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The Decline of Schooling Productivity in OECD Countries

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Abstract:

Based on Baumol's cost-disease model, we develop two alternative measures of the change in the productivity of schooling. Both productivity measures are based on changes in the relative price of schooling. We find that in most OECD countries the price of schooling has increased faster in 1970-94 than would be compatible with constant schooling productivity. In addition, we show that the average performance of pupils has remained constant at best in most OECD countries. Our results imply a larger decline in the productivity of schooling in many OECD countries than in the United States.

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I. INTRODUCTION

In the average OECD country, schooling accounts for larger fractions of Gross Domestic Product (GDP) and employment than many manufacturing industries.[1] Nevertheless, very little is known about changes in the productivity of schooling. Like other services, schooling is most likely to be a sector with stagnant productivity. Similar to performing a symphony or a haircut, schooling is labor intensive and the applied technology may not have changed much over the past quarter century, which is in stark contrast to technological developments in manufacturing industries. The labor input required to produce an automobile has declined significantly, but performing a symphony or a haircut requires the same amount of labor input as ever. Schooling may not be very different.

Despite new communication technologies and the internet, the labor input required to teach a given level of basic literacy and numerical skills has most likely remained constant. Hence we expect zero productivity growth of schooling. We use Baumol's (1967) famous cost-disease model to illustrate the implications of stagnant schooling productivity. In a two-sector economy with labor as the only factor of production, the sector with stagnant productivity (schooling) will face an increasing relative price, which reflects increasing cost pressures. The model shows that the sectoral difference in productivity growth

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1 In the OECD, spending on schools accounted for 3.7 percent of GDP in 1994 and teachers in primary and secondary education accounted for 2.9 percent of total employment in 1995 (OECD 1997, p. 63 and p. 123).

determines the increase in the relative price of schooling. If, however, the increase in the relative price of schooling exceeds the rate of productivity growth in other sectors of the economy, the productivity of schooling must have declined given that the quality of schooling output did not change over time (Section II).

We derive the price of schooling by dividing total current public expenditure on primary and secondary education by the number of pupils enrolled in public schools. We normalize the change in the price of schooling in 1970-1994 by three alternative measures: a GDP deflator, a deflator for producers of government services (PGS), and a deflator for community, social, and personal services (CSPS). Our calculations suggest that in many OECD economies, the price of schooling has risen faster than would be compatible with stagnant schooling productivity. For a given quality of schooling output, these findings imply that schooling productivity has declined (Section III).

We use performance of pupils in standardized achievement tests as a measure of the quality of schooling output. Consistent time series information on changes in the performance of pupils up to now exists only for the United States, where the cognitive achievement of pupils by and large did not change in 1970-1994. We use the constant performance of US pupils as our intertemporal benchmark. By reformatting the level and the distribution of test scores in previous international cross-country tests, we derive a measure of the cognitive

achievement of pupils in mathematics and natural science in OECD countries which can be traced over time relative to the constant performance of US pupils (Section IV).

We find no evidence of substantial improvements in our measure of the quality of schooling output for a sample of OECD countries in 1970-1994, with Sweden and the Netherlands as probable minor exceptions. Hence for many OECD countries, our estimates of the decline in schooling productivity in Section III can be regarded as a lower bound. Our results reveal that what has been called a productivity collapse in US schools (Hanushek 1997) appears to be a small problem when compared with the estimated productivity decline of schooling in other OECD countries.

II. THE PRICE OF SCHOOLING AND SCHOOLING PRODUCTIVITY

In many service industries, measures of total expenditure and inputs are readily available but measures of prices and productivity are notoriously difficult to come by because service output is difficult to disentangle from service price. In schooling, the situation is different. Schooling output can be measured independent of price, because there are regular measures of the quality of schooling. Given that the cognitive achievement of students did not change over time, as in the United States in 1970-1996 (Hanushek 1998), total schooling expenditure (exp_S) equals price (p_S) times the number of pupils (pup_q), so the

price of schooling follows as total schooling expenditures divided by the number of pupils with constant quality:

(1) $p_S = exp_S \,/\, pup_q$.

Knowing the change in the relative price of schooling allows for an assessment of the change in schooling productivity. This reasoning follows from the cost-disease model suggested by Baumol (1967). A constant amount of labor (*L*) is the only factor of production. The model has two sectors. We call one sector *S* (schooling), with productivity growth r_S. The other sector (*O*) has productivity growth r_O. Sectoral productivity growth differs, with r_O larger than r_S. Output of the two sectors can be described by two production functions as

(2) $Y_S = a\, L_S\, e^{r_S \cdot t}$ and

(3) $Y_O = b\, L_O\, e^{r_O \cdot t}$,

where Y_i is the level of output of sector *i* in time *t* (*t* subscripts are omitted), *a* and *b* are constants, and L_i is quantity of labor employed in sector *i*.

Wages per unit of labor (*w*) in the economy are determined in a competitive labor market by labor supply and labor demand. Profit-maximizing firms will demand labor until the value of the marginal product of a unit of labor equals the wage. The marginal products of labor in the two sectors are given by the derivation of the two production functions as

(4) $\frac{\delta Y_S}{\delta L_S} = a e^{r_S \cdot t}$ and

(5) $\frac{\delta Y_O}{\delta L_O} = b e^{r_O \cdot t}$.

Equating the value of the marginal products to the wage gives

(6) $w = p_S \, a e^{r_S \cdot t} = p_O \, b e^{r_O \cdot t}$

and hence the relative price of schooling follows as

(7) $p_S \, / \, p_O = (b \, / \, a) e^{(r_O - r_S) \cdot t}$.

This equation implies that the percentage change over time in the relative price of schooling equals the sectoral difference in productivity growth:

(8) $\frac{\delta (p_S \, / \, p_O) \, / \, \delta t}{p_S \, / \, p_O} = r_O - r_S$.

Thus, a change in the relative price of schooling which exceeds the rate of productivity growth in the other sectors of the economy implies that the productivity of schooling must have declined, given that the quality of schooling output did not change as assumed in equation (1).

For an empirical analysis, the model can be reformulated to focus on the GDP-deflated price of schooling and on total factor productivity growth by using two additional equations. First, the price level of GDP may be written as

(9) $p_{GDP} = p_S^{(Y_S \, / \, Y)} \cdot p_O^{(Y_O \, / \, Y)}$,

with $Y_S \, / \, Y$ as the output share of schooling and $Y_O \, / \, Y$ as the output share of

the other sectors of the economy. It follows that

(10) $\Delta p_S - \Delta p_{GDP} = \Delta p_S - \left(\frac{Y_S}{Y}\right)\Delta p_S - \left(\frac{Y_O}{Y}\right)\Delta p_O$ and hence

(11) $\Delta p_S - \Delta p_O = \frac{\Delta p_s - \Delta p_{GDP}}{Y_O / Y} = r_O - r_S$,

where Δ indicates an annual rate of change.

Second, the economy-wide growth rate of total factor productivity is given by

(12) $g_{TFP} = r_S \frac{Y_S}{Y} + r_O \frac{Y_O}{Y}$, which can be rearranged to

(13) $r_O - r_S = \left(g_{TFP} - r_S\right) / \left(Y_O / Y\right)$.

Inserting (13) into (11) and subtracting g_{TFP} from both sides gives

(14) $\Delta p_S - \Delta p_{GDP} - g_{TFP} = -r_S$,

which shows that an increase in the GDP-deflated price of schooling which exceeds the growth rate of total factor productivity growth implies that schooling productivity must have declined.

