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by

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The Fading Productivity of Schooling in East Asia

ABSTRACT

We estimate changes in the productivity of schooling for six East Asian countries. Our productivity measure is based on changes in the relative price of schooling. A rising price of schooling relative to other labor-intensive service sectors should indicate declining relative schooling productivity. We find that the price of schooling increased by more than the price of other labor-intensive services in 1980-1994. We also find that the cognitive achievement of pupils did not change substantially, which suggests a constant quality of schooling output. Hence we conclude that schooling productivity has declined. The main reason for the fading productivity of schooling in East Asian countries appears to be a strong decline in the pupil-teacher ratio.

JEL: I2
Keywords: Asian countries, schooling, productivity growth

I. Introduction

Most East Asian countries have achieved universal coverage of girls and boys in basic schooling. In addition, pupils from many East Asian countries have performed rather well in recent international comparisons of cognitive achievement. The impressive schooling record has led some observers to conclude that formal education played an important role in explaining the "East Asian miracle" (World Bank 1993). However, not all is well with schooling in East Asia. We show that the productivity of schooling declined in a number of East Asian countries in 1980-1994.

Up to now, possible changes in the relation between schooling output and schooling inputs in East Asia have not been studied in detail. Mingat (1998: 714) provides an optimistic assessment by concluding that East Asian countries have successfully obtained high educational outcomes while keeping the burden on public finance reasonable. Rao (1998: 689) considers public schooling in four highly performing East Asian countries as one of the sectors with an efficient allocation of resources and a strict control on current expenditure. Quibria (1999: 441) provides a less optimistic assessment by pointing out that making appropriate investments in human resources is not a question of simply allocating more resources to the appropriate levels of education and that in many circumstances the quality of the delivered education leaves much to be desired. Behrman (1999: 186) notes that in many studies, the failure to control for quality of schooling may suggest gains too large from extending schooling to more years rather than improving the quality of schooling.

Our assessment of schooling productivity is based on Baumol's cost-disease model (Section II). This model can be used to derive a measure of the change in the productivity of schooling based on the change in the price of a unit of constant-quality schooling output relative to the price of other labor-intensive services. We use deflated public expenditures per pupil on primary and secondary education in 1980 and 1994 to derive a measure of the change in the price of a unit of schooling output (Section III). Notwithstanding quantitative differences across the six East Asian countries, we find that in general the price of schooling increased substantially faster than the price of other services with inherently low productivity growth. This finding implies that the productivity of schooling declined, given that the quality of a unit of schooling output did not improve.

We measure potential changes in the quality of schooling output by changes in the performance of pupils in internationally standardized tests of cognitive achievement in 1980 and in 1994 (Section IV). Neglecting minor improvements and deteriorations, we find that average student performance, and hence the quality of schooling output, largely remained unchanged in Hong Kong, Japan, South Korea, Singapore, and Thailand, while it probably declined in the Philippines. These findings support the view that a rising relative price of schooling in East Asian countries reflects declining schooling productivity. The main reason for the decline of schooling productivity appears to be a decline in the pupil-teacher ratio which did not lead to a corresponding increase in student performance (Section V).

II. Modeling Schooling Productivity

Schooling, like other services, is most likely to be a sector with stagnant productivity. The proverbial example of a stagnant-productivity service is a haircut, where the consumer is part of the product, the production is labor intensive, and the technology is tried and tested. In a way, schooling seems to share the same features. The combination of these features hinders productivity growth: the resources and the time required to produce a haircut or a unit of schooling output of a given quality may not have changed that much over time, notwithstanding changes of fashion.

In service industries like banking and insurance, measures of productivity are difficult to come by because the output of these services is difficult to disentangle from price. But schooling output can be measured independent of price as the number of students with constant quality, which can be measured by the cognitive achievement of students. Hence total schooling expenditure (x) equals price of schooling (p_S) times the number of pupils with constant quality (n_q):

(1) $$p_S = x / n_q \quad .$$

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). Hanushek (1997) and Gundlach et al. (2001) use the Baumol-model to assess the change in schooling productivity in the United States and in other OECD countries. The model has two sectors, which may differ by their rate of productivity growth. A constant amount of labor (*L*) is the only factor of production, which simplifies the analysis if only labor-intensive service sectors are considered. Hence we call one sector *S* (schooling), with productivity growth r_S, and we call the other sector *O* (other services), which has productivity growth r_O. Output of the two sectors can be described by two production functions as

(2) $$Y_i = a_i \, L_i \, e^{r_i \cdot t} \qquad i \in [S, O] \quad ,$$

where Y_i is the level of output of sector *i* at time *t* (*t* subscripts are omitted), a_i is a sector-specific constant, and L_i is the 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

