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THE PRODUCTIVITY CONSEQUENCES OF WHAT IS LEARNED IN HIGH SCHOOL

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Executive Summary

Only 22 percent of American high school graduates take trigonometry, only 30 percent take chemistry, and only 15 percent take physics. The reason for these low enrollment figures is that most high school students see very little connection between how much they learn in math and laboratory science courses and their future success in the labor market. The analysis of NLS data undertaken in this study demonstrates that this perception is correct. During the first 5 years after leaving high school, young men who do not go to college receive no rewards from the labor market for developing competence in science, language arts and mathematical reasoning. For young males, the only academic competency that appears to be rewarded by the labor market is speed in doing simple computations (something that calculators do better than people). The other competency that has major effects on the wages of young men is technical competence (knowledge of mechanical principles, electronics, automobiles and shop tools), something that has been ignored by the reports recommending educational reform.

For the non-college bound female, there is a wage rate benefit to learning advanced mathematics but no wage rate benefits to developing competence in science, language arts or the technical arena. The tendency of American high school students to avoid tough math and science courses and their poor performance on international science and mathematics exams is, therefore, a rational response to market incentives.

Educational reformers are claiming that improved math and science education for the great mass of high school students (not just the 24 percent who report plans to major in

natural science or engineering) is essential if the workforce is to become more productive. If people who are competent in math and science are more productive workers, why aren't employers paying them commensurately more? Employers fail to reward high school graduates who are competent in math and science because (1) they do not know which of the job applicants who approach them have these competencies and because (2) workers and employers prefer employment contracts in which wage rates adjust only partially to reflect outstanding performance. Consequently, when the specific competencies of students are not signaled to the labor market by a credential, there is little reason to expect the wage rate effects of specific competencies to be the same as their productivity effects.

Consequently, the productivity effects of competence in math and science must be measured directly. This is done by analyzing a series of military data sets in which worker competencies have been correlated with hands-on measures of job performance. This analysis demonstrates that greater competence in science, language arts and higher level math is indeed associated with greater success in training and better performance on the job. These results provide support for the Excellence Commission's claim that major improvements in science and math education for the great mass of high school students will improve the productivity of the work force and contradict Morris Shamos's claim that "widespread scientific literacy is not essential to... prepare people for an increasingly technological society."(Education Week, Nov. 23 1988. p. 28). The results also reinforce the findings regarding the important role of technical competence in blue collar, craft and technician jobs. This is an area of study that needs much more attention than it has been getting.

One of the reasons this may occur is that technical skills may be more visible to employers than academic skills because they are easier to assess informally in the interview. Vocational teachers often help their students get jobs and in the process vouch for their competence. In contrast. most employers have little knowledge of job applicants' competence in math, science and reading. A survey of a stratified random sample of 2000 small and medium sized employers who are members of the National Federation of Independent Business found, for example, that aptitude tests had been given to only 3.2 percent of the new hires at these firms and high school transcripts had been obtained for only 13.7 percent of the new hires who had 12 or fewer years of schooling. As a result, the technical skills measured by the electronics, mechanical comprehension and auto and shop knowledge subtests may be better rewarded in the labor market than competence in math and science.

1/15/89

THE PRODUCTIVITY CONSEQUENCES OF WHAT IS LEARNED IN HIGH SCHOOL

The scientific and mathematical competence of American high school students is generally recognized to be very low. The high school graduating class of 1982 took on average of only .43 credits of Algebra II, .31 credits of more advanced mathematics courses, .40 credits of Chemistry and .19 credits of physics (Meyer 1988 Table A.2). The National Assessment of Educational Progress (NAEP) reports that only 7.5 percent of 17 year old students can "integrate specialized scientific information" (NAEP 1988a p.51) and 6.4 percent "demonstrated the capacity to apply mathematical operations in a variety of problem settings." (NAEP 1988b p. 42)