Another possibility to use the model for an empirical analysis is to focus only on the service sector. In this interpretation, *S* indicates schooling as before and *O* indicates other service industries (*Ser*), which are known to exhibit stagnant or near-stagnant productivity. Otherwise, equations (2)-(8) could be used as before, with r_O now expected to be close to zero. In this setting, equation (8) changes to

(8') $\Delta p_S - \Delta p_O^{Ser} = r_O^{Ser} - r_S$ and hence

(15) $\Delta p_S - \Delta p_O^{Ser} - r_O^{Ser} = -r_S$,

which shows that a positive change in the price of schooling relative to the change in the price of other services implies that schooling productivity must have declined, at least relative to the productivity of the reference sectors. The advantage of this approach is that estimates of total factor productivity growth are not required to determine changes in the productivity of schooling. The disadvantage is that only relative changes in productivity can be identified as long as r_O^{Ser} is presumed rather than observed to be close to zero.

Estimates of the change in schooling productivity based on equations (14) and (15) will be identical if

(16) $\Delta p_{GDP} + g_{TFP} = \Delta p_O^{Ser} + r_O^{Ser}$.

If other services than schooling actually exhibit stagnant productivity $(r_O^{Ser} = 0)$, it follows from equation (8) that their relative price should grow with r_O, so that similar to equation (14) it also follows that

(17) $\Delta p_O^{Ser} - \Delta p_{GDP} = g_{TFP}$,

which reproduces equation (16) for $r_O^{Ser} = 0$. Hence with perfect data, choosing a reference service sector with stagnant productivity should result in identical empirical estimates of the change in schooling productivity based on equations (14) and (15).

III. MEASURING CHANGES IN THE PRICE OF SCHOOLING

As in equation (1), we measure the price of schooling by dividing total current expenditure on primary and secondary education by the number of pupils enrolled:

$$(18) \quad p_S = EXPPUP_t^i = \frac{CUREXP_t^i \cdot \left(PERFIR_t^i + PERSEC_t^i\right)}{\left(PUPFIR_t^i + PUPSEC_t^i\right)} \quad ,$$

where $EXPPUP_t^i$ is educational expenditure per pupil in country *i* at time *t*, $CUREXP_t^i$ is current educational expenditure, $PERFIR_t^i$ is the percentage of current expenditure spent at the first level of education, $PERSEC_t^i$ is the percentage of current expenditure spent at the second level of education, $PUPFIR_t^i$ is the number of pupils enrolled at the first level of education, and $PUPSEC_t^i$ is the number of pupils enrolled at the second level of education.

Based on equation (18), we calculate the average annual growth rate of the price of schooling for a sample of OECD countries in 1970-1994. Data on schooling expenditure and pupils are taken from various issues of the UNESCO Statistical Yearbook.[2] For several countries, the UNESCO data had to be

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2 In the UNESCO data, the identification of primary and secondary educational institutions is based on the International Standard Classification of Education (ISCED). According to ISCED, education at the first level (ISCED level 1) is education whose main function is to provide the basic elements of education (e.g. elementary schools, primary schools). Education at the second level (ISCED levels 2 and 3) provides general and/or specialized instruction as provided by middle schools, secondary schools, high schools, and vocational or technical institutions and is based on at least four years of previous

adjusted to ensure comparability over time. In the appendix, we list all adjustments made. The appendix also includes all data used for our calculations.

Basic Results

Column (1) of Table 1 shows the average annual nominal growth rate of the price of schooling for OECD countries in 1970-94. To derive a measure of the change in the relative price of schooling, we use national accounts statistics provided by UN (var. iss.) to calculate three alternative deflators. The GDP deflator (column (2)) measures the increase in the economy-wide price level and can be used to derive an estimate of the change in the price of schooling relative to all other prices. The deflator for producers of government services (PGS, column (3)) measures the increase in the price of services in the public sector, which includes schooling. The deflator for community, social and personal services (CSPS, column (4)) measures the increase in the price of privately provided services,[3] which may be similar to schooling in terms of their labor

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instruction at the first level. In our analysis, we do not consider pre-primary education or education at the third level (e.g. universities).

3 In the System of National Accounts (SNA), "Community, social and personal services" (CSPS) equal that part of ISIC category 9 which is privately provided in a profit-oriented way. That is, economic activities of producers of government services, private non-profit services to households, and domestic services are subtracted from ISIC 9 to obtain only those services which are supplied by establishments whose activities are intended to be self-sustaining, whether through production for the market or for own use. ISIC category 9 does not include services such as wholesale and retail trade, communication and transportation, and financing, insurance, and real estate and business services, which all may be considered to experience at least modest productivity gains.

intensity and their expected low rate of productivity growth.[4]

For a sample of 15 OECD countries all three deflators are available for the period 1970-1994. For every country in the sample, the two service deflators differ only slightly from each other and exceed the GDP deflator by about one percentage point. These empirical facts are in line with the basic assumption of the cost-disease model, namely that productivity growth in services such as schooling is below the economy-wide average.

There are large differences across OECD countries in the GDP-deflated change in the price of schooling, ranging from 9.2 percent in the case of Portugal to 1.7 percent in the case of Sweden and the Netherlands. Service-sector-deflated changes in the price of schooling also differ substantially across OECD countries, again with relatively low rates for Sweden and the Netherlands. Notwithstanding substantial differences in the deflator-specific results for some countries like France, the general impression remains that the implied changes in the relative price of schooling appear to be too large for almost all countries to be compatible with the assumption of constant schooling productivity, because that would imply unreasonably high rates of total factor productivity growth as well as unreasonably high rates of productivity growth in labor-intensive public sector services and in private community, social and

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4 Both Rothstein and Mishel (1997) and Hanushek (1997) use a Consumer Price Index for Services (CPI-S) and a "Net Service Index" (calculated by removing expenditure on medical care and housing from the CPI-S). However, production-side deflators like PGS and CSPS appear to be preferable according to the underlying model.

personal services.

Dougherty and Jorgenson (1997) report average annual rates of total factor productivity growth for G7 countries in 1973-1989. They find differences in the rate of total factor productivity growth ranging from 0.3 percent in the United States to 1.4 percent in France (Table 2, column (4)). Subtracting these figures from the GDP-deflated increase in the price of schooling, we see that the price of schooling in G7 countries has risen by 2.2-4.4 percentage points faster than the rate of total factor productivity growth, which implies a decline of schooling productivity of that order (column (1)).

Our estimates of the change in the price of schooling relative to the two other labor-intensive service sectors support our finding that schooling productivity has declined substantially in many OECD countries. The results based on the PGS deflator and the CSPS deflator are by and large similar and also confirm the direction of our estimates for G7 countries (columns (2) and (3)). Taken together, our three measures of changes in the relative price of schooling indicate that schooling productivity seems to have declined in many OECD countries, and that there seem to be large differences in the change of schooling productivity across OECD countries.

Results for the United States: A Digression

Our results in Table 2 suggest that most OECD countries display a higher increase in the relative price of schooling than the United States. For the United

States, we find that schooling productivity declined by 1.2 percent per year relative to other service sectors, which contrasts with Hanushek's (1997, p. 192) result that "educational productivity is falling at 3.5 percent relative to low productivity sectors of the economy." Differences between national and UNESCO data, differences in the deflators employed, differences in the time periods considered, or a combination of all these factors could explain the different results for the United States.