(3) $$\delta Y_i / \delta L_i = a_i \, e^{r_i \cdot t} \quad .$$

Equating the value of the marginal products to the wage gives

(4) $$w = p_S \, a_S \, e^{r_S \cdot t} = p_O \, a_O \, e^{r_O \cdot t}$$

and hence the relative price of schooling follows as

(5) $$p_S / p_O = (a_O / a_S) e^{(r_O - r_S)\cdot t} \quad .$$

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

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

Thus given that the quality of schooling output does not change, a positive change in the price of schooling relative to the price of other services implies that schooling productivity has risen by less than the productivity in other service sectors. Using those services as a measure of reference which are known to exhibit stagnant or near stagnant productivity $(r_O = 0)$, this result suggests that a positive change in the relative price of schooling indicates declining schooling productivity.

The qualitative relation between changes in relative prices and relative productivity growth does not change if the underlying model is extended to allow for more than one factor input. With more than one production factor, differential sectoral productivity growth would not translate into an identical opposite-sign change in the relative price as in equation (6). But by using other service sectors as a measure of reference, the qualitative relation between a rising relativ price of schooling and declining relative schooling productivity would remain.

In addition, taking account of the fact that in many East Asian economies relative prices may be determined by international goods markets does not impact in a qualitative way on the relation suggested by equation (6). In these economies, a strong increase in the relative price of services like schooling may reflect strong growth in the international sector, and hence a real appreciation. But such an effect should affect all labor-intensive domestic service sectors in the same way. Hence choosing an appropriate service sector as a measure of reference guarantees that equation (6) can be used to identify whether schooling productivity remained constant or not. This result would also hold if the income elasticity of the demand for schooling were higher than the income elasticity of the demand for other services, since different income elasticities would only affect relative quantities but not relative prices.

III. Measuring Changes in the Price of Schooling

We derive a measure of the price of schooling by using the definition given in equation (1). Dividing total current public expenditure on primary and secondary education by the number of pupils enrolled in public schools, we obtain the price of a unit of quality-adjusted schooling output as

$$(7) \qquad p_S = EXPPUP_t^i = \frac{CUREXP_t^i \cdot \left(PERFIR_t^i + PERSEC_t^i\right)}{\left(PUPFIR_t^i + PUPSEC_t^i\right)} ,$$

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.

Data on schooling expenditure and pupils refer to public schools only and are taken from various issues of the UNESCO Statistical Yearbook.[1] The figures for several countries had to be adjusted to ensure comparability of results over time. In the Data Appendix, we list in detail all adjustments made. Table A.1 in the Data Appendix also includes all basic expenditure and enrollment data used for our calculations. Column (1) of Table 1 shows the average annual growth rate of the nominal price of schooling as computed by equation (7) in six East Asian countries in 1980-1994. We find a substantial increase in the nominal price of schooling in all cases. Average annual rates of change range from 6.1 percent in Japan to 18.0 percent in South Korea. As is self-evident, these differences reflect differences in economy-wide inflation rates together with potential differences

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

in the change of schooling productivity.

If spending on more expensive secondary education increased relative to spending on primary education, the calculated increase in the nominal price of schooling may be overstated. Therefore, we recalculate changes in the price of schooling in 1980-1994 as if the shares of pupils in primary and in secondary education had remained constant at their 1980 level. Column (2) of Table 1 shows that for all countries, the difference relative to column (1) is less than 0.2 percentage points. Therefore, a shift in the structure of expenditure towards secondary education cannot account for the large increase in the nominal price of schooling in the East Asian countries.[2]

We employ two alternative deflators to derive a measure of the relative price of schooling which can be used to identify changes in schooling productivity as suggested by equation (6). We use national accounts statistics provided by UN (var. iss.) to calculate (i) a deflator for producers of government services (PGS) and (ii) a deflator for community, social and personal services (CSPS). The PGS deflator (column (3) of Table 1) measures the increase in prices of public sector services, which include the schooling sector. The CSPS deflator (column (4))

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[2] In the Philippines, no breakdown of schooling expenditure between the first and second level is available for 1994 data. However, the shift from first-level to second-level pupils was smaller in the Philippines than in any other country for which results are reported here. Hence it is unlikely that the small shift towards secondary education had a major impact on the change in the price of schooling in the case of the Philippines.

measures the increase in prices of privately provided services[3] which may be similar to schooling in terms of their high labor intensity and their expected low or zero rate of productivity growth.

