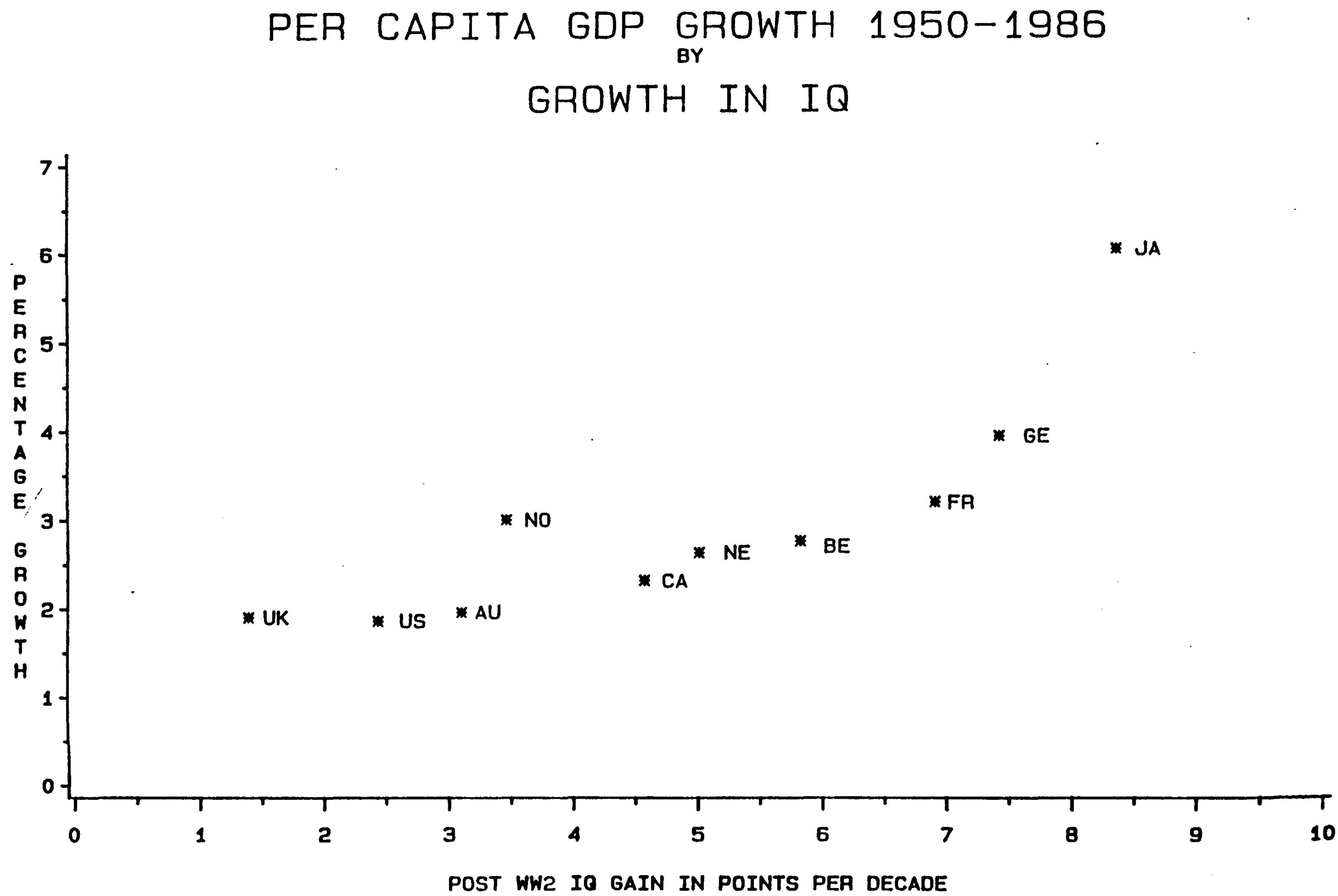
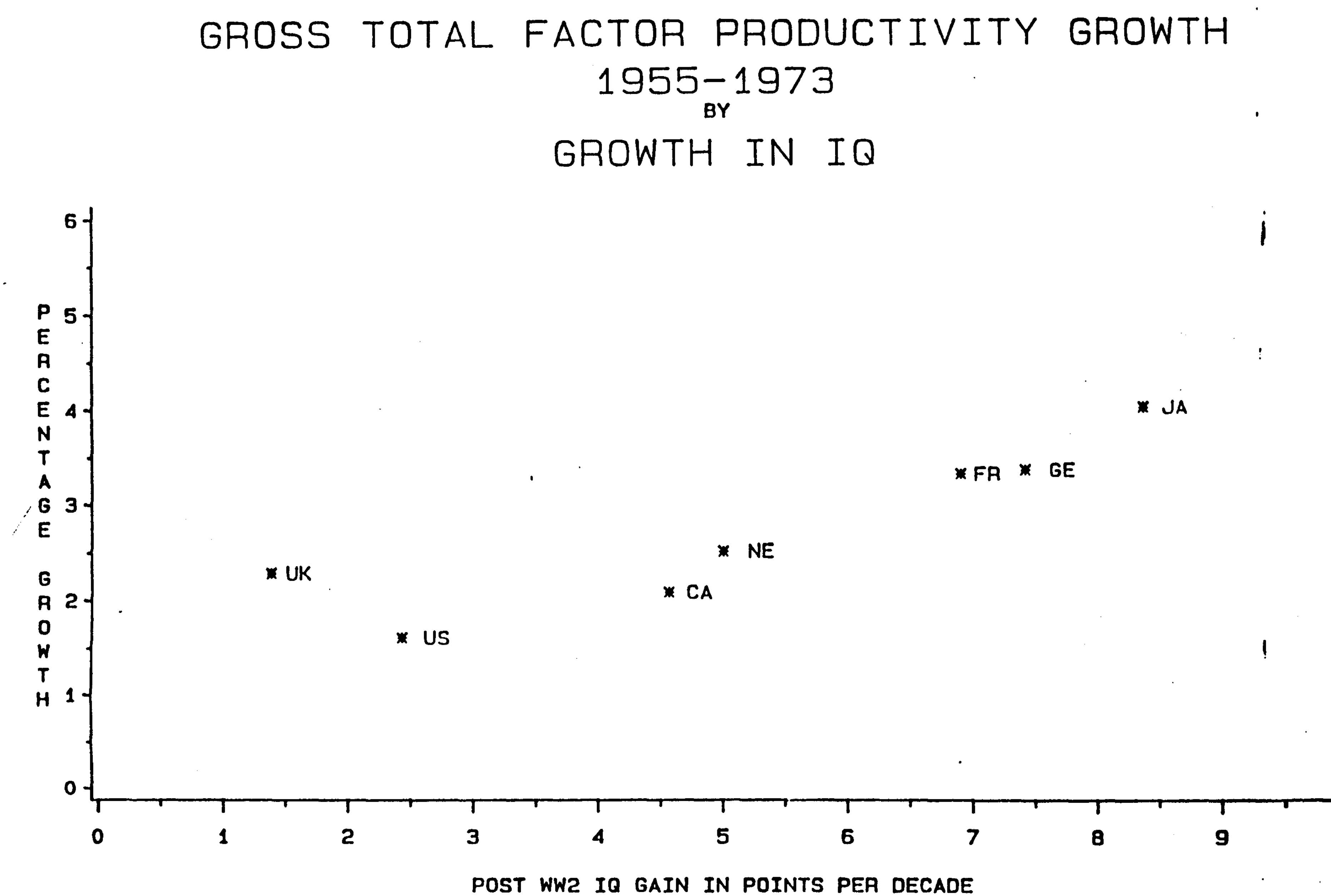
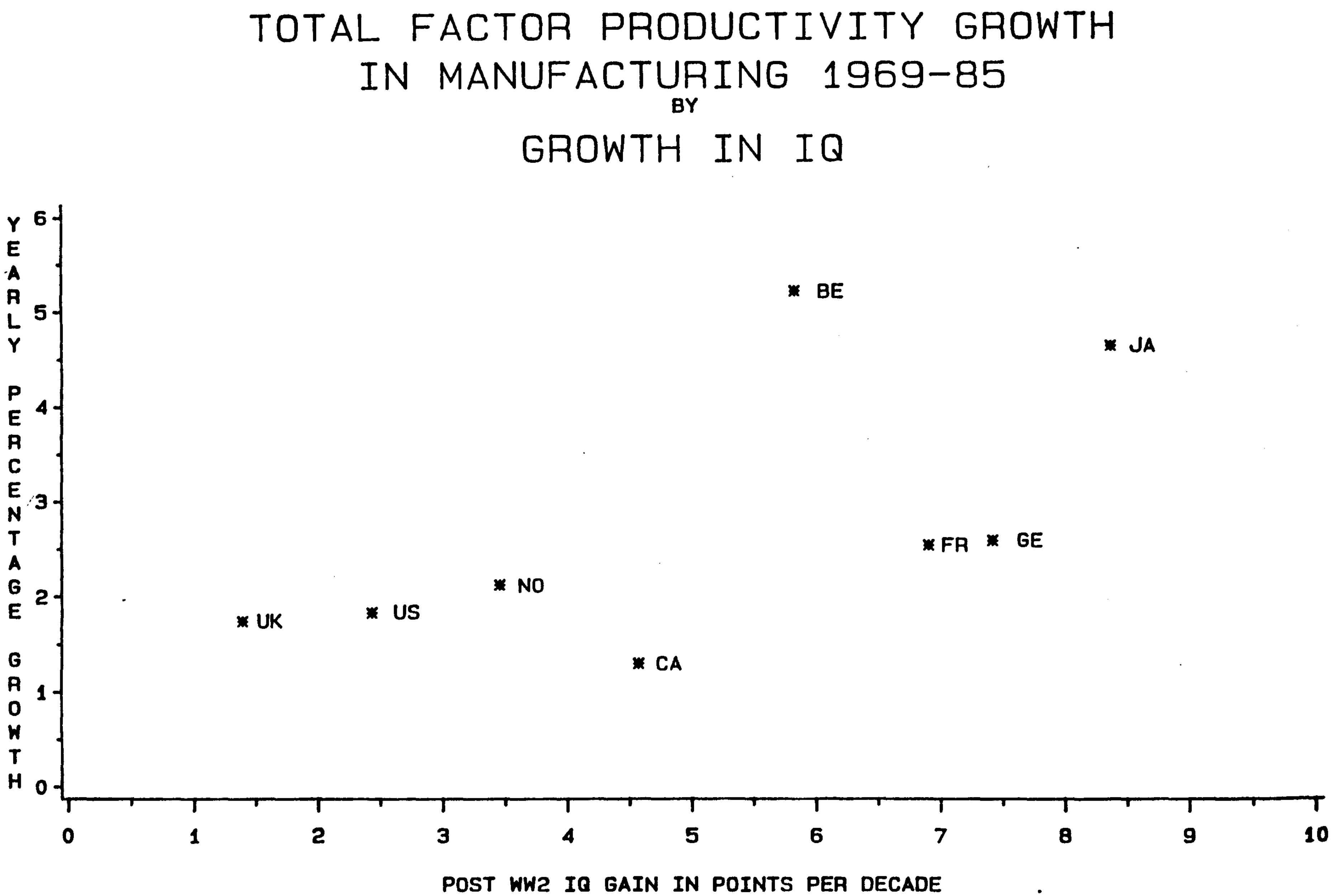