Hanushek (1997) uses education data from the Digest of Education Statistics of the US Department of Education. The reported annual nominal increase in school expenditure per pupil is 7.6 percent in 1982-1991 and 9.5 percent in 1967-1991.[5] Using the same source (US Department of Education 1998) to calculate the figures for our sample periods 1970-94 and 1970-90, we get 8.2 percent and 9.2 percent, which is close to our US figures calculated on the basis of UNESCO data (see Table 1, column (1)).[6]

Furthermore, Hanushek (1997) uses a Consumer Price Index for services (CPI-S) to deflate nominal expenditure per pupil. The entry in his Table 2

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5 Since education data are reported by school year, e.g. 1990-91, it is arbitrary whether the data are allocated to the beginning (1990) or to the end (1991) of the school year. While Hanushek (1997) uses the end of the school year, we use the beginning of the school year because we think that decisions on educational spending and numbers of students enrolled are for the most part fixed at the beginning of the school year. Therefore, what Hanushek calls 1967-91 would be called 1966-1990 in our classification.

6 The difference between the US Department of Education figure of 8.2 percent and the UNESCO figure of 7.8 percent for the 1970-94 period confirms that our 1994 figure may underestimate the increase in the price of schooling because of the structural break in the UNESCO data between 1990 and 1994 (see below).

incorrectly reports the CPI deflator and not the CPI-S deflator in 1982-91. Recalculating the CPI-S deflator on the basis of the original data (Council of Economic Advisors 1999) reveals that the actual increase in the CPI-S is 4.8 percent in 1982-1991 and 7.0 percent in 1967-1991. Therefore, the decline in schooling productivity estimated by Hanushek is 2.8 percent in 1982-91 and 2.5 percent in 1967-91, rather than 3.5 percent. For our sample period 1970-94, the average annual change in the CPI-S deflator is 6.6 percent. That is, it is exactly equal to the PGS deflator and the CSPS deflator calculated on the basis of UN data (see Table 1).

The difference between the annual rate of change in educational expenditure per pupil and the annual rate of change in the CPI-S deflator equals 1.5 percent in 1970-1994. Our reported estimate of 1.2 percent in Figure 1 reflects that our 1994 figure most likely underestimates educational expenditure because of a structural break in the UNESCO data series (see below). Otherwise, the difference between our results and Hanushek's results are neither related to different data sources nor to different deflators and can be completely ascribed to differences in the sample period. In the United States, the increase in the price of schooling has been similar to the increase in the prices of other services since the early 1990s, which is the sole reason for our lower estimate of the increase in the relative price of US schooling in 1970-1994 compared to the (corrected) estimates for 1967-1991 and 1982-1991 by Hanushek (1997).

Robustness of Results

Our general results for 1970-1994 may suffer from structural breaks in the education data series which are due to certain reclassifications after 1990 in countries participating in a survey jointly conducted by UNESCO, OECD, and Eurostat. Comparisons of educational time series data for the 1990s are potentially unreliable because of variations in the schooling programs covered by secondary education and because of conceptual changes which distribute expenditure previously reported as a residual category among the different levels of education. Overall, it seems that in the UNESCO statistics, a large increase in pupils reported to be enrolled in secondary education is not accompanied by an equivalent increase on the expenditure side. For example, the number of pupils enrolled in secondary education in the United Kingdom was 46.4 percent higher in 1993 than in 1991, while expenditure at the secondary level were only 28.5 percent higher.[7] The structural break in the education data series may cause a downward bias in our estimated increase in the price of schooling because the increase in expenditure seems to be underreported relative to the increase in pupils for a number of countries between 1990 and 1994.

To control for this possibility, we calculate the average annual change in the price of schooling in 1970-1990, where no structural break biases our findings. As expected, column (5) of Table 1 shows that the price of schooling increased

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7 This increase in expenditure is even overstated since expenditure in 1993 include capital expenditure, which are excluded in 1991.

faster in every country except Mexico in 1970-1990 than in 1970-94. For many OECD countries, the annualized difference is larger than one percentage point. This finding suggests that our estimates of the increase in the price of schooling in 1970-1994 probably underestimate the true productivity decline in schooling.

In contrast, our findings may overstate the true increase in the price of schooling if spending on more expensive secondary education increased relative to spending on primary education. To take account of such possible shifts in the structure of spending, we calculate changes in the price of schooling in 1970-1994 as if the shares of pupils in primary and in secondary education had remained constant at their 1970 level. Column (6) of Table 1 provides the results. The largest difference relative to column (1) is 0.6 percentage points in the case of Mexico.[8] We conclude that a shift in the structure of expenditure towards secondary education cannot account for the large increase in the relative price of schooling in most OECD countries.

One major objection remains to our finding of a decline in schooling productivity. Our empirical measure of the price of schooling is based on

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8 In Canada, Denmark, and the United States, no breakdown of schooling expenditure between the first and second level is available for 1970 data. However, the shift between first-level and second-level pupils was small in these countries. In the United States, the share of first-level pupils in first-and-second-level pupils changed from 59 percent in 1970 to 53 percent in 1994. In Germany, the 1994 expenditure breakdown is not available. However, the fact that the calculation assuming a constant 1970 pupil share gives an average annual increase in the price of schooling of 7.6 percent for the period 1970-90 as compared to the previous estimate of 8.5 percent suggests that up to one percentage point of the increase in the price of schooling in Germany may be due to the large shift in the German pupil population from primary to secondary education.

expenditure per pupil. Rising expenditure per pupil may not only reflect an increase in the price of schooling, but also an improved quality of schooling output. If the quality of schooling output had actually improved over time, the calculated changes in the relative price of schooling could not be interpreted as indicating a decline of schooling productivity. To clarify this possibility, we calculate a measure of the change in schooling output.

IV. MEASURING CHANGES IN SCHOOLING OUTPUT

The problem with measuring schooling output over time is that consistent time-series data on the cognitive achievement of pupils are available only for the United States. The National Assessment of Educational Progress (NAEP) began to monitor the performance of US pupils aged 9, 13 and 17 years in mathematics and science in the early 1970s. The NAEP has used the same assessment content and administration procedures over time, so the reported average test scores of US pupils are intertemporally comparable.

The test scores show that the average performance of US pupils did not change significantly in 1970-1994. While mathematics and science test scores for 9 and 13 year old pupils have slightly increased, the performance of 17 year old pupils, representing the quality of schooling output at the end of secondary education, has slightly decreased (Figure 1). As a benchmark for our further calculations, we take the cognitive achievement of US pupils to be constant in 1970-1994.

In addition to the intertemporal US evidence, there is cross-country evidence on student performance for selected years. The International Association for the Evaluation of Educational Achievement (IEA) has conducted cross-country science studies in 1970/71 and in 1983/84, and cross-country mathematics studies in 1964 and in 1980-82. The IEA's Third International Mathematics and Science Study (TIMSS), which integrates the two subjects, was conducted in 1994/95. These studies include achievement tests for pupils at different ages. All studies include achievement tests conducted for pupils in the middle and final school years, and except for the two mathematics studies, pupils were also tested in the primary school years.

To match our results for changes in the relative price of schooling with results for changes in the quality of schooling output, we are interested in a comparison of the cognitive achievement of pupils in 1970 and in 1994. We construct two measures to compare the performance of pupils over time. One measure only focuses on the results of the science studies, which are available for 1970 and 1994. The other measure is an equally weighted average of the results of the science and the mathematics studies, where the latter are only available for 1964 instead of 1970.