As outlined in the previous section, comparing the increase in the price of schooling with the increase in the price of comparable services provides an opportunity to assess the relative change in schooling productivity. We show the difference between the increase in the price of schooling and the averaged increase in the PGS- and the CSPS-deflator in 1980-1994 in column (5) of Table 1. Except for the Philippines, all other East Asian countries experienced a substantial rise in the price of schooling relative to the price of other services. The largest increases in the comparative price of schooling occurred in South Korea and Thailand, followed by Hong Kong, Singapore, and Japan.

Our findings reveal that schooling productivity declined in these East Asian countries, at least compared to the change in productivity in other service sectors. Since government services (PGS) and community, social, and private services (CSPS) can reasonably be expected to be stagnant or near-stagnant

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[3] In the System of National Accounts (SNA), "Community, social and personal services" 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,

productivity sectors, a substantial increase in the relative price of schooling appears to indicate that the schooling sector received more resources per unit of output over time. An alternative interpretation of the observed increase in the relative price of schooling would be that the quality of a unit of schooling output might have improved over time.[4]

IV. Calculating Changes in the Quality of Schooling Output

To see whether the quality of schooling output actually changed in East Asia, we use external measures of the cognitive achievement of students in mathematics and science. Such achievement measures are available for selected East Asian countries for selected years. However, the achievement measures refer to different test designs and, therefore, have to be transformed into a common format before they can be interpreted as measuring changes in pupil quality relative to a constant measure of reference.

Consistent time-series data on the cognitive achievement of pupils in standardized tests are available only for the case of the United States. The National Assessment of Educational Progress (NAEP) began to monitor the

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insurance, and real estate and business services, which all may be considered to experience at least modest productivity gains.

[4] Similarly, it could also be argued that the observed increase in the relative price of schooling would reflect a decline in the quality of a unit of output of our reference services (PGS and CSPS). However, changes in quality should be accounted for in the published PGS- and CSPS-deflators. Our further results depend on the assumption that there was no unnoticed decline in the quality of a unit of output of our reference services.

performance of pupils aged 9, 13 and 17 years in mathematics and science in the early 1970s. The NAEP has used the same assessment content and the same administration procedures over time, so the reported average test scores of US pupils are intertemporally comparable.

Table 2 shows US test scores by age groups and subjects in 1977/78, 1982, and 1994. Our interpretation is that there has been no substantial change in the average performance of US pupils in 1980-1994. This interpretation is in line with Hanushek (1997: 186) who concludes on the basis of these data that "the overall trend in student performance has been flat or falling" from the early 1970s through 1994. As a benchmark for our further calculations, we assume a constant cognitive achievement of US pupils in 1980-1994.

In addition to the time series US evidence, test scores in various subjects are available for pupils of different age from a number of countries in selected years. The International Association for the Evaluation of Educational Achievement (IEA) has conducted a cross-country science study in 1983-84 and a cross-country mathematics studies in 1980-82, including selected East Asian countries. The IEA's Third International Mathematics and Science Study (TIMSS) in 1994-95 integrated the two subjects. The studies differ with regard to the inclusion of subtests for pupils in the primary (age 10 or 3rd and 4th grade), middle (age 13 or 7th and 8th grade), and final (age 17) school years, and they also differ with regard to the inclusion of East Asian countries in the various subtests. Table A.3 in the Data Appendix provides the available test score results for Hong Kong, Japan, the Philippines, Singapore, South Korea, and Thailand, in addition to results for OECD countries.

Based on these data, we attempt to estimate changes in the cognitive achievement of East Asian pupils in mathematics and science. Direct comparisons of the results of the early 1980s with the results of the mid-1990s are not possible 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 has changed. Nevertheless, we can calculate changes in the performance of pupils for each country over time subject to specific assumptions about the mean and the standard deviation of the reported test results. This is possible at least as a rough approximation because for each study, we know the performance of pupils from East Asian countries relative to the intertemporally constant performance of US pupils.

To make the different test results comparable over time, the underlying sample distributions and sample means have to be converted to a common scale. We use alternative hypotheses to define such a common scale. Our hypotheses center around the idea that the performance of US pupils has remained constant and that the distribution of results among the relatively homogenous group of OECD countries should not have changed substantially between the early 1980s and the mid-1990s. The Technical Appendix explains in detail how we transform the original test scores, subject to three different assumptions about the sample distributions and sample means, in order to estimate possible changes in the quality of schooling output over time.