Another way of evaluating American performance in math and science is to make comparisons with the upper secondary students of other nations. In the 1960s, the low ranking of American students in such comparisons was defended by citing the fact that higher proportions of American youth took the international test. This is no longer the case. Figures 1 to 4 plot the scores in Algebra, Biology, Chemistry and Physics against proportion of the 18-year old population in the types of courses to which the international test was administered. Where large proportions of the age cohort took the test, lower mean scores tend to result, but this does not explain the poor performance of American high school seniors. In the Second International Math Study, the universe from which the American sample was drawn consisted of high school seniors taking a college preparatory math course. This group represents 13 percent of the age cohort, a proportion that is roughly comparable to the 12 percent of Japanese youth who were in their sample frame and is considerably smaller than the 19 percent of youth in the Canadian province of Ontario and the 50 percent of Hungarians who took the test. In Algebra, the mean score for this very select group of American students was about equal to the mean score of the much larger group of Hungarians and substantially below the Canadian achievement level (McKnight et al 1987). The median score for the Japanese youth was so high it was surpassed by only 2 or 3 percent of the American students taking the test.

The findings of the Second International Science Study are even more "dismal". Take the comparisons with English-speaking Canada, for example. The 25 % of Canadian 18-year

FIGURE 1

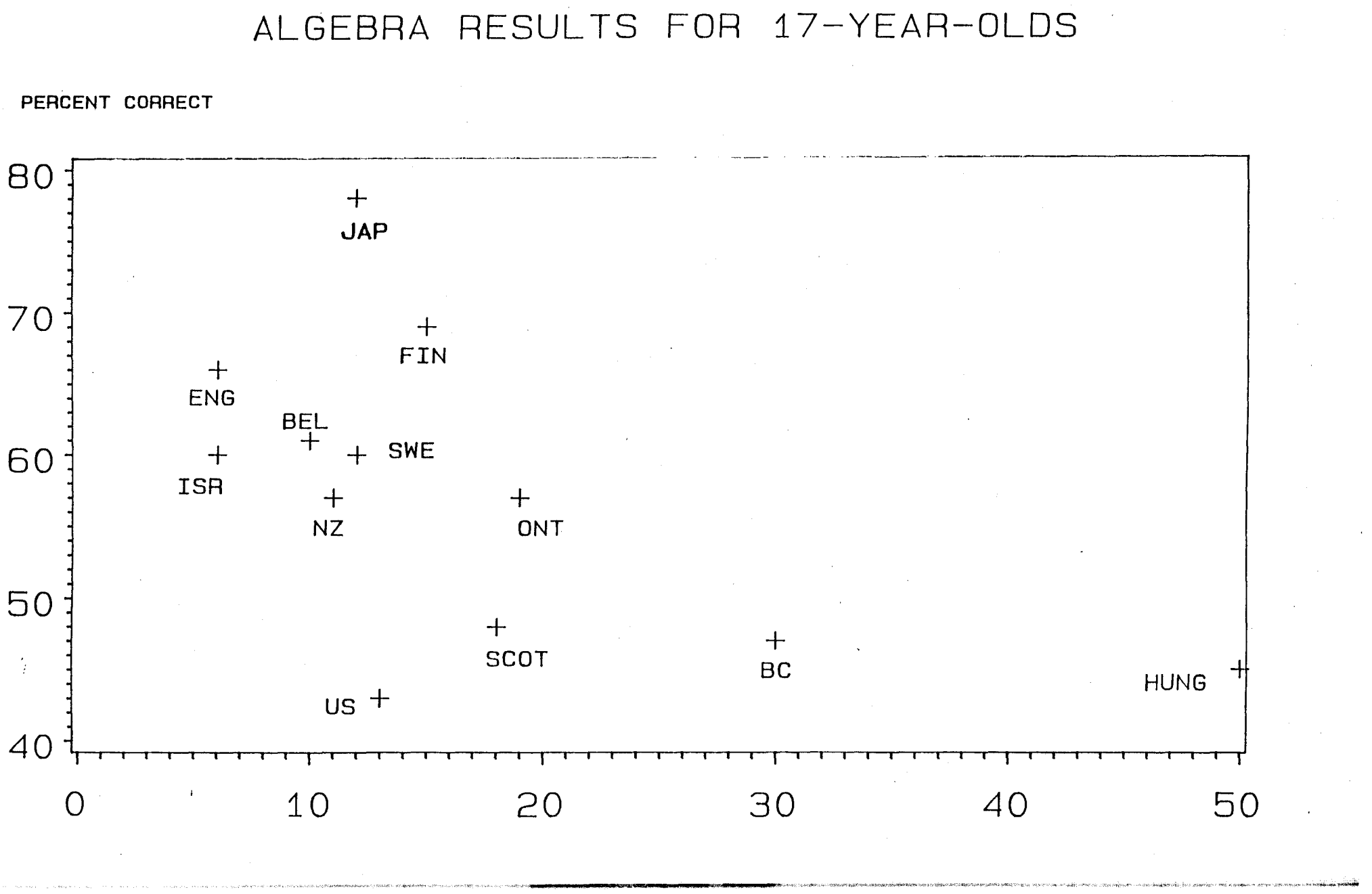

ALGEBRA RESULTS FOR 17-YEAR-OLDS
PERCENT CORRECT
80
70
60
50
40
0
10
20
30
40
50
JAP
FIN
ENG
BEL
SWE
ISR
NZ
ONT
SCOT
BC
US
HUNG