We limit our sample to countries which have participated in both the 1970 study and the 1994 study. This leaves us with a sample of 11 OECD countries. We provide background information on achievement data in the appendix and

we list the original results of the international achievement tests in Table A.2. A direct comparison of the results of the 1970 and the 1994 international tests is impossible because the design of test questions, the distribution of difficult and easy questions within a test, and the format in which test results are reported was not held constant. Nevertheless, we can calculate changes in the performance of pupils for each country over time subject to specific assumptions about the level and the distribution of the reported test results. This is possible because independent of the test actually conducted, in each case we know the performance of pupils from other countries relative to the constant performance of US pupils, which can serve as an intertemporal benchmark.

Even after normalizing the test results to a common level, a direct comparison would be misleading. The reason is that the standard deviation of the reported test results within our sample of 11 OECD countries varies substantially between 1970 and 1994, e.g., from 0.239 in 1970 to 0.037 in 1994 in the science test for the middle school years. These figures imply that constant performance of pupils in country *A* at one standard deviation above the sample mean would translate into a test score of 23.9 percent above the mean in 1970 but only of 3.7 percent above the mean in 1994. That is, one would falsely infer a relative decline in performance when not considering the differences in the standard deviations of the test results, which reflect the different test designs in 1970 and 1994.

We use three hypotheses to adjust the reported results of the separate subtests for differing means and standard deviations. Our first hypothesis is that

H1: The mean and the standard deviation are constant across all subtests within our sample of 11 OECD countries.

Under H1, we transform the original test scores of Table A.2 according to

$$(19) \quad T_t^i(H1) = \left(\frac{S_t^i}{\overline{S}_t} - 1 \right) \cdot \frac{\left(\sigma/\overline{S}\right)_{TIMSS}}{\left(\sigma/\overline{S}\right)_t} + 1 \quad ,$$

where $T_t^i(H1)$ is the transformed test score for country *i* in subtest *t* under H1, S_t^i is the original test score for country *i* in subtest *t*, $\overline{S}_t$ is the mean of test scores of our OECD sample in subtest *t*, $\left(\sigma/\overline{S}\right)_{TIMSS}$ is the average coefficient of variation (ratio of the standard deviation to the mean) of the OECD sample in the TIMSS subtests, and $\left(\sigma/\overline{S}\right)_t$ is the actual coefficient of variation of the OECD sample in subtest *t*.[9]

Given H1, we derive a measure of the change in the cognitive achievement of pupils in country *i* relative to the performance of US pupils as

$$(20) \quad ISO^i = \frac{\frac{1}{s}\sum_s \frac{1}{a}\sum_a \frac{T_{94,s,a}^i}{T_{94,s,a}^{US}}}{\frac{1}{s}\sum_s \frac{1}{a}\sum_a \frac{T_{70,s,a}^i}{T_{70,s,a}^{US}}} \cdot 100 \quad ,$$

9 The results derived on the basis of equation (19) are independent from the level of the mean, which is chosen to be the same in all subtests. The average coefficient of variation in the TIMSS subtests was chosen as the coefficient of variation common to all tranformed test scores.

where ISO^i is an index of schooling output of country *i* in 1994 with base year 1970 set to 100, $T^i_{t,s,a}$ is the transformed test score of country *i* at time *t* in subject *s* and age group *a*, subject *s* is either equal to 1 (science only) or to 2 (mathematics and science), and age group *a* is equal to 3 (with 1 = primary school years, 2 = middle school years, and 3 = final school years) except for the 1964 mathematics study, where it is 2 (given that there were no tests in the primary school years).[10]

The hypothesis of a constant mean and standard deviation in our OECD sample is justified if the distribution of test scores across OECD countries did not change substantially over time.[11] That is, H1 implies that the average standard deviation reported under the TIMSS test design also prevails in all subtests conducted in our sample of countries in the early 1970s. Column (1) of Table 3 shows our results under H1 for the science tests, and column (2) for the combined mathematics and science tests. We find that the performance of pupils in natural science and mathematics did not change much within our sample of OECD countries under H1.

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10 Missing data for subtest scores, as evident from Table A.2, are replaced by assuming that the test score of a country relative to the United States in a specific subtest is equal to the average score of that country relative to the United States in the other subtests for the given subject and year.

11 Hanushek and Kim (1995) assume in one of their calculations that the mean and the standard deviation remain constant *for the sample of countries participating in the respective subtest*. This is a problematic assumption if different groups of countries participate in different subtests. For instance, only developed countries participated in the first IEA mathematics test, while many developing countries participated in the TIMSS tests.

Applying a different coefficient of variation than the one which prevailed under the TIMSS subtests would result in what might be called a concertina effect. A higher coefficient of variation would move our *ISO* figures further away from 100, while a lower coefficient of variation would move our *ISO* figures closer to 100. Therefore, all our results derived for different hypotheses regarding mean and standard deviation can only be interpreted in qualitative terms. An *ISO* figure smaller than 100 means a decrease in the performance of pupils in 1970-1994. This figure can be compared across countries, but not in quantitative terms. For example, we estimated that New Zealand's decrease in science performance under H1 (87.9) was larger than Japan's decrease in science performance (97.2), but our measure does not tell by how much it actually changed because any other common coefficient of variation might be used in equation (19).

Hence assuming alternative standard deviations of test results across countries could have a large impact on our measure of changes in schooling output. To check for the robustness of our results derived under H1, we consider two further assumptions regarding mean and standard deviation of test results.

We next assume that

H2: The US test score and the standard deviation of our OECD sample are constant across all subtests.

This hypothesis takes directly into account that the performance of US pupils

did not change significantly in 1970-1994, but it allows the sample mean to change. For our calculation of the transformed test scores under H2, we use

$$(21) \quad T_t^i(H2) = \left(\frac{S_t^i}{S_t^{US}} - 1 \right) \cdot \frac{\left(\sigma / S^{US}\right)_{TIMSS}}{\left(\sigma / S^{US}\right)_t} + 1 \quad ,$$

where $T_t^i(H2)$ is the transformed test score for country *i* in subtest *t* under H2, S_t^{US} is the original US test score in subtest *t*, $\left(\sigma / S^{US}\right)_{TIMSS}$ is the average ratio of the standard deviation of the OECD sample to the US test score in the TIMSS subtests, and $\left(\sigma / S^{US}\right)_t$ is the actual ratio of the standard deviation of the OECD sample to the US test score in subtest *t*. Using the US test score instead of the sample mean to normalize the test results to a common level, we get transformed test data under the hypothesis that each subtest has the same US test score and the same standard deviation of the OECD sample (but different means).[12] Columns (3) and (4) of Table 3 show our results under H2, which are almost identical to the results derived under H1. For most countries, the quality of schooling output appears to have remained unchanged in 1970-1994, if not declined.

Finally, we assume that

H3: The US test score and the deviation of the test scores of our OECD sample from the US test score (as opposed to the standard

12 Results derived under H2 (and H3) are independent from the chosen level of the US test score applied to all subtests.

deviation of the sample) are constant across all subtests.

We calculate the deviation of the sample test scores from the US test score by

$$(22) \quad d_t^{US} = \sqrt{\frac{1}{n}\sum_{n}\left(U_t^i - U_t^{US}\right)^2} \quad ,$$

where d_t^{US} is the deviation from the US test score in subtest *t*, *n* is the number of countries in the sample (*n=11*), and $U_t^i = S_t^i / S_t^{US}$.

