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Updated Estimates of Earnings Benefits from Reduced Exposure of Children to Environmental Lead

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The recent and important study by Schwartz found that almost three-fourths of the benefits of reduced lead exposure in children are in the form of earnings gains (earnings losses avoided). New data on recent trends in returns to education and cognitive skills in the labor market suggest a need to revise this estimate upward. Based on an analysis of data from the National Longitudinal Survey of Youth, the present study estimates that an upward revision of at least 50% (or $2.5 billion per annual birth cohort) is indicated. The study also finds evidence that percentage earnings gains are considerably larger for females than for males. © 1995 Academic Press, Inc.

INTRODUCTION

In his ground-breaking and comprehensive study on the social benefits of reducing environmental lead exposure, Schwartz (1994) estimated that 73% of the total benefits from reduced exposure in children were in the form of earnings losses averted. The size and significance of these benefits depend upon both the relationship between lead exposure and decrements in IQ and the relationship between IQ loss and earnings. In particular, Schwartz estimated that the total benefit of a 1 μg/dl reduction in blood lead levels for one year's cohort of children was $6.937 billion and that $5.060 billion of that total was from avoiding future earnings losses for these children (due to deleterious effects of lead exposure on cognitive ability and educational achievement). (Of the remaining $1.877 billion in benefits, most were accounted for by reduced infant mortality.)

The $5.060 billion estimate of these earnings benefits relied heavily on data from a thorough review (Barth *et al.,* 1984) of studies relating intelligence and schooling to labor market outcomes. The data used in these studies, however, were drawn from the period 1950 to 1977. Moreover, the large majority of these studies looked only at earnings for males and typically excluded those who were not working. About half of these studies used samples that were not nationally representative because they were limited to local areas or to persons who had served in the armed forces. Schwartz also relied upon additional data relating schooling to earnings from four other studies published during the 1970s (cited below).

Since the completion of these earlier studies, important changes have occurred in the labor market, including large increases in the rate of employment for women (U.S. Bureau of the Census, 1994, Table 616), increases in the return to schooling (Blackburn *et al.,* 1991; Katz and Murphy, 1992), and a growing wage gap between jobs with high and low cognitive demands (Murnane *et al.,* 1995). A more up-to-date analysis, based on a nationally representative sample of both men and women, seems desirable in view of these labor market changes. There is a clear possibility that benefit estimates may be substantially larger with more recent data that are nationally representative.

This paper reports the results of such an analysis based on data from the National Longitudinal Survey of Youth (NLSY). Note that the paper only focuses specifically on the components of Schwartz's analysis that deal with the relationships between education, IQ, work participation, and earnings.

REVIEW OF SCHWARTZ'S METHODS AND RESULTS

The general framework developed by Schwartz is depicted in Fig. 1. The total effect of lead exposure on schooling (Arrow 1 + Arrow 2 × Arrow 1A) was estimated from results in a long-term follow-up study by Needleman *et al.* (1990). Schwartz points

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out that the total effect is larger than the effect due solely to lead-induced IQ loss (Arrow 2 × Arrow 1A) since other effects of lead exposure (e.g., reduced attention span) also contribute to reduced educational achievement (Arrow 1).

Arrow 3, the direct effect of IQ on earnings for persons who work, was estimated by Schwartz from the studies reviewed by Barth *et al.* (1984). Arrow 4, the direct effect of years of schooling on earnings for persons who work, was estimated from studies by Chamberlain and Grilliches (1977), Olneck (1977), Grilliches (1977), and Ashenfelter and Ham (1979). Arrow 5, the effect of schooling on employment participation (i.e., the probability of having any earnings at all), is measured by Schwartz as (1) the difference in participation rates between high school graduates and nongraduates from Krupnick and Cropper (1989) multiplied by (2) the increased risk of not graduating due to lead exposure from Needleman *et al.* (1990).