Given the transformed test scores, the change in quality of schooling output as measured by the change in the cognitive achievement of pupils can be calculated for each country according to

$$(8) \qquad QSO^i = \frac{\frac{1}{s}\sum_s \frac{1}{a}\sum_a \frac{TTS^i_{94,s,a}}{TTS^{US}_{94,s,a}}}{\frac{1}{s}\sum_s \frac{1}{a}\sum_a \frac{TTS^i_{80,s,a}}{TTS^{US}_{80,s,a}}} \cdot 100 \quad ,$$

where QSO^i is an index of the quality of schooling output of country *i* in 1994 with base year 1980 set to 100, subject *s* is either equal to 1 (single measure for science or mathematics) or to 2 (combined science and mathematics measure), age group *a* is equal to 3 for the 1983 science study (with 1 = primary school years, 2 = middle school years, and 3 = final school years) and 2 for the other studies (given that there are no tests in the primary school years in the 1980 mathematics study and that no East Asian country participated in the TIMSS final-year study), and $TTS^i_{t,s,a}$ is the transformed test score of country *i* at time *t* in subject *s* and age group *a*.[5] By construction, *QSO* allows for a comparison within a country over time, but it does not allow for a comparison of levels across countries because the rescaling of tests scores depends on ad hoc

5 Missing data for subtest scores, as evident from Table A.1, 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.

assumptions about the respective sample mean and sample distribution.

We present our results for intertemporal changes in the quality of schooling output relative to the constant US performance in Table 3. H1, H2, and H3 refer to the three alternative hypothesis we use with regard to sample distributions and sample means. For each statistical hypothesis, the first column lists changes in test scores in science, the second column lists changes in test scores in mathematics, and the third column lists an unweighted average. Our figures suggest that the different statistical assumptions under H1-H3 lead to basically the same results. The performance of South Korean and Singaporean pupils (in science) slightly increased in 1980-1994, while the performance of pupils in Hong Kong, Japan and Thailand slightly decreased. The average performance of pupils from the Philippines in science seems to have deteriorated substantially. While the performance trend was similar in both science and mathematics in Hong Kong and Japan, Thai pupils seem to have improved their mathematical skills while their skills in science decreased.

Taken together, the quality of schooling output apparently did not change by much in the East Asian countries considered in 1980-1994 except for the Philippines, where it declined. Hence the by and large constant relative price of schooling in the Philippines (see Table 1) does not point to constant, but also to declining schooling productivity. We interpret our findings for the other East Asian countries as suggesting that there was no major increase in the quality of schooling output in 1980-1994. If so, changes in the price of schooling relative to the price of other services with low or zero productivity growth should approach zero if schooling productivity were to be constant. Since the relative price of schooling actually increased (or the quality of schooling output fell as in the Philippines), schooling productivity appears to have declined in all East Asian countries considered.

V. Assessing the Decline of Schooling Productivity in East Asia

We summarize our results on changes in the quality of schooling output and changes in schooling input in the six East Asian countries in Figure 1. On the vertical axis, we use an average of mathematics and science test results derived under H2 in Section IV as our measure of changes in the quality of schooling output. On the horizontal axis, we use the average of the PGS and the CSPS deflators as in Section III to calculate the change in the relative price of schooling. Under an efficient allocation of resources, the expected correlation between changes in the relative price of schooling and changes in the quality of schooling output would result as an upward-sloping line through the point where the index of changes in the quality of schooling output is equal to 100 (no change) and the change in the relative price of schooling is zero (no change). Yet no such picture emerges in Figure 1. Recalling that the increase in the relative price of schooling mirrors an overproportionate increase in schooling resources, generously rising schooling expenditures apparently did not generate strong performance effects. At the same time, holding schooling expenditure at bay, as in the Philippines, seems to have generated devastating performance effects.

To understand where the changes in schooling expenditure per pupil come from, we first note that total spending on teachers accounts for two thirds to more than 90 percent of total schooling expenditure in all East Asian countries for which data is available. This figure reduces the possible impact of changes in spending on other educational inputs. Second, since teacher wages are usually constrained by the overall wage level in an economy, changes in the number of teachers employed emerge as the main determinant of changes in educational expenditure per pupil.

We use changes in the pupil-teacher ratio to measure changes in the number of teachers employed. Using data on teaching staff and pupils enrolled in primary and secondary education, Table 4 reports the pupil-teacher ratios in public schools in the six East Asian countries. Pupil-teacher ratios range from 43.5 in South Korea in 1980 to 15.8 in Japan in 1994. In all countries but the Philippines, the pupil-teacher ratio decreased in 1980-1994. Our disaggregated data show that the decline in the pupil-teacher ratio in five East Asian countries results from an increasing number of teachers on top of a decreasing number of pupils. Hence declining pupil-teacher ratios not only reflect demographic factors but a political decision to reallocate government resources towards the education sector. The strongest decline in the pupil-teacher ratio happened in South Korea. This is the country (except for Thailand) with the highest reported increase in relative expenditure per pupil.[6]