PER CAPITA GDP GROWTH 1950-1986
BY
GROWTH IN IQ
PERCENTAGE GROWTH
0
1
2
3
4
5
6
7
UK
US
AU
NO
CA
NE
BE
FR
GE
JA
0
1
2
3
4
5
6
7
8
9
10
POST WW2 IQ GAIN IN POINTS PER DECADE

Figure 12



FLYNN; CHRISTENSEN, CUMMINGS, AND JORGENSEN.

Figure 13



SOURCES: FLYNN; MADDISON; OECD (2).

3. Tuijnman's estimated "true" correlations were used to estimate a model in which log earnings is a function of schooling, home background and the two tests.

4. Its ability to accomplish these objectives has been thoroughly researched and the battery has been periodically modified to incorporate the findings of this research. Eighty percent of the jobs held by enlisted personnel in the military have civilian counterparts so the research on the validity of the ASVAB in military settings generalizes quite well to major segments of the civilian economy (US Department of Defense, 1984). The test is highly correlated with the cognitive subtests of the General Aptitude Test Battery, a personnel selection test battery used by the US Employment Service, the validity of which has been established by studies of over 500 occupations. A validity generalization study funded by the armed forces concluded "that ASVAB is a highly valid predictor of performance in civilian occupations" (Hunter Crossen and Friedman, 1985, p. ix). During the summer of 1980 all members of the NLS Youth sample were asked to take this test and offered a $50 honorarium as an inducement. The tests were successfully administered to 94 percent of the sample. Testing was generally conducted in groups of 5 to 10 persons. The 1980 version of the ASVAB (Form 8A) was administered by staff of the National Opinion Research Corporation according to strict guidelines conforming to standard ASVAB procedures. At the time of the testing the NLS youth were between 15 and 23 years of age.

5. These subtests have some similarities with the occupational competency examinations developed to assess high school vocational students. However, the ASVAB technical subtests assess knowledge in a much broader domain and the individual items are, consequently, more generic and less detailed. The ASVAB technical composite is interpreted as a measure of knowledge and trainability for a large family of jobs involving the operation, maintenance and repair of complicated machinery and other technically oriented jobs.

6. The alternate form reliabilities of these composites are approximately .92-.93 for Technical, .93 for Math, .93-.94 for Verbal, .80 for General Science, .72 for Numerical Operations and .77 for Clerical Checking (US Military Entrance Processing Command 1984; Palmer et al, 1988).

7. Technical and academic competencies were assumed to have linear and additive effects on labor market outcomes:

(1) $\underline{Y}_t = \underline{a}_t\underline{A} + b_tC + c_tT + e_tS + \underline{g}_t\underline{Z}_t + \underline{u}_t$ for t = 1983...1986

where $\underline{Y}_t$ is a vector of labor market outcomes (wage rates and earnings) for year t.

$\underline{A}$ is a vector of test scores measuring competence in mathematical reasoning, reading and vocabulary and science knowledge.

C is a measure of speed in simple arithmetic computation.

T is he technical composite measuring mechanical comprehension and electronics, auto and shop knowledge.

S is clerical checking speed.

$\underline{Z}_k$ is a vector of control variables such as age, civilian work experience, schooling, school attendance, military status, marital status, parenthood, minority status, region, residence in an SMSA and local unemployment rate.

$\underline{u}_t$ is a vector of disturbance terms for each year.