Arrow 2, the effect of lead exposure on IQ, is estimated by Schwartz from reviewing the results of numerous epidemiologic studies. Finally, the net decrement in earnings is the combined result of the loss in earnings for those who do work (Arrow 6) and the reduced participation rate (Arrow 7).

Schwartz provides an algebraic formulation of his approach in simpler terms. He notes that $E = P \cdot W$, where E is earnings, P is probability of working (the participation rate), and W is earnings of people who do in fact work. Therefore, the decline in earnings due to lead exposure (or the gain in earnings due to exposure avoided) can be expressed as

$$\Delta E = P \cdot \Delta W + W \cdot \Delta P + \Delta P \cdot \Delta W. \quad (1)$$

When ΔP and ΔW are small relative to P and W, the third term on the right-hand side of Eq. (1) becomes negligible so

$$\Delta E = P \cdot \Delta W + W \cdot \Delta P = E \cdot [(\Delta W/W) + (\Delta P/P)] \quad (2)$$

Equation (2) indicates that the decline in earnings due to lead exposure equals the baseline earnings figure, E, times the sum of two percentage changes: (1) the percentage decrease in earnings for people who do work plus (2) the percentage decrease in the probability of working at all (the participation rate). The sum of these percentage changes reported in Schwartz (1994) was a decrease of 0.432% for each 1μg/dl increase in a child's blood lead level. This figure was multiplied by Schwartz's estimate of E (the net present value of expected lifetime market and nonmarket earnings per child) of $301,000 to obtain his benefit estimate of $1300 per child.

The benefit percentage could also be expressed on a per IQ point basis using Schwartz's assumption of a 0.245 IQ point decrease for each 1 μg/dl increase in blood lead level. Dividing 0.432% by 0.245 yields a percentage earnings loss per IQ point decrement of 1.763. Applying this figure to Schwartz's value for E ($301,000) implies a loss per IQ point of $5307.

THE APPROACH OF THE CURRENT STUDY

This study used Schwartz's basic approach with minor extensions to explicitly estimate the direct effects of IQ on educational attainment (Arrow 1A) and on participation (Arrow 5A). (As noted above, Schwartz estimated combined effects for Arrows 1 and 1A.) New estimates were also developed for Arrows 3, 4, and 5. Since the analysis was limited to recent economic data rather than new epidemiologic data, no new estimates are provided for the direct effect of lead exposure on educational attainment (Arrow 1) and the effect of exposure on IQ (Arrow 2).

Estimation of these effects will yield an estimated percentage change figure analogous to Schwartz's earlier result of 0.432% per 1 μg/dl. Since the omission of Arrow 1 biases our estimate downward, we also present a corrected estimate incorporating Schwartz's information pertaining to Arrow 1.

The present study reports separate estimates for males and females. The analysis reported below indicates that percentage effects of lead exposure on earnings are clearly greater for females than for males.

We do not attempt to develop a revised estimate of E, since Schwartz's estimate is based on recent data. The reader should note, however, that Schwartz uses a very conservative approach in developing this estimate with regard to such factors as discounting and the relationship of earnings to the marginal productivity of labor in market work.

DATA AND METHODS

New estimates are obtained from analyses of data in the NLSY, which surveyed a stratified random sample of 12,686 persons aged 14–22 in 1979 and has carried out follow-up surveys of this sample annually since that year (Center for Human Resources Research, 1994). Our study uses data from 1990 on educational attainment (highest grade completed) and on annual earned income. (At that time, respondents ranged in age from 25 to 33.)