Using equation (22) we can transform the original test scores according to

$$(23) \quad T_t^i(H3) = \left(\frac{S_t^i}{S_t^{US}} - 1\right) \cdot \frac{d_{TIMSS}^{US}}{d_t^{US}} + 1 \quad ,$$

where $T_t^i(H3)$ is the transformed test score for country *i* in subtest *t* under H3, d_{TIMSS}^{US} is the average deviation of the sample test scores from the US test score in the TIMSS subtests, and d_t^{US} is the actual deviation of the sample test scores from the US test score in subtest *t*. In this case, each subtest has the same US test score and the same deviation of the test scores of the OECD sample from the US score. Columns (5) and (6) of Table 3 show our results under H3, which do not differ substantially from our results for changes in the quality of schooling output derived under H1 and H2.

We interpret our findings under H1-H3 as suggesting that no OECD country has achieved a sizable increase in schooling output in 1970-1994. While there may have been a slight increase in the cognitive achievement of pupils in the Netherlands and in Sweden, and probably constant performance in Italy, all

other countries in the sample seem to have faced a decline in student achievement in mathematics and science. On average, the performance of pupils appears to be flat in OECD countries in 1970-1994.

V. CONCLUSION

Figure 2 summarizes our empirical findings. We plot the average change in the performance of pupils in science and mathematics against the average increase in the relative price of schooling. We find a negative relation between our measure of the change in the quality of schooling output and changes in the relative price of schooling across OECD countries (the Pearson rank correlation coefficient is -0.47). Since the quality of schooling output tends to have declined in those countries with the highest increase in the relative price of schooling, the true decline in schooling productivity could be underestimated when measured as reported in Table 2.

We conclude that what has been termed a productivity collapse in US schools by Hanushek (1997) is dwarfed by the decline of schooling productivity in many other OECD countries, with Sweden and the Netherlands as probable exceptions. Only in these two countries, an increase in our measure of student performance is accompanied by a moderate increase in the relative price of schooling. Other OECD countries in our sample experienced larger increases in the relative price of schooling than the United States and, with the exception of Italy, a relative decline in the performance of their pupils in cognitive

achievement tests.

The observed large international differences in the decline of schooling productivity are a question for further research. Different schooling institutions may be one reason for differences in the decline of productivity. For instance, differences in the degree of competition between private and public schools, the existence of nation-wide examinations, or the degree of autonomy of schools in deciding on the hiring and the remuneration of teachers are institutional features which may help to understand why the decline in the productivity of schooling is larger in some countries than in others.

Overall, our findings tend to confirm the positive theory of education expenditure by Pritchett and Filmer (1999), who claim that resource allocation in the education sector does not follow a constrained output-maximizing rule. They develop a behavioral theory of expenditure allocation where educational resource allocation is mainly determined through rent seeking, and not through competitive markets. With regard to educational policies, their theory and our empirical findings imply that instead of higher expenditures on education, the structure of decision making and the incentives within the education sector have to be changed in order to improve the productivity of schooling.

REFERENCES

Baumol, William J. (1967). Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis. American Economic Review 57: 415-426.

Council of Economic Advisors (1999). Economic Report of the President 1999. Washington, D.C.: U.S. Government Printing Office.

Dougherty, Chrys, Dale W. Jorgenson (1997). There is no Silver Bullet: Investment and Growth in the G7. National Institute Economic Review No. 162: 57-74.

Hanushek, Eric A. (1997). The Productivity Collapse in Schools. In: W. Fowler, Jr. (ed.). Developments in School Finance 1996. U.S. Department of Education, National Center for Education Statistics. Washington, D.C.: 183-195.

Hanushek, Eric A. (1998). Conclusions and Controversies about the Effectiveness of School Resources. Federal Reserve Bank of New York Economic Policy Review 4: 11-27.

Hanushek, Eric A., Dongwook Kim (1995). Schooling, Labor Force Quality, and Economic Growth. NBER Working Paper, 5399, December.

International Association for the Evaluation of Educational Achievement (IEA) (1998). Third International Mathematics and Science Study. International Achievement Reports.
http://wwwcsteep.bc.edu/TIMSS1/Achievement.html.

Lee, Jong-Wha, Robert J. Barro (1997). Schooling Quality in a Cross Section of Countries. NBER Working Paper, 6198, September.

Organisation for Economic Co-operation and Development (OECD), Centre for Educational Research and Innovation (1997). Education at a Glance: OECD Indicators. Paris.

Pritchett, Lant, Deon Filmer (1999). What Education Production Functions Really Show: A Positive Theory of Education Expenditure. Economics of Education Review 18: 223-239.

Rothstein, Richard, Lawrence Mishel (1997). Alternative Options for Deflating Education Expenditures Over Time. In: W. Fowler, Jr. (ed.). Developments in School Finance 1996. U.S. Department of Education, National Center for Education Statistics. Washington, D.C.: 159-182.

UNESCO (var. iss.). Statistical Yearbook. Paris.

United Nations (UN) (var. iss.). National Accounts Statistics: Main Aggregates and Detailed Tables. New York.

U.S. Department of Education, National Center for Educational Statistics (1997). The Condition of Education 1997. Washington, D.C.: U.S. Government Printing Office.

U.S. Department of Education, National Center for Educational Statistics (1998). Digest of Education Statistics 1997. Washington, D.C.

APPENDIX

Basic education data and the deflators used in our calculations are presented in Table A.1. Test scores reported for various international tests of the cognitive achievement of pupils are presented in Table A.2. The following list reports definitions of variables and their sources. Adjustments and intrapolations of the data used for individual countries are explained in detail where appropriate.

(1) Education Data (from UNESCO, Statistical Yearbook, var. iss.)

- The 1970 and 1990 education data for Germany refer to West Germany only, while the 1994 data refer to unified Germany. The inclusion of East German data in 1994 may understate the schooling price increase in West Germany since teacher wages and other costs were lower in the East Germany in 1994.

CUREXP: Current public expenditure on education (Table 4.1 of the 1998 Yearbook)

- For Greece, Japan, Sweden, the United Kingdom, and the United States the 1994 figure is total expenditure on education in 1994 times current expenditure as percent of total expenditure (in the most recent year available). For Austria, the 1994 figure is the average of 1993 and 1995. For Denmark, the 1990 figure is the average of 1989 and 1991. For Japan, the 1990 figure is the average of 1988 and 1992, where the 1992 figure is total expenditure on education in 1992 times current expenditure as percent of total expenditure (in the most recent year available).

PERFIR: Percentage of current educational expenditure spent at the first level of education (Table 4.2 of the 1998 Yearbook)

- For the United Kingdom, the 1994 figure is the average of 1993 and 1995. For Japan, the 1990 figure is the average of 1988 and 1992. For Denmark, the 1990 figure is the average of 1989 and 1991. For Portugal, the 1970 figure is the average of 1965 and 1975. For Austria, Denmark, Greece, and Ireland the 1994 percentage figure is taken from 1995. For Austria, the 1970 percentage figure is taken from 1968.
- For several countries, published expenditure on primary education include

expenditure on pre-primary education for selected years. In these cases, we extracted the pre-primary expenditure share in the following way: We use the data on pupils enrolled at the pre-primary level (Table 3.3 in the 1998 Yearbook), which is available for all years of our samples, to calculate the share of pre-primary pupils in the sum of pre-primary and primary pupils for the year in which the spending breakdown between primary and pre-primary level is given and for the year in which it is not given. We then calculate the share of pre-primary spending in the sum of pre-primary and primary spending for the year in which the breakdown is given. Assuming that the share of pre-primary spending moved parallel to the share of pre-primary pupils, we can extrapolate the pre-primary spending figure to the year in which the breakdown is not given. This enables us to subtract the pre-primary share of educational expenditure from the published joint expenditure on primary and pre-primary education. Since pre-primary spending and pupils always represent a minor share relative to primary or secondary spending and pupils, this adjustment does not significantly influence our results.