8. Reports of weeks spent in civilian employment were available all the way back through 1975. For each individual, these weeks worked reports were aggregated across time and an estimate of cumulated civilian work experience was derived for January 1 of each year in the longitudinal file. This variable and its square was included in every model as was age, age squared and current and past military experience. School attendance was controlled by four separate variables: a dummy for respondent is in school at the time of the interview; a dummy for respondent has been in school since the last interview; a dummy for part time attendance and the share of the calendar year that the youth reported attending school derived from the NLS's monthly time log. Years of schooling was controlled by four variables: years of schooling, a dummy for high school graduation, years of college education completed, and years of schooling completed since the ASVAB tests were taken. The individual's family situation was controlled by dummy variables for being married and for having at least one child. Minority status was controlled by a dummy variable for Hispanic and two dummy variables for race. Characteristics of the local labor market were held constant by entering the following variables: dummy variables for the four Census regions, a dummy variable for rural residence and for residence outside an SMSA and measures of the unemployment rate in the local labor market during that year.

9. Bishop, Blakemore and Low's (1985) studied the effect of math, reading and vocabulary test scores on the wage rates and earnings of high school graduates for both 1972 and 1980 in a model that contained controls for grade point average and the number of credit hours of academic and vocational courses. In both these years, none of the variables representing academic performance--the three test scores, GPA and the number of academic courses--had a significant (at the ten percent level) effect on the wage rate of the first post high school job. Only one variable (the vocabulary test for female members of the class of 1972) had a significant effect on the wage 18 months after graduation.

10. The survey was of a stratified random sample of the National Federation of Independent Business membership. Larger firms had a significantly higher probability of being selected for the study. The response rate to the mail survey was 20 percent and the number of usable responses was 2014 (Bishop and Griffin, forthcoming).

11. Studies that measure output for different workers in the same job at the same firm, using physical output as a criterion, can be manipulated to produce estimates of the standard deviation of non-transitory output variation across individuals. It averages about .14 in operative jobs, .28 in craft jobs, .34 in technician jobs, .164 in routine clerical jobs and .278 in clerical jobs with decision making responsibilities (Hunter, Schmidt & Judiesch 1988). Because there are fixed costs to employing an individual (facilities, equipment, light, heat

and overhead functions such as hiring and payrolling), the coefficient of variation of marginal products of individuals is assumed to be 1.5 times the coefficient of variation of productivity. Because about 2/3rds of clerical jobs can be classified as routine, the coefficient of variation of marginal productivity for clerical jobs is 30 % [1.5*(.33*.278+.67*.164)]. Averaging operative jobs in with craft and technical jobs produces a similar 30% figure for blue collar jobs. The details and rationale of these calculations are explained in Bishop 1988b and in Appendix B.

12. Only deviations of rated performance (R^m_{ij}-R^m_j) from the mean for the establishment (R^m_j) were analyzed. The variance of the job performance distribution was also standardized across establishments by dividing (R^m_{ij}-R^m_j) by the standard deviation of rated performance, ($SD_j(R^m_{ij})$, calculated for that firm (or 3 if the sample SD is less than 3). Seperate models were estimated for each major occupation. They were specified as follows:

$$\frac{R^m_{ij}-R^m_j}{SD_j(R^m_{ij}} = \beta_o + \beta_1(\underline{T}_{ij}-\underline{T}_j) + \beta_2(S_{ij}-S_j) + \beta_3(\underline{X}_{ij}-\underline{X}_j) + \beta_4(\underline{D}_{ij}-\underline{D}_j) + v_2$$

where R_{ij} = ratings standardized to have a zero mean and SD of 1.

$\underline{T}_{ij}$ = a vector of the five GATB aptitude composites

S_{ij} is the schooling of the i^{th} individual.

$\underline{X}_{ij}$ = a vector of age and experience variables--age, age^2, total occupational experience, total occupational $experience^2$, plant experience and plant $experience^2$.

$\underline{D}_{ij}$ = a vector of dummy variables for black, Hispanic and female.

$\underline{T}_j$, S_j, $\underline{X}_j$ and $\underline{D}_j$ are the means of test composites, schooling, experience variables and race and gender dummies for the j^{th} job/establishment combination.

13. When all variables are multivariate normal, the ratio of the coefficients estimated in the selected sample to the true coefficient estimated in an unselected population is equal to:

$$\beta^*/\beta = VR/(1-R^2(1-VR)) = VR + R^{*2}(1-VR)$$

where VR is the ratio of the variance of y in the selected sample to its variance in the full population, R^2 is the multiple coefficient of determination of y on $\underline{x}$ in the full population and R^{*2} is the multiple coefficient of determination of y on $\underline{x}$ in the selected population (Goldberger 1981). Estimates of VR, the ratio of incumbent job performance variance to new hire job performance variance can be derived from the NCRVE employer survey analyzed in Bishop (1987a, 1988a). Data on the reported productivity in the 3rd through 13th week after being hired of two different workers was employed to calculate a variance ratio by dividing job performance variance of incumbents (pairs of workers both of whom were still at the firm at the time of the interview a year or so after being hired) by the job performance variance of a group of very recent hires (pairs of workers both of whom stayed at least 13 weeks but who may or may not have remained at the firm through the interview). The resulting estimate of VR was .486. Assuming multi-variate normality and noting that the R^2 of the models in table 8 averages about .16, our estimate of ß/ß*, the multiplier for transforming the coefficients estimated in the selected sample into estimates of population parameters, is 1.76.

14. Variables which were not used to select new hires such as the GATB test scores may have a positive correlation with unobservable characteristics of the individual which are used in selection. If the unobservable has its own independent effect on job performance (ie. it is not serving solely as a proxy for test scores), test score coefficients may be positively biased. Mueser and Maloney (1987) experimented with some plausible assumptions regarding this selection process and concluded that coefficients on education were severely biased but that coefficients on test scores were not substantially changed when these incidental selection effects were taken into account.

15. Mueser and Maloney (1988) argue persuasively that since schooling is a very important factor in the selection process, the coefficients on schooling in estimations like these are negatively biased estimates of true population relationships. This argument probably applies as well to the coefficients on work experience in the occupation but not at the firm.

16. The only way to prevent these forecasts from being realized is to change the relationship between GIA at age 17 and GIA as an adult. This might be accomplished by attracting massive numbers of adults back into school, by expanding educational offerings on television and/or by inducing employers to provide general education to long term employees.

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Table 1
Effect of ASVAB and Early School Tests on Wage Rates and Earnings in 1985

	ASVAB	School Test	Controls For Educ. & Background	R^2	N	FTest of Equality of Coef.
Males						
Log Wage Rate	.119 (4.91)	-.049 (2.53)	X	.243	1244	18.7***
Log Earnings	.207 (5.54)	-.067 (2.27)	X	.396	1330	21.2***
Females						
Log Wage Rate	.092 (3.03)	.016 (.73)	X	.274	1211	
Log Earnings	.100 (1.87)	-.016 (.43)	X	.315	1199	2.0

Source: Analysis of NLS Youth Data. The ASVAB test score was an average of all 9 subtests. The school test was the Z score relative to national norms on a test taken early in the youth's school career were included in the models. A full set of controls for years of schooling, school attendance, actual cumulated work experience, gender, race, Hispanic and characteristics of the local labor market. The sample was limited to youth for whom an early test score was available.