Three different relationships are estimated separately for male and female respondents using re-

TABLE 1

Regression Estimates for Arrows 1A, 3, 4, 5, and 5A

	Male[a]	Female	Schwartz[b]
1. IQ effect (+1 pt) on years of schooling (Arrow 1A)	+0.1007	+0.1007	+0.131[c]
2. IQ effect (+1 pt) on probability of participation ($\times 10^{-2}$) (Arrow 5A)	+0.1602	+0.3679	
3. Schooling effect (+1 year) on probability of participation ($\times 10^{-2}$) (Arrow 5)	+0.3536	+2.8247	
4. Schooling effect (+1 year) on 1990 earnings (Arrow 4)	+4.88%	+10.08%	+6%
5. IQ direct effect (+1 pt) on 1990 earnings (Arrow 3)	+1.24%	+1.40%	+0.5%

[a] Percentage effects for males and females are calculated at means reported in the Appendix.
[b] Sources are Schwartz (1994) and Center for Disease Control (1991), Appendix II.
[c] This figure also incorporates direct lead exposure effects on schooling (Arrow 1). See text for explanation.

gression techniques: (1) a least-squares regression of highest grade on cognitive ability; (2) a multiple probit regression of a 0–1 indicator of positive earnings in 1990 on highest grade and cognitive ability; and (3) a least-squares regression, for persons with positive earned income, of the logarithm of earnings on highest grade and cognitive ability. (The semilogarithmic form for the earnings regression follows the approach used in 16 of the 17 analyses reviewed by Barth *et al.* (1984).) Other variables were included in each regression to control for effects of family background (parents' education and income), the age of the respondent, ethnic identification (African-American, Hispanic, other), and residence location (urban vs farm vs other nonurban; south vs nonsouth).

The measure of cognitive ability used in the analysis is the Armed Forces Qualifying Test (AFQT) score for each NLSY respondent. (The AFQT was administered to all NLSY respondents in 1980 by the U.S. Defense Department.) The overall AFQT score is based on responses to three batteries of questions that test arithmetic, mathematics, and verbal skills. This test was used as a measure of cognitive ability in several of the studies relating cognitive ability to income that were reviewed by Barth *et al.* (e.g., Grilliches and Mason, 1972; Jencks, 1979). It has also been used as a measure of cognitive ability in a wide variety of studies in the sociology, psychology, and neurology literatures (e.g., Mare, 1980; Parcell and Menaghan, 1990; Luster and Dubow, 1992; Grafman *et al.,* 1988). In the current application, the AFQT score for each respondent was expressed as a percentile score and was then converted to IQ units by assigning a score to each percentile based on a normal distribution with a mean of 100 and a standard deviation of 15. [A very small number of extremely low (high) scores were truncated at 3 standard deviations below (above) the mean.] Since this translation of the AFQT score onto an IQ scale is an exact linear transformation of the AFQT percentile score, it does not influence the results of our statistical analysis.

Separate regression results were estimated for males and females. These results are presented in the Appendix to this paper.

RESULTS

The relevant findings of the regression analysis are summarized in Table 1; comparable estimates from Schwartz are also shown for comparison purposes. Row 1 reports our finding that each additional IQ point is associated with an increase of 0.1007 years of educational attainment for males and females. It is interesting to compare this result with Schwartz's calculation that for each one point IQ loss caused by lead exposure, there is a corresponding loss of 0.131 years of schooling (Center for Disease Control, 1991, Appendix II). The 0.131 figure was computed as the difference in years of schooling, divided by the IQ difference, for the high versus low lead exposure groups in Needleman *et al.* (1990) and Needleman and Gatsonis (1990). The estimate can be viewed a combining Arrows 1 and 1A in Fig. 1. One would therefore expect it to exceed our estimate of the IQ effect on schooling because we exclude direct lead effects (Arrow 1).

Results in Row 2 pertain to Arrow 5A (which was not explicitly included in Schwartz's study) and indicate that for males an additional IQ point increases the probability of having any earnings in a year by 0.0016. The corresponding effect for females is more than twice as large. In Row 3, the male–

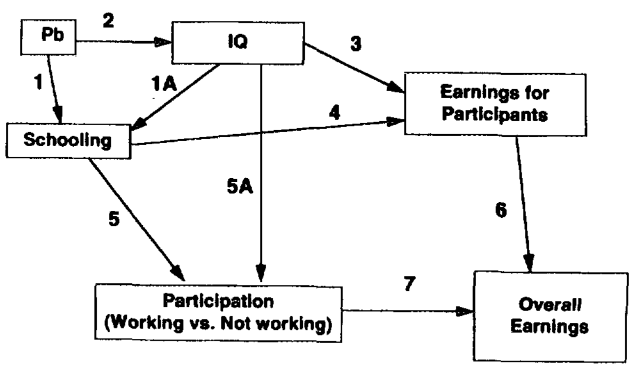

FIG. 1. Lead exposure effects on earnings.