FIGURE 2

BIOLOGY RESULTS FOR 18-YEAR-OLDS

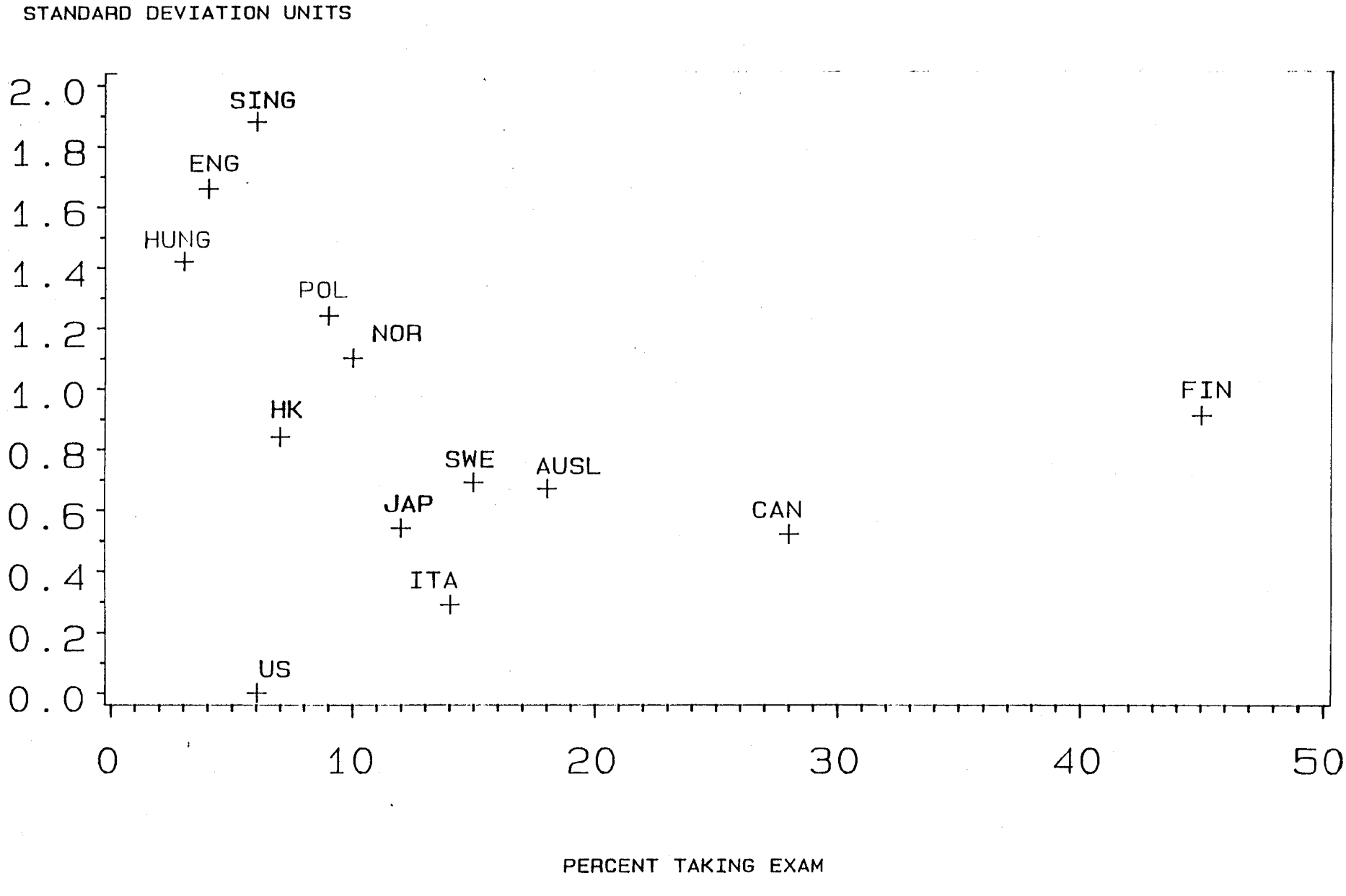
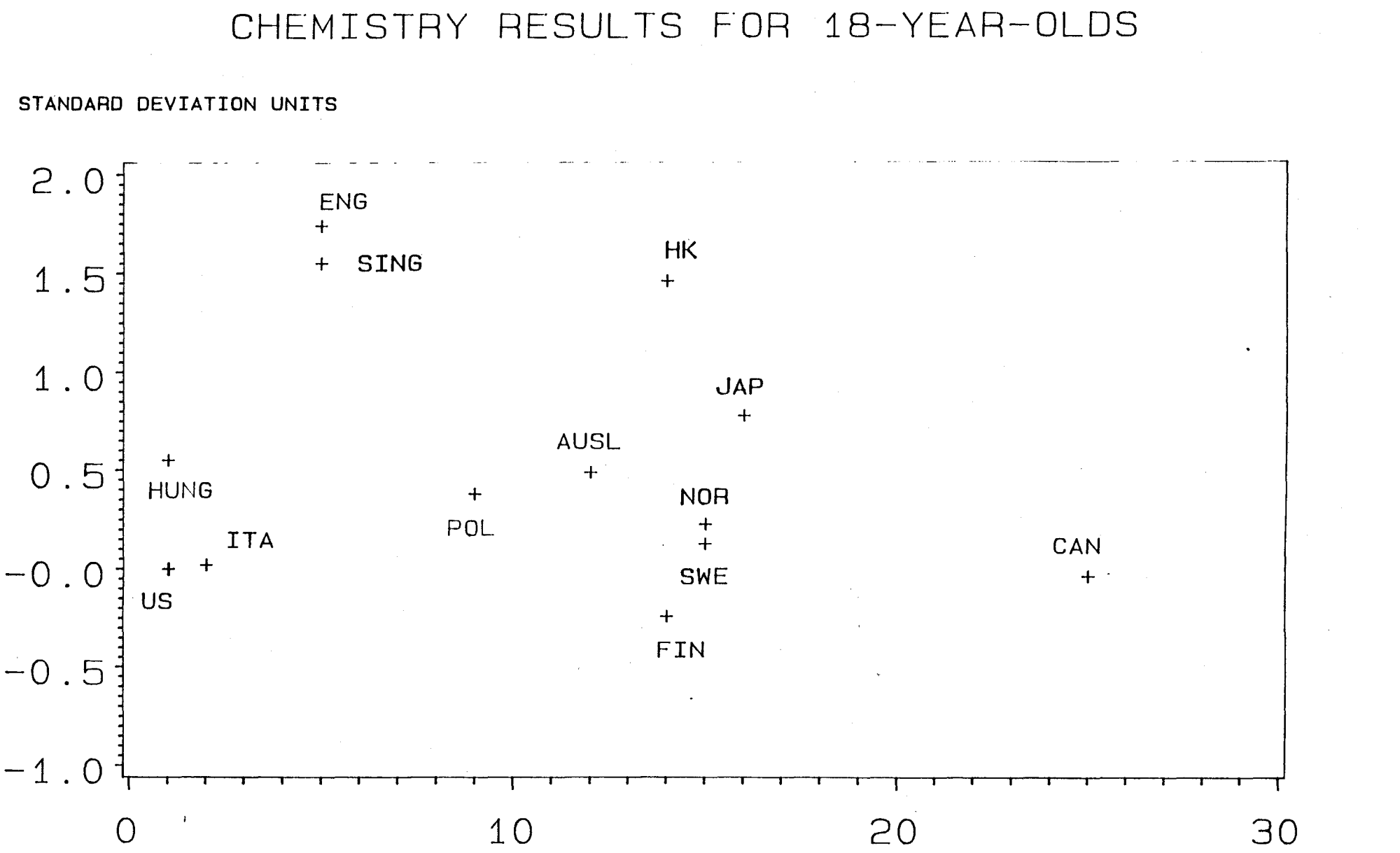