Table 2
Determinants of Occupation
Swedish Malmo Data

	Test Age 20	Test Age 10	Youth Educ.	Home Back Ground	Adult Educ.
Occ 25	.45	-.24	.39	.08	-
	(3.0)	(1.8)	(7.2)	(1.9)	-
Occ 30	.41	-.21	.46	.04	-
	(3.0)	(1.6)	(9.0)	(1.1)	-
Occ 35	.35	-.16	.45	.10	.13
	(2.6)	(1.3)	(9.0)	(2.6)	3.1
Occ 40	.39	-.20	.38	.14	.20
	(2.8)	(1.6)	(7.5)	(3.6)	4.7
Occ 43	.38	-.23	.34	.14	.31
	(2.8)	(1.9)	(6.7)	(3.7)	(6.1)
Occ 52	.31	-.20	.33	.09	.42
	(2.4)	(1.7)	(7.0)	(2.6)	(9.0)
Occ 56	.36	-.22	.31	.09	.43
	(2.8)	(1.9)	(6.5)	(2.5)	(9.3)

Source: Standardized regression coefficients (with T statistics in parenthesis) for models predicting occupational attainment are from Tuijnman, 1989, Supplementary Tables A 9.2 to A 9.8.

Table 3
Determinants of Earnings
Swedish Malmo Data

	Test Age 20	Test Age 10	Youth Educ.	Home Back	R^2
Earn 25	.036	-.002	.056	.015	.104
	(1.23)	(.09)	(3.13)	(1.16)	
Earn 30	.029	.008	.129	.022	.302
	(1.05)	(.36)	(7.60)	(1.77)	
Earn 35	.061	.018	.161	.071	.434
	(1.89)	(.66)	(8.00)	(4.79)	
Earn 40	.063	-.017	.247	.037	.431
	(1.69)	(-.56)	(10.68)	(2.15)	
Earn 43	.066	-.009	.222	.048	.385
	(1.65)	(.28)	(9.01)	(2.64)	
Earn 52	.032	.020	.165	.034	.261
	(.79)	(.60)	(6.69)	(1.86)	
Earn 56	.059	.005	.151	.032	.223
	(1.35)	(.15)	(5.58)	(1.60)	

Source: For log earnings models unstandardized regressions coefficients are reported so the test score coefficients provide an estimate of the percentage change in earnings that results from a one population standard deviation change in the test score. They were fitted using Tuijnman's estimated "true" correlations reported in Tables 9.2, 9.8 and Appendix C.

Table 4
Cognitive Determinants of Success
in Marine Training Programs

	Mechanical Comprehension	Auto & Shop Knowledge	Electronics	Clerical Speed	Computational Speed	Math Reasoning	Math Knowledge	Verbal	Science	Spatial	R^2
Sims & Hiatt											
ASVAB 6/7											
(23061)											
All Occupations	.043***	.098***	.047***	.013**	.060***	.116***	.205***	.086***	.089***	.037	.345
	(5.20)	(12.46)	(5.78)	(2.29)	(8.96)	(14.44)	(25.26)	(11.68)	(10.68)	(5.89)	
Maier & Truss											
ASVAB 8/9/10											
Electronics	.055***	.027	.102***	.009	.062***	.151***	.256***	.031	.130***	---	.492
Repair (4103)	(2.73)	(1.40)	(4.81)	(.69)	(3.44)	(6.41)	(11.91)	(1.40)	(5.73)		
Mechanical	.058***	.253***	.094***	.063***	.014	.086***	.135***	.120***	.005	---	.444
Maintenance	(3.29)	(15.02)	(5.02)	(4.44)	(.87)	(4.16)	(7.14)	(6.27)	(.27)		
(5841)											
Operators, Food	.079***	.063**	.018	.086***	.022	.137***	.199***	.164***	.093***	---	.490
(1897)	(2.72)	(2.27)	(.57)	(3.66)	(.82)	(4.02)	(6.41)	(5.20)	(2.84)		
Clerical	.014	-.022	.026	.136***	.037**	.125***	.259***	.206***	-.101	---	.443
(5231)	(.74)	(1.22)	(1.33)	(9.03)	(2.26)	(5.70)	(13.02)	(10.14)	(.47)		
Combat	.087***	.078***	.020	.027*	.056***	.069**	.143***	.073***	.061***	---	.251
(8191)	(4.98)	(4.68)	(1.09)	(1.95)	(3.62)	(3.40)	(7.71)	(3.88)	(3.12)		
Field Artillery	.055	.237***	-.009	.178***	.060	.148***	.138***	-.011	.065	---	.448
(1062)	(1.34)	(6.01)	(.21)	(5.36)	(1.64)	(3.07)	(3.13)	(.24)	(1.41)		

Table 5. Effect of competencies on job performance (SQT).

	Mechanical Comprehension	Auto. Info.	Shop Info.	Electr. Info.	Attention to Detail	Comp. Speed	Word Knowl.	Arith. Reasoning	Math Knowl.	Science	R^2
Skilled technical	0·092***	0·017	0·132***	0·174***	0·024	0·031	0·215***	0·062**	0·121***	0·057*	0·548
(1324)	(3·07)	(0·58)	(4·28)	(5·09)	(1·12)	(1·17)	(6·77)	(1·96)	(3·76)	(1·83)	
Skilled electronic	0·086	0·098	0·246***	0·045	0·084	−0·013	−0·004	−0·021	0·261***	0·072	0·426
(349)	(1·30)	(1·49)	(3·64)	(0·60)	(1·81)	(0·22)	(0·06)	(0·30)	(3·67)	(1·05)	
General (const.) maintenance	−0·004	0·082**	0·117***	0·121***	0·043*	0·068***	0·066*	−0·101***	0·441***	0·134***	0·592
(879)	(0·11)	(2·34)	(3·25)	(3·05)	(1·76)	(2·19)	(1·80)	(2·73)	(11·70)	(3·67)	
Mechanical maintenance	0·042	0·314***	0·206*	−0·089	0·055	0·235**	−0·004	−0·068	0·061	0·096	0·412
(131)	(0·38)	(2·88)	(1·84)	(0·71)	(0·72)	(2·43)	(0·03)	(0·59)	(0·52)	(0·85)	
Clerical	−0·068	0·087***	−0·030	0·065	0·015	0·085**	0·118***	0·241***	0·206***	0·064	0·425
(830)	(−1·59)	(2·05)	(−0·69)	(1·33)	(0·50)	(2·24)	(2·61)	(5·33)	(4·46)	(1·44)	
Operators and food	0·109*	0·179***	0·062	0·100**	0·050	−0·037	0·061	0·114*	0·106**	0·076*	0·414
(814)	(2·50)	(4·11)	(1·39)	(2·02)	(1·62)	(0·96)	(1·33)	(2·47)	(2·25)	(1·66)	
Unskilled electronic	0·004	0·027	0·062*	0·077**	0·036	0·053*	−0·010	0·058*	0·018	−0·025	0·052
(2545)	(0·14)	(0·87)	(1·93)	(2·15)	(1·65)	(1·92)	(0·31)	(1·75)	(0·55)	(0·76)	
Combat	0·147***	0·060***	0·080***	0·058***	0·048***	0·035**	0·069***	0·070***	0·139***	0·070***	0·358
(5403)	(8·28)	(3·38)	(4·42)	(2·86)	(3·82)	(2·23)	(3·71)	(3·74)	(7·29)	(3·82)	
Field artillery	0·059	0·047	0·030	0·134**	0·088**	−0·009	0·000	0·186***	0·230***	0·061	0·422
(534)	(1·10)	(0·89)	(0·56)	(2·21)	(2·33)	(0·19)	(0·01)	(3·28)	(3·99)	(1·10)	

Source: Reanalysis of Maier and Grafton's (1981) data on the ability of ASVAB 6/7 to predict Skill Qualification Test (SQT) scores. The correlation matrix was corrected f restriction of range by Maier and Grafton.