South Korea is the only country for which intertemporally comparable data is available on the breakdown of schooling expenditure into further sub-categories. We focus on spending on teachers. Teacher salaries increased by an average annual rate of 11.9 percent in 1980-1993 in nominal terms. In real terms, teacher salaries increased by less than 5 percent per year on the basis of a GDP deflator. At the same time, real GNP per capita increased by an average annual rate of 8.2 percent (World Bank 1995: 163). That is, rising schooling expenditure in South Korea does not reflect disproportionately large increases in teacher salaries but rather the strong increase in the number of teachers employed. The rise in schooling expenditure would have been even larger had the teachers maintained their relative income position.

VI. Conclusion

Taken together, our findings suggest that the productivity of public schooling

[6] A possible qualification of our analysis is that lower pupil-teacher ratios might positively affect the later labor-market productivity of school graduates. If so, the more or less unchanged test scores estimated in the previous section would turn out to be a poor indicator of a changing quality of schooling output. However, we are not aware of any study addressing this possibility for the countries concerned. Recently, a number of studies for other countries have appeared which link measures of schooling quality to measures of lifetime earnings and lifetime occupational achievement. From this literature, there is a growing consensus indicating that within current ranges in most developed economies, measured inputs such as class size and spending per pupil have little, if any, effect on the future earnings of students (Heckman 2000).

has declined in six East Asian countries. In South Korea, Thailand, Hong Kong, Singapore, and Japan the observed productivity decline of schooling seems to result from a government decision to increase the amount of schooling inputs without ensuring improved quality of schooling output. While the performance of pupils has largely remained constant, the number of teachers per pupil has increased. The exception is the Philippines, where the pupil-teacher ratio actually increased. But schooling productivity most likely also declined in the Philippines because the performance of pupils substantially deteriorated.

Our results on the fading productivity of schooling in East Asia tend to confirm the positive theory of education expenditure by Pritchett and Filmer (1999), who claim that resource allocation in schooling does not follow a constrained output-maximizing rule. In their model of the schooling sector, resource allocation is mainly determined through rent seeking and not through competitive markets, which could explain the observed productivity decline. For the case of the United States, Hanushek et al. (1994) argue that because the structure of public schools does not provide incentives to improve the performance of pupils or to save on costs, it is not particularly surprising that these do not happen. With regard to incentives, public schools in East Asia may not be that different.

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Data Appendix

- Data on public schooling expenditure and on pupils enrolled used in our calculations are presented in Table A.1, and the deflators in Table A.2. Original test scores reported for various international tests of the cognitive achievement of pupils are presented in Table A.3.
- The following list reports definitions of variables and their sources. Adjustments and interpolations of the data used for individual countries are explained in detail where appropriate.

(1) Data on Schooling Expenditure and Pupils Enrolled (from UNESCO, Statistical Yearbook, var. iss.)

- For Hong Kong, the ending year of the education data sample period is 1995 instead of 1994, so that the figures reported are average annual growth rates over a 15 year period. For South Korea, the ending year of the education data sample period is 1993 instead of 1994 because of a structural break in South Korean data in 1994, so that the figures reported are average annual growth rates over a 13 year period.

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

- For the Philippines, the 1994 figure is taken from 1995. For Japan, the 1994 figure is total expenditure on education in 1994 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 Philippines, the 1994 percentage figure is the figure in the most recent year available. For Singapore, the 1994 percentage figure is taken from 1995. For Thailand, the 1980 percentage figure is taken from 1981.

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

- For the Philippines, the 1994 percentage figure is the figure in the most recent year available. For Singapore, the 1994 percentage figure is taken from 1995. For Thailand, the 1980 percentage figure is taken from 1981.

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

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

- For Singapore, the vocational part of the 1994 figure is full time enrollment only.

(2) Deflator Data (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 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 of the UN National Accounts Statistics.

The GDP figures are taken from Tables 1.1 and 1.2.

- The reported deflator figures for South Korea are average annual growth rates in 1980-1993 instead of 1980-1994.
- PGS and CSPS data were not available for the sample period for Hong Kong.

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

- The 1980-82 mathematics study and the 1983-84 science study were conducted in 17 countries. The different TIMSS subtests were conducted for different sample sizes ranging from 21 countries to 39 countries. The 1980-82 mathematics study was conducted in the middle (pupils aged 13) and final school years. The 1983-84 science study includes three subtests for pupils in the primary (10), middle (13), and final school years. The TIMSS study was conducted in the primary, middle, and final school years. However, no East Asian country took part in the final-years test. For 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 second IEA mathematics study and the second 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. For the Philippines, the characteristics of its school sample are not completely known.