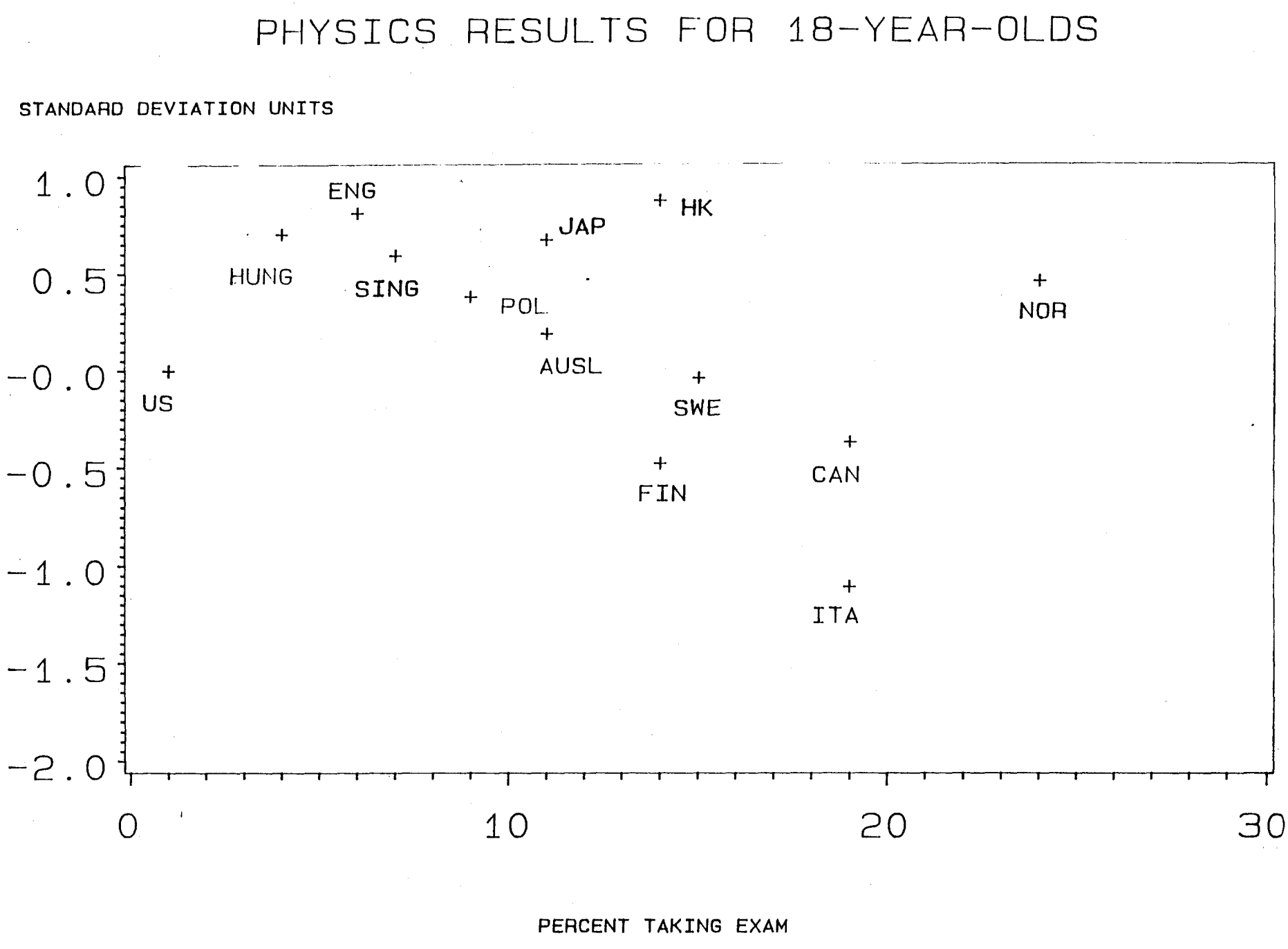