Table 6
ASVAB SUBTESTS WHICH ARE THE BEST PREDICTORS OF CORE TECHNICAL PROFICIENCY
by Military Occupational Specialty Cluster

Subtest	Technical	Speed	Quantitative	Verbal/Science
Electronics Repair (123)	Electronics	Compute-Speed		Science
Skilled Tech. (1329)	Mechanical Comp.		Math Knowledge	Science Verbal
Mechanical Maintenance (716)	Auto-Shop Know. Mechanical Comp. Electronics			Science
General Maintenance (272)	Auto-Shop Know.		Math Knowledge	Science Verbal
Operators/Food (1215)	Auto-Shop Know.		Arith Reasoning Math Knowledge	Verbal
Surveillance & Communication (289)	Auto-Shop Know.	Compute-Speed	Math Knowledge or Arith Reason.	Verbal
Clerical (1210)			Arith Reasoning Math Knowledge	Verbal
Combat (1429)	Auto-Shop Know. Mechanical Comp.		Math Knowledge	Science
Field Artillery (464)	Auto-Shop Know. Mechanical Comp.	Compute-Speed		Science

Source: Summarized from Table 2 of Wise, McHenry, Rossmeissl and Oppler, 1987. Based on an analysis of the ability of ASVAB subtests to predict Core Technical Proficiency ratings after the recruit has been in the US Army for 2 or 3 years. Core Technical Proficiency ratings are about 50 percent based on hands-on work sample tests and 50 percent based on paper and pencil job knowledge exams. The subtests listed in the table are the 3 or 4 subtests which in combination maximized the R^2 of the model predicting Core Technical Proficiency.

Table 7.

Effect of ASVAB Composite
on other Dimensions of Job Performance

	Technical	Speed	Quantitative	Verbal	R^2
General Soldering Proficiency	.26	.03	.20	.10	.461
Effort and Leadership (resid)	.21	.07	.08	.03	.280
Effort and Leadership (raw)	.21	.09	.03	-.07	.206
Personal Discipline	.06	.04	.07	-.03	.10

Source from John Campbell, 1986, Table 10. Standardized Coefficients from an Analysis of Project A Data on Performance in the Military.

Table 8

Raw Validity Coefficients

	Mechanical Comprehension	Intelligence	Arithmetic	Spatial Relations	Perceptual Accuracy	Psychomotor Abilities
Foreman	23[e]	28[e]	20[d]	21[d]	27[d]	15[b]
Craftworkers	26[d]	25[f]	25[f]	23[f]	24[e]	19[f]
Industrial Workers	24[d]	20[f]	21[f]	21[f]	20[f]	22[f]
Vehicle Operators	22[d]	15[d]	25[c]	16[c]	17[b]	25[d]
Service Occupations	----	26[d]	28[d]	13[d]	10[d]	15[d]
Protective Occupations	23[b]	23[d]	18[c]	17[d]	21[c]	14[d]
Clerical	23[d]	30[f]	26[f]	16[e]	29[f]	16[f]

Source: Ghiselli (1973) compilation of published and unpublished validity studies for job performance. The raw validity coefficients have not been corrected for restriction of range or measurement error in the performance rating. The Perceptual Accuracy category include number comparison, name comparison, cancellation and perceptual speed tests. They assess the ability to perceive detail quickly. Psychomotor tests measure the ability to perceive spatial patterns and to manipulate objects quickly and accurately. This category of tests includes tracing, tapping, doting, finger dexterity, hand dexterity and arm dexterity tests.

[a] Less than 100 cases.
[b] 100 to 499 cases.
[c] 500 to 999 cases.
[d] 1,000 to 4,999 cases.
[e] 5,000 to 9,999 cases.
[f] 10,000 or more cases

Table 9
Determinants of Job Performance

	Technician	High Skill Clerical	Low Skill Clerical	Craft Workers	Operatives	Service
Mathematics	.198***	.161***	.207***	.168***	.107***	.223***
	(.035)	(.033)	(.026)	.017	(.018)	(.039)
Verbal	.051	.073**	.070**	-.018	.012	.078*
	(.038)	(.035)	(.030)	(.020)	(.023)	(.046)
Spatial Perception	.025	-.068***	-.002	.075***	.022	.039
	(.029)	(.026)	(.021)	(.014)	(.016)	(.034)
Perceptual Ability	.026	.106***	.103***	.048***	.082***	.063*
	(.036)	(.031)	(.025)	(.018)	(.019)	(.038)
Psychomotor Ability	.113***	.094***	.091***	.083***	.145***	.133***
	(.027)	(.026)	(.021)	(.013)	(.015)	(.030)
Yrs. of Schooling	.031*	.026	-.014	-.009	-.036***	-.020
	(.016)	(.016)	(.013)	(.007)	(.008)	(.017)
Relevant Experience	.041***	.019	.042***	.040***	.036***	.082***
	(.014)	(.015)	(.012)	(.005)	(.010)	(.016)
(Relevant Experience)^2	-.00094**	-.00012	-.0009**	-.00025*	-.0005	-.0021***
	(.00046)	(.00046)	(.0004)	(.00015)	(.0003)	(.0005)
Tenure	.085***	.113***	-.0925***	.0620***	.079***	.054***
	(.015)	(.016)	(.014)	(.0056)	(.011)	(.019)
Tenure^2	-.0024***	-.0031***	-.0026***	-.00156***	-.0017***	-.00131
	(.0006)	(.0006)	(.0006)	(.00018)	(.0004)	(.00077)
Age	-.0024	.040***	.037***	.052***	.053***	.044***
	(.0163)	(.015)	(.010)	(.0078)	(.007)	(.013)
(Age-18)^2	-.00012	-.00064***	-.00062***	-.00071***	-.00072***	-.00055*
	(.00021)	(.00020)	(.00013)	(.00010)	(.00009)	(.00017)
Female	.057	.063	-.024	-.396***	-.194***	.166**
	(.056)	(.072)	(.063)	(.066)	(.043)	(.073)
Black	-.138**	-.390***	-.146***	-.247***	-.216***	-.031
	(.060)	(.054)	(.042)	(.032)	(.029)	(.063)
Hispanic	.046	-.286***	.053	-.109***	-.053	-.076
	(.099)	(.086)	(.069)	(.042)	(.049)	(.108)
R. Square	.114	.167	.139	.150	.145	.153
Number of Obs.	2384	2570	4123	10016	8167	1927

Source: Analysis of GATB revalidation data in the US Employment Services Individual Data File. Deviations of job performance ratings from the mean for the job/establishment are modeled as a function of deviations of worker characteristics from the mean for the job/establishment. The test scores are in a population standard deviation metric. The metric for job performance is the within job/establishment standard deviation.