Table A.1: Data on Public Schooling Expenditure and Pupils Enrolled

	CUREXP[a]		PERFIR[b]		PERSEC[b.c]		PUPFIR		PUPSEC	
	1980	1994	1980	1994	1980	1994	1980	1994	1980	1994
Hong Kong	3 036	29 852	33.7	21.4	35.7	35.0	540 260	467 718	468 975	473 817
Japan	9 416 591	17 200 449	38.2	37.0	34.6	41.8	11 826 573	8 612 106	9 557 563	9 878 568
Philippines	4 023	36 834	61.4	73.1	15.7	inc.	8 033 642	10 903 529	2 928 525	4 762 877
Singapore	587	2 486	35.8	25.7	41.1	34.6	291 722	251 097	187 532	210 473
South Korea	1 158 967	9 344 751	49.9	40.9	33.2	39.0	5 658 002	4 347 317	4 285 889	4 580 040
Thailand	15 867	108 485	55.1	51.0	28.3	21.5	7 392 563	6 291 945	1 919 967	3 382 755

[a]In million units of the local currency. – [b]In percent. – [c]inc. indicates that the figure is included in PERFIR.

Source: UNESCO (var. iss.).

Table A.2: Deflators

	Base-year	PGS[a]		CSPS[a]		Note: GDP[a]	
		1980	1994	1980	1994	1980	1994
Hong Kong	1990	n.a.	n.a.	n.a.	n.a.	0.457	1.397
Japan	1990	0.747	1.121	0.691	1.093	0.841	1.054
Philippines	1985	0.473	3.171	0.456	2.731	0.400	2.209
Singapore	1990	0.611	1.155	0.576	1.182	0.747	1.151
South Korea	1990	0.305	1.461	0.452	1.357	0.505	1.222
Thailand	1988	0.814	1.829	0.765	1.569	0.725	1.340

[a]Base year = 1.
Source: UN (var. iss.).

Table A.3: Scores in International Student Achievement Tests

	IEA II[a]					TIMSS[b]							
Year:	1980-82		1983-84			1994-95							
Subject:	Mathematics		Science			Mathematics		Science		Mathematics		Science	
Age/Grade:	13	Final	10	13	Final	4th	3rd	4th	3rd	8th	7th	8th	7th
East Asia													
Hong Kong	49.9	73	46.7	54.7	62.9	587	524	533	482	588	564	522	495
Japan	63.5	68	64.2	67.3	51.4	597	538	574	522	605	571	571	531
Philippines	-	-	39.6	38.3	-	-	-	-	-	399	386	395	382
Singapore	-	-	46.7	55	62.6	625	552	547	488	643	601	607	545
South Korea	-	-	64.2	60.3	-	611	561	597	553	607	577	565	535
Thailand	42.7	31.3	-	55	-	490	444	473	433	522	495	525	493
OECD													
Australia	-	-	53.8	59.3	47.8	546	483	562	510	530	498	545	504
Belgium	52.8	47	-	-	-	-	-	-	-	545.5	532.5	510.5	485.5
Canada	50.9	41.6	57.1	62	40.8	532	469	549	490	527	494	531	499
France	53.5	-	-	-	-	-	-	-	-	538	492	498	451
Netherlands	58.1	-	-	66	-	577	493	557	499	541	516	560	517
New Zealand	46.4	49.8	-	-	-	499	440	531	473	508	472	525	481
Norway	-	-	52.9	59.7	49.8	502	421	530	450	503	461	527	483
Sweden	43.5	55.8	61.3	61.3	44.4	-	-	-	-	519	477	535	488
U.K.	48.8	49.4	48.8	55.7	63.7	516.5	457	543.5	491.5	502	469.5	534.5	490
U.S.A.	46	35.8	55	55	40.4	545	480	565	511	500	476	534	508

[a]Results reported in percent-correct format. – [b]Results reported in proficiency scale.
Sources: Lee and Barro (1997): IEA II; IEA (1998): TIMSS.

Technical Appendix

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

H1: The mean of the OECD test scores and the standard deviation per mean of the OECD test scores are constant across all subtests.