FIGURE 3


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


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

olds taking chemistry know just as much chemistry as the very select 1 % of Americans high school seniors taking their second chemistry course (most of whom are in "Advanced Placement"). The 28 % taking biology know much more than the 6 % of American 17-18 year olds who are taking their second biology course (International Association for the Evaluation of Educational Achievement, 1988).

Clearly, there is a large gap between the science and math competence of young Americans and their counterparts overseas. Will this gap have major consequences for the nation's standard of living? In the view of the National Commission on Excellence in Education, it will:

> If only to keep and improve on the slim competitive edge we still retain in world markets, we 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. (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. With respect to science, however, there is controversy about these claims. Morris Shamos, an emeritus professor of physics at New York University, argues 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 addresses the following question: "Are the young workers who have above average competence in these fields receiving higher wage rates?" The findings from this analysis appear on the surface to contradict the recommendations of the Excellence Commission and support Shamos. For young men in the NLS Youth sample, 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 the reports recommending educational reform. For young women, the findings are that verbal and mathematical reasoning competence lower unemployment and increase earnings but only mathematical reasoning competence and computational speed increases 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. For the 90 percent of the society who are not going to be scientists, engineers, doctors or technicians, 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.

The Excellence Commission's report, however, makes claims about the **productivity** effects not the **wage rate** effects of science, mathematics and language arts competency. Are these effects necessarily the same? The second 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 third section of the paper, therefore, tackles 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 the Excellence Commission's 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.

I. WHICH COMPETENCIES ARE REWARDED BY THE LABOR MARKET ?

The first task of the study is to determine to what degree achievement in the various subjects taught in high school are rewarded by the labor market. This is accomplished by estimating models predicting wage rates, earnings and unemployment 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.

1.1 DATA

The data set for this analysis is the Youth Cohort of National Longitudinal Survey (NLS)--all eight waves from 1979 to 1986. The measures of achievement are derived from 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. Its ability to accomplish these objectives has been thoroughly researched and the battery has been periodically modified to incorporate the findings of this research. The ASVAB Manual reports:

> Extensive research demonstrates that the ASVAB composites used in military selection and classification predict performance in training for a variety of military occupations. (Booth-Kewley, 1983; Maier & Truss, 1983; Rossmeissl, Martin & Wing, 1983; Wilbourn, Valentine, & Ree, 1984). For example, validity coefficients for electrical & mechanical equipment repair specialties range from .36 to .74; those for communication specialties range from .36 to .52; those for data processing specialties range from .39 to ,77; and those for clerical and supply specialties range from .53 to .73. These coefficients have been corrected for restriction of range. (US Military Entrance Processing Command, 1984, p. 18)

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. The Department of Defense which funded this project had Dr.

R. D. Bock an authority on educational and psychological testing evaluate the quality of the resulting ASVAB data. He concluded:

> Data from responses of [the NLS Youth Sample] to the ASVAB are free from major defects such as high levels of guessing or carelessness, inappropriate levels of difficulty, cultural test-question bias, and inconsistencies in test administration procedures. (quoted in US Military Entrance Processing Command, 1984, p. 19)

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. A fuller description of each of these subtests together with sample questions is given in Appendix B.

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.[3]

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 six

test composites have all been normalized to have zero mean and unit variance. 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). 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.

Four measures of labor market success are being studied: the log of the hourly wage rate in the current or most recent job, the log of calendar year earnings if they exceed $500, earnings in dollars (with nonworkers over age 16 included in the sample) and the share of labor force time that the individual was unemployed (defined only for people who were in the labor force for at least 8 weeks during the calendar year).

An extensive set of controls are included in the estimating equations. Reports of weeks spent in employment are available all the way back through 1975. For each individual, these weeks worked reports were aggregated across time and an estimate of cumulated work experience (EXP_{it}) was derived for January 1 of each year in the longitudinal file. This variable and its square is included in every model as is age and its square. School attendance is controlled by four separate variables. The first variable indicates whether the youth is in school at the time of the interview. The second is a dummy variable indicating whether the youth has been in school since the last interview. The third is a dummy variable indicating whether the student is attending school part time. A positive coefficient is expected on this variable when the other controls for school attendance are entered in the model. The fourth variable is a measure of the share of the calendar year that the youth reported attending school derived from the NLS's monthly time log. Years of schooling is also controlled for 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 is controlled by dummy variables for being married and for having at least one child. Minority status is 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.