Table 10

Increases in IQ Test Scores Over Time

Country	IQ Point Gain	Period	Test	Age Group	Status
United States	11.0	1918-1943	Army--Wells Alpha	18-33	(4)
	6.0	1932-1953	SB--WAIS	16-48	3
	9.9	1932-1971	SB-LM--SB-72	2-18	2
	6.4	1954-1978	WAIS--WAIS:R	16-70	(3)
	5.3	1942-1987	ITED-Iowa Seniors	17	(3)
United Kingdom	7.4	1939-1979	Ravens	8-30	3
France	25.1	1949-1974	Ravens	18	3
	9.4	1949-1974	Verbal & Math	18	3
Japan	20.0	1951-1975	Wechsler	6-15	3/4
Netherlands	20.0	1952-1982	Ravens	18	1
Norway	8.8	1954-1968	Ravens	19	1
	8.2	1954-1968	Verbal & Math	19	1
Edmonton, Canada	11.0	1956-1977	CTMM	9	1
Belgium	6.8	1958-1967	Ravens/Shapes	18	1
	3.7	1958-1967	Verbal/Math	18	1

Note: WAIS--WAIS:R, ITED and Army Alpha results are discussed in the text. For all other comparisons the source is Flynn 1987. SB stands for Stanford Binet, CTMM stands for California Test of Mental Maturity, ITED stands for Iowa Test of Educational Development, and Ravens stands for the Ravens Progressive Matrices test of Abstract Reasoning. All tests have been adjusted to give them a standard deviation of 15. Flynn's classification of the reliability of the estimate is given in the column headed by status. It has the following key 1 = verified, 2 = probable, 3 = tentative, and 4 = speculative. The status classifications in parenthesis were assigned by the author.

Table 11
Effect of IQ Gains
on
Labor Productivity Growth

	IQ Growth	Schooling Growth	Growth GDP/hr 1938-50	Growth GDP/hr 1938-60	Level GDP/hr 1960	Intercept	R^2
GDP/hr 1960-84 excluding mining							
	5.2*** (4.19)					1.1 (1.72)	.65
	2.0** (2.08)		-.42*** (4.41)			3.3*** (5.41)	.89
	3.7*** (6.51)			-.89*** (6.22)		4.1*** (7.44)	.94
	2.2** (2.97)				2.2*** (5.75)	15.3*** (6.16)	.93
	3.4*** (7.18)	.06 (.13)		.95*** (9.65)		4.4*** (8.44)	.98
Manufacturing 1960-85							
	5.8*** (3.39)					1.8* (1.93)	.57
	4.1** (3.10)			-.94** (2.96)		5.1*** (3.97)	.80

Estimates of GDP/hr levels and growth rates are from Maddison 1982, 1984 with updates derived from data in OECD National Accounts, OECD Economic Outlook and OECD Employment Outlook. The sample comprises Australia, Belgium, Canada, France, West Germany, Japan, Netherlands, Norway, United States and United Kingdom. Mining input and hours worked were excluded. The sample for the model containing schooling growth comprises Canada, France, West Germany, Japan, Netherlands, U.S. and the U.K. Estimates of growth of output per hour in manufacturing are from BLS 1987. The sample comprises Belgium, Canada, France, Germany, Japan, Netherlands, Norway, United States and the United Kingdom. T statistics are in parenthesis below the coefficient.

* significant at the 10 percent level on a one tail test.
** significant at the 5 percent level on a one tail test.
*** significant at the 1 percent level on a one tail test.

Table 12
Effect on IQ Growth
on
Wages and Per Capita Income

	IQ Growth	Growth GDP/hr 1938-50	Growth GDP/hr 1938-60	Log Level GDP per person 1950	Intercept	R^2
Hourly Compensation in Manufacturing 1960-85	4.7***				1.4	.49
	(3.15)				(1.73)	
	3.8**		-.54		3.2	.55
	(2.45)		(1.39)		(2.12)	
Percapita Income 1950-86	4.9***				.5	.66
	(4.54)				(.85)	
	2.0**	-.33***			2.5***	.83
	(2.10)	(3.12)			(3.96)	
	1.9*			-2.0***	17.6***	.86
	(1.74)			(3.76)	(3.85)	

Data on hourly compensation in manufacturing is from BLS (1986), and OECD Main Economic Indicator. Data on percapita income is from Summers and Heston (1984) and BLS (1987) and OECD Economic Outlook. The sample comprised Australia, Belgium, Canada, France, Germany, Japan, Netherlands, Norway, US and the UK. T statistics are in parenthesis below the coefficient.

* significant at the 10 percent level on a one tail test
** significant at the 5 percent level on a one tail test
*** significant at the 1 percent level on a one tail test.

Table 13

Effect of IQ Gains
on
Total Factor Productivity Growth

	IQ Growth	Schooling Growth 1955-73	Growth GDP/hr 1938-50	Growth GDP/hr 1938-60	Intercept	R^2
Private Business Sector 1955-73						
	1.5**	--	-.18***	--	2.27***	.93
	(2.76)		(3.78)		(6.69)	
	1.4*	-.13	-.18**	--	2.35***	.91
	(2.29)	(.27)	(2.88)		(4.45)	
Manufacturing 1969-85						
	2.0	--	--	-.83**	3.90**	.53
	(1.19)			(2.90)	(2.41)	
	2.4**	1.0	--	-.72**	2.5**	.90
	(3.15)	(1.29)		(4.58)	(2.94)	

The estimates of total factor productivity for the Private Business Sector are from Christensen, Christensen and Cummings. The countries which matched with the IQ data were Canada, France, West Germany, Japan, Netherlands, United States and the United Kingdom. Estimates of capital labor productivity for the manufacturing sector are from OECD Economic Outlook, May 1986 Table 5. The countries which matched with the IQ data were Belgium, Canada, France, Germany, Japan, Norway, United States and the United Kingdom. T statistics are in parenthesis below the coefficient.

* significant at the 10 percent level on a one tail test.
** significant at the 5 percent level on a one tail test.
*** significant at the 1 percent level on a one tail test.

COMPARISONS OF SCIENCE PERFORMANCE

In the US only 6 % take two biology classes during high school and only 1 % take Chemistry or Physics for two years. Much larger proportions of the age cohort take science courses in other countries.

1983 DIFFERENCE BETWEEN US AND OTHER COUNTRIES (in US standard deviation units)

	At Age 18						At Age 15
	Percent Taking Biology	Biology Score	Percent Taking Chem.	Chem Score	Percent Taking Physics	Physics Score	General Science
UNITED STATES	6 %	---	1 %	---	1 %	---	---
CANADA	28 %	.52	25 %	-.04	19 %	-.37	.42
AUSTRALIA	18 %	.67	12 %	.49	11 %	.19	.26
ENGLAND	4 %	1.66	5 %	1.74	6 %	.81	.04
JAPAN	12 %	.54	16 %	.78	11 %	.67	.74
NORWAY	10 %	1.10	15 %	.23	24 %	.46	.28
SWEDEN	15 %	.69	15 %	.13	15 %	-.04	.38
FINLAND	45 %	.91	14 %	-.24	14 %	-.48	.40
ITALY	14 %	.29	2 %	.02	19 %	-1.11	.04
SINGAPORE	6 %	1.88	5 %	1.55	7 %	.59	.00
HONG KONG(F6)	7 %	.84	14 %	1.46	14 %	.87	-.02
HUNGARY	3 %	1.42	1 %	.55	4 %	.70	1.04
POLAND	9 %	1.24	9 %	.38	9 %	.38	.32

Source: International Association for the Evaluation of Educational Achievement (IEA) Science Achievement in Seventeen Nations, Pergammon Press, 1988

APPENDIX B

The ASVAB

Purposes

The ASVAB is a multiple aptitude battery designed for use with students in Grades 11 and 12 and in postsecondary schools. The test was developed to yield results that are useful to both schools and the military. Schools use ASVAB test results to provide educational and career counseling for students. The military services use the results to identify students who potentially qualify for entry into the military and for assignment to military occupational training programs.