To implement H1, we can transform the test scores of Table A.3 according to

$$\text{(A.1)} \quad TTS_t^i = \left(\frac{S_t^i}{mean_t^{OECD}} - 1 \right) \cdot \frac{\overline{sdm_{TIMSS}^{OECD}}}{sdm_t^{OECD}} + 1 \quad ,$$

where TTS_t^i is the transformed test score for country *i* in subtest *t*, S_t^i is the original test score for country *i* in subtest *t*, $mean_t^{OECD}$ is the mean of test scores of the OECD countries in subtest *t*, $\overline{sdm_{TIMSS}^{OECD}}$ is the average standard deviation per mean across the OECD countries in the TIMSS subtests, and sdm_t^{OECD} is the actual standard deviation per mean across the OECD countries in subtest *t*. The results derived on the basis of equation (A.1) are independent of the level of the mean which is chosen to be the same in all subtests.

This transformation gives us a test score for each East Asian country which represents a sample distribution with the constant mean of the OECD countries and the constant standard deviation per mean across the OECD countries in all subtests. Hypothesis 1 is justified if the distribution of test scores across OECD countries did not change substantially over time. Hanushek and Kimko (2000) assume in one of their calculations that the mean and the standard deviation remains constant *for the sample of countries participating in the respective subtest*. This is a problematic assumption because different groups of countries participated in the different subtests.

Under H2, which is probably less restrictive than H1, we assume that the US test score and the standard deviation of the OECD countries' test scores per US score remained constant across all subtests, while the OECD sample mean is now allowed to differ:

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

This hypothesis directly takes into account that the performance of US pupils did not change significantly in 1980-1994 while leaving open the performance of pupils from other OECD countries. For our calculation of the transformed test scores under H2, equation (A.1) now uses the US test score and the average standard deviation of OECD scores per US test score in the TIMSS subtests instead of the OECD mean and the average standard deviation per mean across the OECD countries as before. Hence our transformed test data under H2 imply that each subtest has the same US test score and the same standard deviation per US test score of the OECD countries, but different OECD means.

Under H3, we allow for an alternative sample distribution. We assume that in addition to a constant US test score across subtests, the deviation of the test scores of the OECD countries from the US test score (as opposed to the standard deviation of the OECD countries) did not change across subtests:

H3: The US test score and the deviation of OECD test scores from the US test score are constant across all subtests.

We calculate the deviation of OECD test scores from the US test score as

(A.2) $$dev_t^{US} = \sqrt{\frac{1}{n}\sum_n \left(U_t^i - U_t^{US}\right)^2} \quad ,$$

where dev_t^{US} is the deviation from the US test score in subtest *t*, *n* is the size of the OECD sample excluding the United States (*n*=9), and U_t^i are transformed test scores for OECD country *i* in subtest *t* with the same US test score across subtests ($U_t^i = S_t^i / S_t^{US}$).

Using equation (A.2) and the average deviation of OECD test scores from the US test score of the TIMSS subtests as the common standard deviation, we can again transform the East Asian test scores according to equation (A.1).

Table 1: Changes in the Price of Schooling and of Other Services, 1980-1994[a]

	Price of schooling Δp_S	Δp_S with constant enrollment shares[b]	Service deflators PGS Δp_{PGS}	CSPS Δp_{CSPS}	Change in relative price $(1)-\frac{(3)+(4)}{2}=$
	(1)	(2)	(3)	(4)	(5)
Hong Kong[c]	15.4	15.3	10.6	9.7	5.2
Japan	6.1	6.1	2.9	3.3	3.0
Philippines	13.8	n.a.	14.6	13.6	-0.3
Singapore	9.2	9.0	4.7	5.3	4.2
South Korea[d]	18.0	18.1	12.8	8.8	7.2
Thailand	13.3	13.5	6.0	5.3	7.6

[a]Average annual rates of change, in percent. – [b]Calculated by assuming that the shares of primary and secondary pupils in total schooling enrollment remained constant at the 1980 level. – [c]1980-1995. Service deflators are calculated by adding the average difference between the GDP deflator and the respective service deflator of the other five countries to Hong Kong's GDP deflator, which increased by 8.3 percent per year in 1980-1995. – [d]1980-1993.

Source: Based on Tables A.1 and A.2.

Table 2: US Student Achievement by Subject and Age Group

Subject	Age Group	1977/78[a]	1982	1994
Mathematics	9	219	219	231
	13	264	269	274
	17	300	299	306
Science	9	220	221	231
	13	247	250	257
	17	290	283	294

[a]Mathematics: 1978. Science: 1977.
Source: U.S. Department of Education (1997: 86-88).