- We made the following adjustments. For Canada, Denmark, Ireland, Spain, the United Kingdom, and Australia, data on educational expenditure in 1994 were used to subtract pre-primary educational expenditure in 1970. For Belgium, Canada, and the United States, 1994 data were used to adjust the 1990 figure. For Greece, 1970 data were used to adjust the 1994 figure. For Germany, 1990 data were used to adjust the 1970 and 1994 figures. For New Zealand, the 1970 figure was adjusted by using the average of the pre-primary percentages reported for 1965 and 1975.

PERSEC: Percentage of current educational expenditure spent at the second level of education (Table 4.2 of the 1998 Yearbook)

- For the United Kingdom, the 1994 figure is the average of 1993 and 1995. For Japan, the 1990 figure is the average of 1988 and 1992. For Denmark, the 1990 figure is the average of 1989 and 1991. For Portugal, the 1970 figure is the average of 1965 and 1975. For Austria, Denmark, Greece, and Ireland, the 1994 percentage figure is taken from 1995. For Austria, the 1970 percentage figure is taken from 1968.

PUPFIR: Total pupils enrolled at the first level of education (Table 3.4 of the 1998 Yearbook)

- The 1994 figure for the United Kingdom includes pupils enrolled in infant classes in primary schools, previously considered as pre-primary education, as well as pupils below compulsory school age in independent and special pre-primary schools.

PUPSEC: Total pupils enrolled at the second level of education (Table 3.7 of the 1998 Yearbook)

- For New Zealand, the 1970 figure is pupils enrolled in general secondary education in 1970 times the 1975 relation of pupils enrolled in total secondary education to pupils enrolled in general secondary education.

(2) Deflators (from United Nations, National Accounts Statistics, var. iss.)

- Deflators for a given year are calculated by dividing expenditure in current prices by expenditure in constant prices, after adjusting the constant-price data so as to reflect the most recent base year as a common base year. The GDP figures are taken from Tables 1.1 and 1.2 of the UN National Accounts Statistics. The PGS and CSPS figures are the categories of the SNA kind-of-activity classification called "Producers of government services" and "Community, social and personal services", taken from Tables 1.10 and 1.11.
- The reported PGS and CSPS figures for Mexico and the United States and the CSPS figure for Germany are average annual growth rates in 1970-93 instead of 1970-1994. The PGS and CSPS figures of Canada are average annual growth rates in 1970-92.
- PGS and CSPS data were not available for the sample period for Ireland, New Zealand, Norway, Portugal, Switzerland, and the United Kingdom. CSPS data were not available for Spain.
- For France, the PGS data include "Other producers" (private non-profit services to households and domestic services). For Italy, the CSPS data include Finance, insurance, real estate and business services. The constant-price CSPS figures for the Netherlands encompass ISIC codes 6 to 9 until 1986.

- The GDP data for New Zealand were taken from the OECD Statistical Compendium CD-Rom, edition 2/1998, since the UN publications did not include the 1970 figures.

(3) Achievement Data (from Lee and Barro (1997) and IEA (1998))

- The 1964 mathematics study was conducted in 11 countries, the 1970-71 science study in 17 countries, and the different TIMSS subtests were conducted for different sample sizes ranging from 21 countries to 39 countries. Almost all studies include three subtests for pupils in the primary, middle, and final school years. The exception is the 1964 mathematics study, which was not conducted for pupils in the primary school years. In this study, pupils in the middle school years were aged 13. In the first science study (1970-71), pupils in the primary school years were aged 10 and pupils in the middle school years were aged 14. In the TIMSS study, pupils in the primary school years are selected from the two grades with the largest proportions of 9-year-olds (third and fourth grades) and pupils in the middle school years are selected from the two grades with the largest proportions of 13-year-olds (seventh and eighth grades). Final school years always refers to pupils in their last year of secondary education.
- The data for the first IEA mathematics study and the first IEA science study are taken from Lee and Barro (1997). They are reported in percent-correct format.
- The TIMSS data are taken from several publications by the IEA (1998). They are reported in proficiency scale, which is constructed to generate an international mean of 500 and a standard deviation of 100 over the range of 0 to 1000 for the countries participating in a test.