Like other multiple aptitude batteries, the ASVAB measures developed abilities and predicts what a person could accomplish with training or further education. This test is designed especially to measure potential for occupations that require formal courses of instruction or on-the-job training. In addition, it provides measures of general learning ability that are useful for predicting performance in academic areas.

The ASVAB can be used for both military and civilian career counseling. Scores from this test are valid predictors of success in training programs for enlisted military occupations. Through the use of validity generalization techniques, predictions from military validity studies can be generalized to occupations that span most of the civilian occupational spectrum. Although some enlisted occupations are military specific, more than 80% of these occupations have direct civilian occupational counterparts.

Since the ASVAB was first used in high schools in 1968, it has been the subject of extensive research and has been updated periodically. Appendix A contains a brief history of the ASVAB and the various forms that have been used.

Key Features

ASVAB-14, introduced in the 1984-85 school year, contains several key features that were not included in previous forms. These key features include

- **improved usefulness in measuring vocational aptitudes:** In addition to yielding *academic composites* that provide measures of academic potential, ASVAB-14 supplies *occupational composites* that provide measures of potential for successful performance in four general career areas.
- **increased reliability:** Changes in the length and number of subtests have increased the test's reliability without a substantial increase in testing time.
- **nationally representative norms:** ASVAB-14 is normed on a nationally representative sample of 12,000 women and men, ages 16-23, who took the test in 1980.

Content

Subtests

The ASVAB consists of 10 subtests. Eight are power subtests that allow maximum performance with generous time limits. Two subtests are speeded.

Figure 1-1 presents the subtests, the time allowed for the administration of each subtest, the number of items per subtest, and the descriptions of the abilities or knowledge measured. The subtests are designed to measure general cognitive abilities and acquired information in specific areas. Sample questions for each subtest are provided in Appendix B.

GENERAL SCIENCE
11 Minutes
25 Items
Description
Measures knowledge of the physical and biological sciences.

ARITHMETIC REASONING
36 Minutes
30 Items
Description
Measures ability to solve arithmetic word problems.

Figure 1-1. ASVAB-14 CONTENT.

Testing Time	144 minutes
Administrative Time	36 minutes
Total Testing Time	180 minutes
Total Number of Items	334

WORD KNOWLEDGE
11 Minutes
35 Items
Description
Measures ability to select the correct meaning of words presented in context and to identify the best synonym for a given word.

PARAGRAPH COMPREHENSION
13 Minutes
15 Items
Description
Measures ability to obtain information from written passages.

NUMERICAL OPERATIONS
3 Minutes
50 Items
Description
Measures ability to perform arithmetic computations in a speeded context.

CODING SPEED
7 Minutes
84 Items
Description
Measures ability to use a key in assigning code numbers to words in a speeded context.

AUTO & SHOP INFORMATION
11 Minutes
25 Items
Description
Measures knowledge of automobiles, tools, and shop terminology and practices.

MATHEMATICS KNOWLEDGE
24 Minutes
25 Items
Description
Measures knowledge of high school mathematics principles.

MECHANICAL COMPREHENSION
19 Minutes
25 Items
Description
Measures knowledge of mechanical and physical principles and ability to visualize how illustrated objects work.

ELECTRONICS INFORMATION
9 Minutes
20 Items
Description
Measures knowledge of electricity and electronics.

B. Sample Test Items

General Science

1. An eclipse of the sun throws the shadow of the

   1-A moon on the sun.
   1-B moon on the earth.
   1-C earth on the sun.
   1-D earth on the moon.

2. Substances which hasten chemical reaction time without themselves undergoing change are called

   2-A buffers.
   2-B colloids.
   2-C reducers.
   2-D catalysts.

Arithmetic Reasoning

3. How many 36-passenger busses will it take to carry 144 people?

   3-A 3
   3-B 4
   3-C 5
   3-D 6

4. It costs $0.50 per square yard to waterproof canvas. What will it cost to waterproof a canvas truck cover that is 15' x 24'?

   4-A $ 6.67
   4-B $ 18.00
   4-C $ 20.00
   4-D $180.00

Word Knowledge

5. The wind is <u>variable</u> today.

   5-A mild
   5-B steady
   5-C shifting
   5-D chilling

6. <u>Rudiments</u> most nearly means

   6-A politics.
   6-B minute details.
   6-C promotion opportunities
   6-D basic methods and procedures.

Paragraph Comprehension

7. Twenty-five percent of all household burglaries can be attributed to unlocked windows or doors. Crime is the result of opportunity plus desire. To prevent crime, it is each individual's responsibility to

7-A provide the desire.
7-B provide the opportunity.
7-C prevent the desire.
7-D prevent the opportunity.

8. In certain areas water is so scarce that every attempt is made to conserve it. For instance, on one oasis in the Sahara Desert the amount of water necessary for each date palm tree has been carefully determined.

How much water is each tree given?

8-A no water at all
8-B water on alternate days
8-C exactly the amount required
8-D water only if it is healthy

Numerical Operations

9. 3 + 9 =

9-A 3
9-B 6
9-C 12
9-D 13

10. 60 ÷ 15 =

10-A 3
10-B 4
10-C 5
10-D 6

Coding Speed

KEY

bargain 8385	house 2859	owner 6227
chin 8930	knife 7150	point 4703
game 6456	music 1117	sofa 9645
	sunshine 7489	

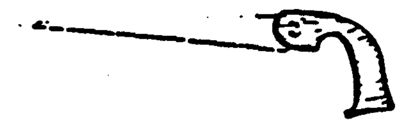
QUESTIONS	A	B	C	D	E
11. game	6456	7150	8385	8930	9645
12. knife	1117	6456	7150	7489	8385
13. bargain	2859	6227	7489	8385	9645
14. chin	2859	4703	8385	8930	9645
15. house	1117	2859	6227	7150	7489
16. sofa	7150	7489	8385	8930	9645
17. owner	4703	6227	6456	7150	8930

	A	B	C	D	E
18. music	1117	2859	7489	8385	9645
19. knife	6227	6456	7150	7489	8485
20. sunshine	4703	6227	6456	7489	8930
21. chin	1117	2859	4703	7150	8930
22. sofa	4703	6227	7150	8485	9645
23. bargain	2859	6456	8385	8930	9645
24. point	1117	4703	6227	6456	7150

Auto & Shop Information

25. A car uses too much oil when which parts are worn?

25-A pistons
25-B piston rings
25-C main bearings
25-D connecting rods



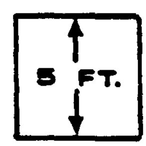
26. The saw shown above is used mainly to cut

26-A plywood.
26-B odd-shaped holes in wood.
26-C along the grain of the wood.
26-D across the grain of the wood.

Mathematics Knowledge

27. If $x + 6 = 7$, then x is equal to

27-A 0
27-B 1
27-C -1
27-D 7/6



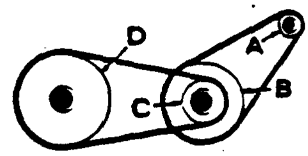
28. What is the area of this square?