TABLE 2
Overall Effects per IQ Point

	Male	Female	Schwartz
Results derived from regression estimates			
1. IQ direct + indirect effect on probability or participation ($\times 10^{-2}$) (Arrow 1A × Arrow 5 + Arrow 5A)	+0.1958 +0.2%	+0.6523 +0.81%	+0.47%
2. IQ direct + indirect effect on 1990 earnings (Arrow 1A × Arrow 4 + Arrow 3)	+1.731%	+2.415%	+1.29%
3. Total percentage effect (Row 1 + Row 2)	+1.931%	+3.225%	+1.763%
Results derived from regression estimates and Schwartz's schooling effect			
4. IQ direct + indirect effect on probability of participation ($\times 10^{-2}$) (0.131) years × Arrow 5 + Arrow 5A)	+0.2065 +0.215%	+0.7379 +0.911%	+0.47%
5. IQ direct + indirect effect on 1990 earnings (0.131 years × Arrow 4 + Arrow 3)	+1.879%	+2.720%	+1.29%
6. Total percentage effect (Row 4 + Row 5)	+2.094%	+3.631%	+1.763%

Notes. See Table 1 for explanation.

female differential is even more striking. An additional year of schooling raises the probability of earnings for females by 0.028, about eight times as large as the corresponding effect for males.

Direct effects of IQ and schooling on earnings are shown in Rows 4 and 5. The schooling effect is approximately twice as large in percentage terms for females as for males while the IQ effects are similar. In comparison to Schwartz's estimates, we find direct IQ effects that are more than twice as large (Row 5) and direct schooling effects that are much larger for females but not for males (Row 4).

The combined direct and indirect effects per IQ point are shown in Table 2. Row 1 shows a small participation effect for males that is actually somewhat lower than Schwartz's estimate but a corresponding effect for females that is 4 times as large. The earnings effects shown in Row 2 are considerably larger than Schwartz's estimates for both males and females. In this case, our estimate for females is about 1.4 times our estimate for males. Total percentage effects are shown in Row 3. Once again both figures exceed Schwartz's estimates and the figure for females is considerably larger.

We noted previously a downward bias in our regression estimates in that we did not capture non-IQ effects of lead exposure on schooling. We also noted that Schwartz derived a combined effect of lead exposure on schooling of 0.131 years per IQ point loss that incorporated these non-IQ effects. To correct for the bias in our estimate, we incorporated the estimated combined effect into our calculations (replacing our estimate of 0.1007 years per IQ point). Results of this correction are shown in Rows 4 through 6 in Table 2. While all estimated percentage effects increase, the relative increase for females is considerably larger. The corrected overall estimate of a 3.631% gain in earnings per IQ point is more than twice as large as Schwartz's estimate. (There are, of course, other possible sources of gender differences in effects which we did not explore, such as differences in the physiologic effects of blood lead or differences in the effect of lead exposure on schooling.)

The amount of the upward revision in earnings benefits implied by these corrected estimates depends upon the ratio (not reported by Schwartz) of E for females to the corresponding value for males. Assuming this ratio is in the range of 0.5 to 1.0, and that each birth cohort has an equal number of males and females, our corrected estimates imply an upward revision of 47.9 to 62.4%. Thus, a conservative estimate of this revision is 50% or approximately \$2.5 billion per birth cohort. (Of course, a less conservative approach of estimating E would imply an even larger upward revision in dollar terms.)