Table A.1: Education Data and Deflators

	Education data															Deflators									
	CUREXP[a]			PERFIR[b]			PERSEC[c]			PUPFIR			PUPSEC			Base	GDP[d]			PGS[d]			CSPS[d]		
	1970	1990	1994	1970	1990	1994	1970	1990	1994	1970	1990	1994	1970	1990	1994	year	1970	1990	1994	1970	1990	1994	1970	1990	1994
Australia	1 139	17 889	22 823	30.6	57.4	29.9	23.2	inc.	39.6	1 812 000	1 583 024	1 639 577	1 136 960	1 278 163	2 003 504	1989	0.178	1.031	1.096	0.176	1.044	1.142	0.194	1.055	1.149
Austria	13 503	89 858	111 112	29.6	17.7	21.1	47.8	46.6	47.7	531 934	370 210	381 363	630 254	746 272	786 156	1983	0.465	1.246	1.443	0.376	1.312	1.579	0.412	1.323	1.642
Belgium	54 166	321 427	435 593	24.7	20.8	21.1	51.7	42.9	46.9	1 021 511	719 372	738 768	723 703	769 438	1 061 790	1985	0.380	1.167	1.325	0.307	1.131	1.343	0.323	1.171	1.408
Canada	6 428	40 288	46 123	62.8	59.0	61.5	inc.	inc.	inc.	3 736 450	2 375 704	2 413 126	1 978 564	2 292 497	2 469 552	1986	0.328	1.185	1.254	0.239	1.238	1.355	0.309	1.249	1.355
Denmark	6 294	53 583	69 787	69.8	10.9	21.5	inc.	54.2	39.7	443 031	340 267	328 875	407 103	464 555	444 682	1980	0.396	1.749	1.889	0.367	1.824	2.038	0.401	2.071	2.358
Finland	2 405	26 757	34 978	35.8	27.9	25.3	49.5	39.4	37.7	386 230	390 587	387 306	509 691	426 864	454 707	1990	0.173	1.000	1.068	0.133	1.000	1.122	0.187	1.000	1.193
France	24 599	327 427	397 868	23.8	17.6	20.4	43.9	40.7	50.0	4 939 683	4 149 143	4 071 599	4 281 446	5 521 862	6 003 797	1980	0.391	1.836	2.013	0.240	1.883	2.133	0.665	1.852	2.087
Germany	16 927	88 499	140 600	35.0	13.4	67.9	31.5	47.5	inc.	6 344 774	2 561 267	3 727 157	2 704 796	5 972 607	8 152 297	1991	0.436	0.963	1.098	0.364	0.949	1.086	0.337	0.954	1.091
Greece	5 091	306 303	550 698	48.8	28.2	32.9	28.3	45.1	40.9	907 446	813 353	710 774	520 323	851 353	842 633	1970	1.000	19.17	32.81	1.000	25.83	42.42	1.000	26.10	45.58
Ireland	69	1 303	1 880	41.7	29.0	25.2	40.9	40.1	41.6	520 122	416 747	380 983	208 705	345 941	390 680	1990	0.139	1.000	1.093	-	-	-	-	-	-
Italy	2 429	40 400	75 370	28.4	26.6	22.8	38.1	63.2	48.5	4 856 953	3 055 883	2 815 631	3 823 556	5 117 897	4 825 719	1985	0.129	1.394	1.694	0.095	1.660	1.963	0.116	1.502	1.905
Japan	2 098	17 038	17 200	37.6	31.0	37.0	37.3	37.7	41.8	9 558 139	9 373 295	8 612 106	8 666 937	11 025 720	9 878 568	1990	0.399	1.000	1.054	0.251	1.000	1.121	0.255	1.000	1.093
Mexico	7.148	16 617	61 672	47.7	26.7	39.8	27.2	29.6	32.1	9 248 290	14 401 588	14 574 202	1 584 342	6 704 297	7 264 619	1980	0.197	130.2	214.2	0.144	89.27	181.7	0.175	155.2	305.0
Netherlands	7 069	29 200	31 113	20.8	16.3	23.1	38.6	37.7	39.0	1 462 376	1 082 022	1 189 112	1 006 327	1 401 739	1 508 772	1990	0.383	1.000	1.097	0.391	1.000	1.126	0.336	1.000	1.152
New Zealand	213	4 252	5 270	36.6	26.9	23.7	25.5	25.3	40.7	400 445	318 568	331 666	305 897	340 915	404 563	1990	0.116	1.000	1.069	-	-	-	-	-	-
Norway	3 696	44 109	65 407	47.5	39.5	31.2	23.4	24.7	23.0	385 628	309 432	314 062	302 792	370 779	370 925	1990	0.245	1.000	1.051	-	-	-	-	-	-
Portugal	2 743	378 252	724 138	47.3	42.3	34.5	27.5	32.5	38.8	992 446	1 019 794	896 681	445 574	670 035	945 077	1985	0.085	1.851	2.712	-	-	-	-	-	-
Spain	35.420	1 936	2 941	45.3	23.3	22.3	23.4	45.0	53.2	3 929 569	2 820 497	2 364 910	1 950 496	4 755 322	4 744 829	1986	0.127	1.285	1.594	0.123	1.290	1.619	-	-	-
Sweden	10 785	93 083	106 680	42.7	47.6	26.2	17.7	19.6	40.2	615 331	578 359	643 768	554 480	588 474	791 848	1991	0.176	0.929	1.066	0.153	0.947	1.071	0.164	0.929	1.165
Switzerland	2 766	14 395	18 116	33.2	46.3	27.0	40.2	25.1	47.0	500 492	404 154	461 805	345 786	567 396	561 716	1980	0.603	1.500	1.680	-	-	-	-	-	-
United King.	2 334	25 318	34 223	22.2	26.1	30.0	32.0	43.8	44.2	5 806 349	4 532 500	5 208 961	4 149 067	4 335 600	6 677 836	1990	0.147	1.000	1.172	-	-	-	-	-	-
United States	56 000	265 074	326 853	70.5	36.0	31.7	inc.	37.0	36.1	28 700 000	22 429 000	23 823 662	19 910 000	19 270 000	21 122 633	1985	0.379	1.193	1.317	0.330	1.254	1.436	0.366	1.364	1.602

[a] In million units of the local currency; in billion units of the local currency in Italy, Japan, Mexico, and Spain. - [b] In percent. - [c] inc. indicates that the figure is included in PERFIR. - [d] Base year = 1.

Sources: UNESCO (var. iss.): education data; UN (var. iss.): deflators.

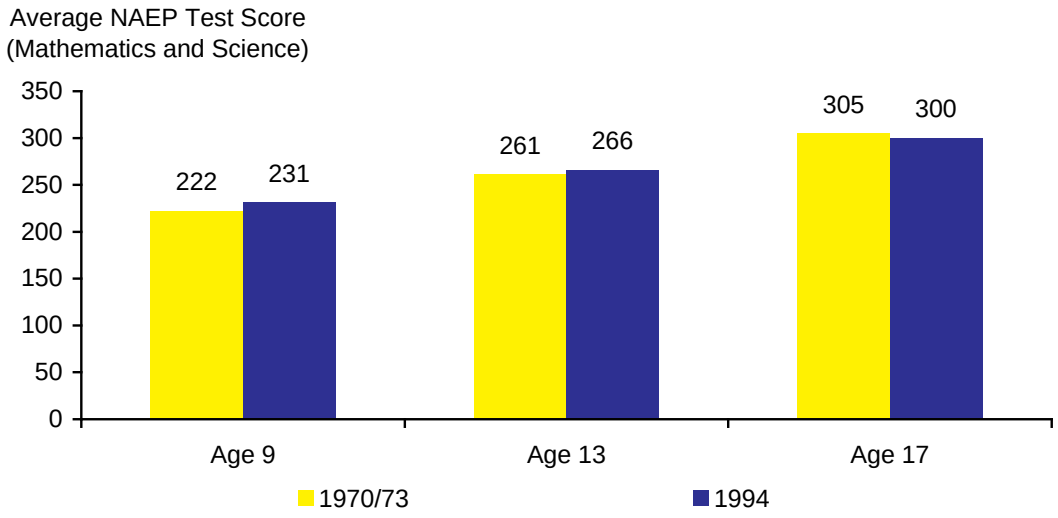
Table A.2: Scores in International Student Achievement Tests

	IEA I[a]					TIMSS[b]									
Year:	1964		1970-71			1994-95									
Subject:	Mathematics		Science			Mathematics		Science		Mathematics		Science		Math.	Sci.
Age/Grade:	13	Final	10	14	Final	4th	3rd	4th	3rd	8th	7th	8th	7th	Final	Final
Australia	27.0	31.3	-	30.8	41.2	546	483	562	510	530	498	545	504	522	527
Belgium	43.4	50.1	39.8	22.9	27.3	-	-	-	-	545.5	532.5	510.5	485.5	-	-
France	30.0	48.4	-	-	30.5	-	-	-	-	538	492	498	451	523	487
Germany	36.3	41.7	37.3	29.6	44.8	-	-	-	-	509	484	531	499	495	497
Italy	-	-	41.3	23.1	26.5	-	-	-	-	-	-	-	-	476	475
Japan	46.0	45.5	54.3	39.0	-	597	538	574	522	605	571	571	531	-	-
Netherlands	30.6	46.2	38.3	22.3	38.8	577	493	557	499	541	516	560	517	560	558
New Zealand	-	-	-	30.3	48.3	499	440	531	473	508	472	525	481	522	529
Sweden	21.9	39.6	45.8	27.1	32.0	-	-	-	-	519	477	535	488	552	559
United King.	32.9	43.6	37.1	26.7	38.5	516.5	457	543.5	491.5	502	469.5	534.5	490	-	-
United States	25.4	20.0	44.3	27.0	22.8	545	480	565	511	500	476	534	508	461	480
Note:															
Iran	-	-	10.3	9.8	17.0	429	378	416	356	428	401	470	436	-	-

[a] Results reported in percent-correct format. - [b] Results reported in proficiency scale.