1.2 HYPOTHESES, MODEL SPECIFICATION AND RESULTS

The labor market consequences of the competencies that a young person develops early in life will be examined by testing seven hypotheses relating to the impact of ASVAB subtest scores on wages, earnings and unemployment. These hypotheses are first specified and then the relevant statistical evidence is reviewed.

Main Effects of Test Scores

Hyp. 1: Subtests measuring academic competencies do not have significant positive effects on wage rates and earnings in the years immediately following high school graduation.

The reason for expecting the academic subtests to have modest effects on labor market success is that analyses of other data sets such as High School and Beyond and NLS Class of 1972 have typically found that academic achievement test scores have small effects on early labor market success (Taubman and Wales 1975; Hauser and Daymont 1977; Gardner 1982; Meyer 1982; Kang and Bishop 1986).

Hyp 2: Subtests measuring generic technical knowledge have positive effects on wage rates and earnings and negative effects on unemployment of young men.

The primary reason for expecting tests of generic technical knowledge to have positive effects on labor market success of young men is the demonstrated positive effect of trade and technical course taking on labor market success when the student obtains a job which uses the skills learned in school (Bishop 1988). Since technical skills appear to payoff only when used, the returns to technical skills are likely to be gender specific. Very few young women

have jobs for which knowledge of electronics, mechanical principles, auto mechanics and shop tools are essential, so the technical composite is not likely to be good predictor of wages and earnings for women. Very few young men work in clerical jobs, so the clerical checking subtest is not likely to be a useful predictor of wages and earnings for men. These hypotheses are first tested in a model in which the technical and academic competencies are assumed to have linear and additive effects on labor market outcomes:

$$(1)\ \underline{Y}_t = \underline{a}_t\underline{A} + b_tC + c_tT + e_tS + \underline{g}_t\underline{Z}_t + \underline{u}_t \quad \text{for } t = 1979...1986$$

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

$\underline{Z}_t$ is a vector of control variables such as age, work experience, schooling, school attendance, 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.

Young men: The results of estimating model 1 are presented in Table 1 through Table 4. Complete results for sample runs are available in Appendix A. The results for young men are as predicted--high level academic competencies do not have positive effects on wage rates and earnings. The mathematics reasoning, verbal and science composites all have negative effects on wage rates and earnings and often positive effects on unemployment. In the wage rate models, 23 of 24 coefficients were negative. F tests on the sum of the coefficients on the three academic composites are presented in columns 9-11 of tables 1 through 4. The sum of the three coefficients in the wage rate models was significantly (at the 5 percent level) negative in 5 of the 8 years. In the log earnings models, 20 of 21 coefficients were negative. In the dollar earnings models, 19 of 21 coefficients were negative. F tests on the sum of the

coefficients on academic tests in the dollar earnings models find they are significantly negative in 5 of the 7 years. In the unemployment models, about half of the coefficients were positive and the F test on the sum of the coefficients was never significantly different from zero at even the 10 percent level.

Speed in arithmetic computation has substantial positive effects on labor market success of young men. A one standard deviation increase in computational speed increased wage rates by 5.3 percent and earnings by $837 (10.4 percent) on average. The wage and earnings effects grew over time. The unemployment effects, in contrast, diminished with time. They were significant in 1979-80 but not later. In all eight of the years studied, computational speed had a significantly larger impact on wage rates and earnings than the aggregated academic tests. Computational speed, however, is something that calculators do better than people and is not viewed by most educators as an appropriate goal for a high school mathematics curriculum (National Council of Teachers of Mathematics 198_).

Being able to do clerical checking rapidly significantly lowered unemployment in 4 of the 7 years, significantly increased dollar earnings in 6 of 7 years but had no effect on wage rates.

Technical competence had large and significant positive effects on wage rates and earnings and negative effects on unemployment. The F tests indicate that in all eight years analyzed, it had significantly more positive effects on wage rates and earnings than the aggregated academic tests. A one standard deviation increase in the technical composite increased wage rates by 5.6 percent and yearly earnings by $1065 (12.5 percent) and reduced the rate of unemployment by 1.9 percentage points. This is a very substantial return to technical achievement.