CONCLUDING REMARKS

The seminal study by Schwartz synthesized a wide variety of relevant research and developed a valuable framework for deriving comprehensive estimates of social benefits from reduced environmental lead exposure. In the case of children, Schwartz's estimates indicated that almost 75% of the benefits are in the form of earnings gains. Recent labor market trends point to the need to revise these estimates upward. Our analysis suggests that this upward revision should be at least 50% of the \$5.060 billion in earnings per 1 μg/dl reduction previously reported.

It is reasonable to expect the importance of education and cognitive skills in our economy to continue growing in the future. Our analysis suggests this will have a major effect in further increasing the benefits of lead exposure reduction among children.

More generally, the rapid pace of economic change and the accumulation of additional epidemiologic data highlight the need for regular reassessment of social benefit estimates. This reassessment process will ensure that policy analysts and decision-makers have up-to-date information in setting program priorities for protecting the environment and the public's health and well-being.

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APPENDIX

Results of Regression Analysis with NLSY Data: Estimate Coefficients (Standard Errors in Parentheses)

	Highest grade		Participation (1 = working, 0 = not)		Log 1990 earnings	
	1	2	3	4	5	6
Sample	Males	Females	Males	Females	Males	Females
Dependent variable mean	13.35	13.56	0.96	0.81	9.95	9.37
			Independent variables			
Highest grade			0.04097	0.10427	0.047621	0.096016
			(0.02055)	(0.01371)	(0.007088)	(0.009970)
Family income unknown	-0.016331	-0.002469	0.00217	0.16519	0.109432	0.135450
	(0.084818)	(0.084949)	(0.12341)	(0.08233)	(0.044471)	(0.060393)
African-American	1.125425	1.383839	−0.21895	0.05318	−0.152120	0.121420
	(0.077113)	(0.076302)	(0.09480)	(0.06882)	(0.037719)	(0.053083)
Mother's highest grade	0.050928	0.089589	0.02972	−0.00244	−0.018752	0.001515
	(0.012503)	(0.012297)	(0.01584)	(0.01088)	(0.006030)	(0.008389)
Rural nonfarm	0.054676	0.051209	−0.29060	0.27926	0.023072	−0.014849
	(0.133586)	(0.139028)	(0.22215)	(0.12335)	(0.062508)	(0.091986)
Nonsouth	−0.089239	−0.161860	−0.14963	−0.07811	−0.015880	−0.030830
	(0.060542)	(0.059559)	(0.08091)	(0.05275)	(0.028803)	(0.039964)
Age (in 1987)	−0.037328	−0.003501	0.00824	−0.03601	0.045070	0.008025
	(0.012722)	(0.012655)	(0.01688)	(0.01102)	(0.006040)	(0.008437)
Hispanic	0.724895	0.854372	−0.04651	0.03728	0.031254	0.146536
	(0.090523)	(0.087892)	(0.11365)	(0.07525)	(0.042253)	(0.058916)
Family income (in 1979) $\times 10^{-3}$	0.013006	0.0114222	0.00786	0.00716	0.007008	0.008455
	(0.002618)	(0.002600)	(0.00426)	(0.00242)	(0.001198)	(0.001643)
IQ (AFQT)	0.100713	0.100696	0.01856	0.01358	0.012307	0.013991
	(0.002227)	(0.002469)	(0.00367)	(0.00265)	(0.001295)	(0.001996)
Father's highest grade	0.073027	0.062353	−0.02355	−0.00435	0.013395	0.001849
	(0.009831)	(0.009611)	(0.01315)	(0.00847)	(0.004783)	(0.006524)
Urban	0.114487	0.083336	−0.42630	−0.02900	−0.001841	−0.007618
	(0.118708)	(0.126531)	(0.20314)	(0.10919)	(0.055191)	(0.084106)
R^2	0.674	0.650	N/A	N/A	0.441	0.374
n	4491	4441	3506	3726	3318	2955

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