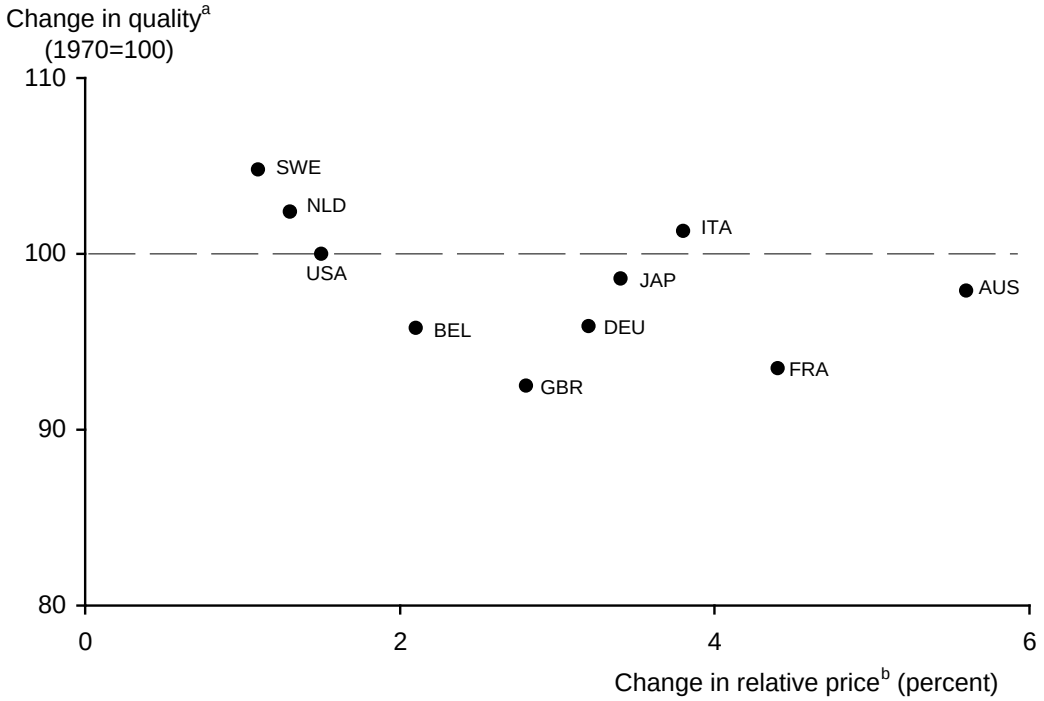
Sources: Lee and Barro (1997): IEA I; IEA (1998): TIMSS.

Figure 1: US Student Achievement by Age Group in 1970 and in 1994



Source: US Department of Education (1997, pp. 86-88).

Figure 2: Changes in the Quality of Schooling Output and in the Relative Price of Schooling, 1970–1994



[a]Average of estimated change in performance in science and mathematics under H1-H3.— [b]Average of estimated changes in the relative price of schooling and in the TFP-adjusted change in the GDP-deflated price of schooling.

Source: Tables 2 and 3.

Table 1: Nominal Changes in the Price of Schooling and Various Deflators[a]

	Price of Schooling	**GDP Deflator**	**Service Deflators**		**Note: Price of Schooling** Constant Structure[b]	
			PGS	**CSPS**		
	1970-94	1970-94	1970-94	1970-94	1970-90	1970-94
	(1)	(2)	(3)	(4)	(5)	(6)
Australia (AUS)	13.5	7.9	8.1	7.7	15.3	13.5
Austria (AUT)	8.6	4.8	6.2	5.9	9.1	8.6
Belgium (BEL)	8.4	5.3	6.3	6.3	9.2	8.1
Canada (CAN)	9.2	5.7	8.2	7.0	10.4	-
Denmark (DNK)	10.4	6.7	7.4	7.7	11.2	-
Finland (FIN)	10.7	7.9	9.3	8.0	12.0	10.7
France (FRA)	12.1	7.1	9.5	4.9	12.7	11.8
Germany (DEU)	8.1	3.9	4.7	5.2	8.5	-
Greece (GRC)	20.9	15.7	16.9	17.3	21.5	20.9
Ireland (IRL)	13.5	9.0	-	-	14.5	13.0
Italy (ITA)	16.3	11.3	13.4	12.4	17.2	16.1
Japan (JPN)	9.3	4.1	6.4	6.3	9.9	9.3
Mexico (MEX)	41.4	33.8	36.4	38.3	40.5	40.8
Netherlands (NLD)	6.2	4.5	4.5	5.3	6.8	6.0
New Zealand (NZL)	14.3	9.7	-	-	15.6	14.1
Norway (NOR)	11.5	6.3	-	-	12.7	11.7
Portugal (PRT)	24.8	15.5	-	-	26.9	24.7
Spain (ESP)	19.7	11.1	11.3	-	20.6	19.5
Sweden (SWE)	9.5	7.8	8.5	8.5	12.0	9.4
Switzerland (CHE)	7.3	4.4	-	-	7.7	7.1
United Kingdom (GBR)	12.5	9.0	-	-	14.8	12.4
United States (USA)	7.8	5.3	6.6	6.6	9.1	-

[a]Average annual rate of change, in percent. - [b]Calculated by assuming that the shares of primary and secondary pupils in total schooling enrollment remained constant at the 1970 level.

Source: Table A.1.

Table 2: Changes in Schooling Productivity[a]

	$\Delta p_S - \Delta p_{GDP} - g_{TFP}$	$\Delta p_S - \Delta p_{PGS}$	$\Delta p_S - \Delta p_{CSPS}$	Note: g_{TFP}
	(1)	(2)	(3)	(4)
Australia	-	5.4	5.8	-
Austria	-	2.5	2.7	-
Belgium	-	2.1	2.1	-
Canada	3.1	1.0	2.2	0.3
Denmark	-	3.0	2.7	-
Finland	-	1.4	2.6	-
France	3.6	2.5	7.2	1.4
Germany	3.3	3.4	2.8	0.9
Greece	-	4.0	3.7	-
Italy	4.4	2.9	4.0	0.6
Japan	4.1	2.9	3.1	1.1
Mexico	-	5.0	3.1	-
Netherlands	-	1.7	0.9	-
Spain	-	8.4	-	-
Sweden	-	1.1	1.0	-
United Kingdom	2.8	-	-	0.7
United States	2.2	1.2	1.2	0.3

[a]Average annual rate of change, in percent; (1),(2), and (3): 1970-1994; (4):1973-1989.

Source: (1), (2), and (3): Table 1; (4): Dougherty and Jorgenson (1997).

Table 3: Changes in the Quality of Schooling Output, 1970-1994[a]

	H1		H2		H3	
	Science	Ma&Sc	Science	Ma&Sc	Science	Ma&Sc
	(1)	(2)	(3)	(4)	(5)	(6)
Australia	94.3	97.7	94.4	97.8	94.9	98.1
Belgium	95.8	95.3	95.7	95.4	95.5	96.7
France	88.2	93.4	87.9	93.4	86.6	93.6
Germany	96.0	95.2	96.2	95.4	97.8	97.1
Italy	99.7	101.3	99.7	101.3	100.1	101.4
Japan	97.2	98.1	97.3	98.3	97.5	99.3
Netherlands	103.5	101.7	103.7	101.9	105.7	103.5
New Zealand	87.9	90.3	87.8	90.3	87.7	90.5
Sweden	104.3	104.3	104.5	104.5	105.9	105.6
United Kingdom	94.3	91.8	94.4	92.1	95.1	93.6
United States	100.0	100.0	100.0	100.0	100.0	100.0

[a]1970=100; index of schooling output based on the performance of pupils in standardized international achievement tests relative to the constant performance of US pupils in 1970 (1964 in mathematics) and 1994.