Young women: The competencies that pay off for women are different from the competencies that payoff for men. As with men, scientific competence has no effect on their wage rates, earnings or unemployment. Unlike men, however, technical competence does not pay off. In fact, technical competence had a significant tendency to increase unemployment from 1979 through 1983. As with men, speed of arithmetic computation significantly raised wage rates and earnings. A one SD increase in computational speed increased wage rates by 3.2 percent and earnings by $311 (6.4 percent) on average. Unlike men, mathematical reasoning capability had a significant impact on wage rates, earnings and unemployment. A

one SD increase in mathematical reasoning competency raised the wage rates of young women by 2.5 percent and earnings by $407 (4.4 percent) and decreased unemployment by 1.0 percentage point. The wage and earnings effects appear to have grown with time.

Still another contrast with men is the large effects of verbal competence on the unemployment and earnings of young women. A one SD improvement in verbal achievement lowered the risk of unemployment by 2.3 percentage points and raised earnings by $229 (6.2 percent). Wage rate effects were much smaller. Verbal competence had a significant effect on a women's wage rate only in 1985 and 1986.

The overall effect of the three academic competencies on unemployment and earnings was quite substantial. A one SD increase in all three tests lowered the risk of unemployment by 3.6 percentage points and raised earnings by $594 (8.1 percent). The impact of the academic tests on wage rates was much smaller--3.3 percent on average--though it appears to be growing over time.

The clerical checking subtest had weak positive effects on wage rates of young women and large significant effects on their earnings and unemployment.

Interaction Effects

The rest of the hypotheses to be tested relate to how the payoff to academic and technical competencies and speed in arithmetic computation varies with further education, student status and age. To test these hypotheses, a composite of the academic subtests (TA) with unit variance was defined and this composite, the technical composite and the computational speed subtest were then interacted with age deviated from 22, with years of college and with student status. In order to maximize the power of these tests it was assumed that the main effects of the test composites and all interactions with these composites were the same in all years.

$$(2)\ \underline{Y_t} = \underline{aA} + bC + cT + dTA + e_s + \underline{g_t Z_t} + \underline{u_t} \quad t = 1981,...1986$$

where $b = b_0 + b_1(Age_t\text{-}22) + b_2(Student_t)$

$c = c_0 + c_1(Age_t\text{-}22) + c_2(Student_t)$

$d = d_1(Age_t\text{-}22) + d_2(Student_t) + d_3(Yrs\ of\ College_t)$

$Student_t$ = proportion of the calendar year t attending school

The models were estimated using seemingly unrelated regression. This analysis is conducted on a reduced sample of young people who were valid observations in the model in all of the years between 1981 and 1986. When interactions are defined in this way, the main effects coefficients on the six composites ($\underline{a}$, b_0 and c_0) provide estimates for year t of the effect of the competency on labor market outcomes of 22 year old high school graduates who are not attending school. These subtest main effects coefficients are reported in the top panel of Table 5. The coefficients on the interaction of age and the test composites (b_1, c_1 and d_1) provide estimates of the effect of age on the payoff to academic and technical competencies while controlling on years of college and student status.

Age and the Payoff to Academic Competency

Hyp 3: The return to academic competency grows with the age of the worker.

$d_1 > 0$.

A number of studies have found that the return to overall academic achievement increases with the age of the worker (Hauser and Daymont 1977; Taubman and Wales 1975). This would occur if academic achievement improves access to jobs offering considerable training and enables the worker to get more out of the training. A second possible cause of a positive age interaction is that academic achievement is poorly signaled to employers so there are long delays before the labor market identifies and rewards workers who because of their academic achievements are exceptionally productive workers.

The findings regarding the effect of age on the payoff to academic competency are presented in row 8 of Table 5. They do not support hypothesis 3. None of the age/academic composite interaction coefficients in the wage and earnings regressions come even close to being significantly positive and one is significantly negative. The statistically significant interaction coefficient in the male unemployment regression suggests that academic competency has its most favorable effect on unemployment immeadiately after graduating from high school.

The competency that interacts positively with age is computational speed. Interactions of age and computational speed are statistically significant in the male wage rate and dollar