28-A 1 square foot
28-B 5 square feet
28-C 10 square feet
28-D 25 square feet

Mechanical Comprehension

29. Which post holds up the greater part of the load?

29-A post A
29-B post B
29-C both equal
20-D not clear



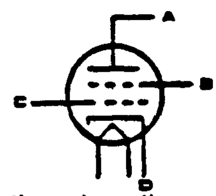
30. In this arrangement of pulleys, which pulley turns fastest?

30-A A
30-B B
30-C C
30-D D

Electronics Information

31. Which of the following has the least resistance?

31-A wood
31-B iron
31-C rubber
31-D silver



32. In the schematic vacuum tube illustrated, the cathode is element

32-A A
32-B B
32-C C
32-D D

Key To The Sample Test Items

1.	B	17.	B
2.	D	18.	A
3.	B	19.	C
4.	C	20.	D
5.	C	21.	E
6.	D	22.	E
7.	D	23.	C
8.	C	24.	B
9.	C	25.	B
10.	B	26.	B
11.	A	27.	B
12.	C	28.	D
13.	D	29.	A
14.	D	30.	A
15.	B	31.	D
16.	E	32.	D

NAME OF WORKER (Print) (Last) (First)

SEX: MALE_______ FEMALE_______

Company Job Title: ______________________________

How often do you see this worker in a work situation?

☐ All the time.

☐ Several times a day.

☐ Several times a week.

☐ Seldom.

How long have you worked with this worker?

☐ Under one month.

☐ One to two months.

☐ Three to five months.

☐ Six months or more.

A. How much can this worker get done? (Worker's ability to make efficient use of time and to work at high speed.) (If it is possible to rate only the quantity of work which a person can do on this job as adequate or inadequate, use #2 to indicate "inadequate" and #4 to indicate "adequate.")

☐ 1. Capable of very low work output. Can perform only at an unsatisfactory pace.

☐ 2. Capable of low work output. Can perform at a slow pace.

☐ 3. Capable of fair work output. Can perform at an acceptable pace.

☐ 4. Capable of high work output. Can perform at a fast pace.

☐ 5. Capable of very high work output. Can perform at an unusually fast pace.

B. How good is the quality of work? (Worker's ability to do high-grade work which meets quality standards.)

☐ 1. Performance is inferior and almost never meets minimum quality standards.

☐ 2. Performance is usually acceptable but somewhat inferior in quality.

☐ 3. Performance is acceptable but usually not superior in quality.

☐ 4. Performance is usually superior in quality.

☐ 5. Performance is almost always of the highest quality.

C. How accurate is the work? (Worker's ability to avoid making mistakes.)

☐ 1. Makes very many mistakes. Work needs constant checking.

☐ 2. Makes frequent mistakes. Work needs more checking than is desirable.

☐ 3. Makes mistakes occasionally. Work needs only normal checking.

☐ 4. Makes few mistakes. Work seldom needs checking.

☐ 5. Rarely makes a mistake. Work almost never needs checking.

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D. How much does the worker know about the job? (Worker's understanding of the principles, equipment, materials and methods that have to do directly or indirectly with the work.)

- ☐ 1. Has very limited knowledge. Does not know enough to do the job adequately.
- ☐ 2. Has little knowledge. Knows enough to get by.
- ☐ 3. Has moderate amount of knowledge. Knows enough to do fair work.
- ☐ 4. Has broad knowledge. Knows enough to do good work.
- ☐ 5. Has complete knowledge. Knows the job thoroughly.

E. How large a variety of job duties can the worker perform efficiently? (Worker's ability to handle several different operations.)

- ☐ 1. Cannot perform different operations adequately.
- ☐ 2. Can perform a limited number of different operations efficiently.
- ☐ 3. Can perform several different operations with reasonable efficiency.
- ☐ 4. Can perform many different operations efficiently.
- ☐ 5. Can perform an unusually large variety of different operations efficiently.

F. Considering all the factors already rated, and only these factors, how good is this worker? (Worker's all-around ability to do the job.)

- ☐ 1. Performance usually not acceptable.
- ☐ 2. Performance somewhat inferior.
- ☐ 3. A fairly proficient worker.
- ☐ 4. Performance usually superior.
- ☐ 5. An unusually competent worker.

Complete the following ONLY if the worker is no longer on the job.

G. What do you think is the reason this person left the job? (It is not necessary to show the official reason if you feel that there is another reason, as this form will not be shown to anybody in the company.)

- ☐ 1. Fired because of inability to do the job.
- ☐ 2. Quit, and I feel that it was because of difficulty doing the job.
- ☐ 3. Fired or laid off for reasons other than ability to do the job (i.e., absenteeism, reduction in force).
- ☐ 4. Quit, and I feel the reason for quitting was not related to ability to do the job.
- ☐ 5. Quit or was promoted or reassigned because the worker had learned the job well and wanted to advance.

RATED BY	TITLE	DATE

COMPANY OR ORGANIZATION	LOCATION (City, State, ZIP Code)

Appendix Table D
Data for Figures and Regressions

	Au	Be	Ca	Fr	Gr	Ja	Ne	No	US	UK
Growth										
GDP/hr										
1938-50	2.21	1.14	5.36	.75	-.41	-3.23	1.93	1.88	4.03	2.21
1938-60	2.46	2.05	4.33	2.41	2.80	.77	2.57	2.86	3.29	2.21
1960-84 (exc. Min.)	2.37	4.51	2.07	4.36	4.29	6.64	3.98	3.26	2.42	1.98
Level GDP/hr 1960	\$4.02	\$2.89	\$4.54	\$2.87	\$2.72	\$1.03	\$3.17	\$3.04	\$5.41	\$2.99
Growth MFG. Output/hr 1960-85	--	6.26	3.31	5.34	4.70	7.72	6.01	3.17	2.68	3.45
Total Factor Productivity Growth										
Private Domestic Ec. 1955-73	--	--	2.08	3.32	3.36	4.02	2.51	--	1.60	2.28
Manufacturing 1969-85	--	5.20	1.29	2.53	2.58	4.63	--	2.11	1.83	1.74
Rates of Return										
Gross Mfg. 1972-83	--	--	12.15	--	14.03	23.73	--	--	15.45	6.89
Gross Indust. 1972-83	--	15.72	9.88	13.10	12.48	--	--	--	--	7.70
Net Private 1955-73	--	--	9.60	12.54	7.49	14.63	10.74	--	9.60	7.35
Gross Fixed Capital Formation										
1965-84	24.97	20.16	22.18	22.55	22.60	31.95	22.41	--	18.13	18.59
Growth of Hrly. Comp. in Mfg.										
1960-85	2.00	4.92	2.22	4.41	4.99	5.00	4.92	3.49	1.14	3.28
Growth Percapita GDP										
1950-86 (exc. Min.)	1.96	2.76	2.31	3.19	3.94	6.05	2.63	3.00	1.85	1.90
Level GDP/pop 1950	\$3324	\$2454	\$3596	\$2221	\$1888	\$810	\$2332	\$2403	\$4550	\$2700
Schooling Growth	--	--	.84	.45	.10	.51	.50	--	.84	.60
Growth IQ (pts. per yr.)	.31	.58	.46	.69	.74	.84	.50	.35	.24	.14

Ratio variables (ROR and investment) are expressed in percent. Logarithmic rates of growth have been multiplied by 100 so they represent percentage rates of growth.