Table 3: Changes in the Quality of Schooling Output, 1980-1994[a]

	H1			H2			H3		
	Science (1)	Math (2)	Average (3)	Science (4)	Math (5)	Average (6)	Science. (7)	Math. (8)	Average (9)
Hong Kong	92.6	96.0	94.4	92.6	96.7	94.8	94.6	101.5	98.2
Japan	95.5	94.1	94.7	96.0	94.7	95.3	97.5	98.7	98.1
Philippines	78.6	n.a.	78.6	76.8	n.a.	76.8	78.3	n.a.	78.3
Singapore	101.7	n.a.	101.7	101.9	n.a.	101.9	104.5	n.a.	104.5
South Korea	101.9	n.a.	101.9	102.4	n.a.	102.4	102.2	n.a.	102.2
Thailand	88.6	103.1	95.7	88.1	102.8	95.3	90.5	101.0	95.7

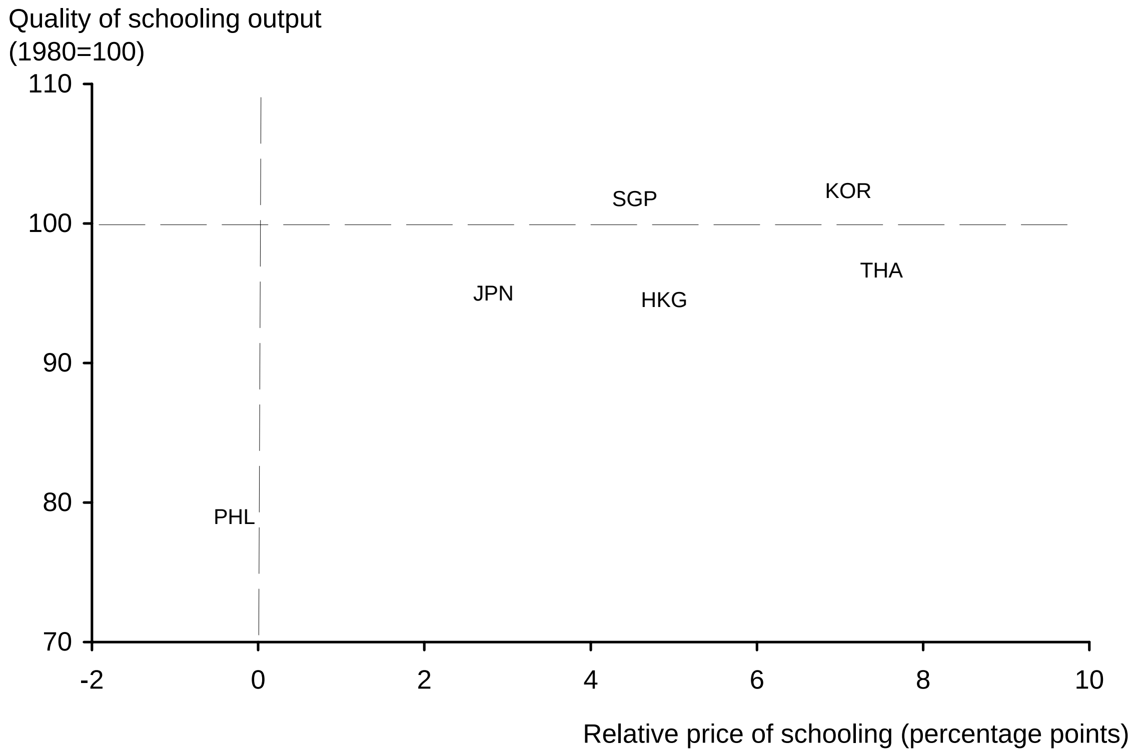
[a]1980=100.
Source: Based on Table A.3.

Table 4: Pupil-Teacher Ratios, 1980 and 1994

	Pupil-teacher ratio		Average annual rate of change[b]		
	1980	1994[a]	Pupils	Teachers	PTR
	(1)	(2)	(3)	(4)	(3)-(4)
Hong Kong	29.8	21.8	-0.5	1.6	-2.1
Japan	20.9	15.8	-1.0	0.9	-1.9
Philippines	31.3	34.3	2.6	1.9	0.7
Singapore	25.5	21.4	-0.3	1.0	-1.2
South Korea	43.5	26.7	-0.8	3.0	-3.7
Thailand	n.a.	19.6	0.1	n.a.	n.a.

[a]Hong Kong: 1995; Thailand: 1992; South Korea: 1993. – [b]In percent.
Source: UNESCO (var. iss.).

Figure 1: Changes in the Quality of Schooling Output[a] and in the Relative Price of Schooling[b], 1980-1994



HKG: Hong Kong; JPN: Japan; PHL: Philippines; SGP: Singapore; KOR: South Korea; THA: Thailand.

[a]Index of quality of schooling output based on average mathematics and science test results derived under H2. – [b]Average annual rate of change of the price of schooling minus the average annual rate of change of the average of the PGS and the CSPS deflators.

Source: Tables 1 and 3.