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Trends in mathematics and science performance in 18 countries: Multiple regression analysis of the cohort effects of TIMSS 1995-2007

Hee Kyung Hong
Hong Kong Institute of Education
Hong Kong, SAR

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Abstract: The purpose of this study was to simultaneously examine relationships between teacher quality and instructional time and mathematics and science achievement of 8th grade cohorts in 18 advanced and developing economies. In addition, the study examined changes in mathematics and science performance across the two groups of economies over time using data from the TIMSS 1995-2007 assessments. While economy did not account for variation in mathematics and science achievement, findings from regression analyses indicated significant relationships between school inputs and achievement in both groups of countries across the years. Teaching experience was a strong indicator of mathematics performance in developing countries, while instructional time was mildly related to achievement in both subjects in advanced economies.
Keywords: TIMSS; advanced economies; developing economies; school resources; student achievement

Tendencias en el desempeño en matemáticas y ciencias en 18 países: Análisis de regresión múltiple de los efectos de cohorte en TIMSS 1995-2007
Resultados usando TIMSS 1995-2007.

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Resumen: El objetivo de este estudio fue examinar simultáneamente las relaciones entre la calidad docente y el tiempo de instrucción y los logros en matemáticas y ciencias de una cohorte de 8° grado en 18 economías avanzadas y en desarrollo. Además, el estudio examinó los cambios en el rendimiento en matemáticas y ciencias entre dos grupos de economías a lo largo del tiempo utilizando los datos de las evaluaciones de TIMSS de 1995-2007. Aunque la variable "economía" no mostró variación en los resultados de logros de aprendizaje en matemáticas y ciencias, los análisis de regresión muestran relaciones significativas entre los insumos escolares y logros de aprendizaje en los dos tipos de países a lo largo de los años. La experiencia docente fue un fuerte indicador del rendimiento en matemáticas en los países en desarrollo, mientras que el tiempo de instrucción se relaciona medianamente con el rendimiento en ambas materias en las economías avanzadas.
Palabras clave: TIMSS; economías avanzadas; economías en desarrollo; recursos escolares; aprendizaje estudiantil.

Tendências no desempenho em matemáticas e ciências em 18 países: análise de regressão múltipla de efeitos de coorte no TIMSS 1995-2007
Resumo: O objetivo deste estudo foi examinar, simultaneamente, as relações entre a qualidade do professor e o tempo de instrução e os resultados em matemática e ciências de grupos do último ano do ensino básico (*8th grade*) em 18 economias avançadas e em desenvolvimento. Para além disso, o estudo examinou as mudanças no desempenho em matemática e em ciências entre os dois grupos de economia ao longo do tempo, usando dados das avaliações do TIMSS 1995-2007. Embora a economia não conte para a variação nos resultados em matemática e ciências, os resultados das análises de regressão indicam relações significativas entre as condições das escolas e os resultados em ambos os grupos de países, ao longo dos anos. A experiência de ensino foi um forte indicador do desempenho em matemática em países em desenvolvimento, enquanto o tempo de instrução relacionou-se moderadamente com os resultados alcançados em ambas as disciplinas em economias avançadas.
Palavras-chave: TIMSS; economias avançadas; economias em desenvolvimento; recursos das escolas; resultados dos estudantes

Introduction

As greater emphasis is placed on mathematics and science in national education systems as a means of generating a high rate of return to the economy (Schofer, Ramirez, & Meyer, 2000), there has been an increasing focus on cross-national comparisons of student performance in the two subject areas. The aim of these comparisons is to assess the quality and educational efficiency of such programs in relation to the financial reforms driven by the national economy. International donor agencies such as the World Bank and International Monetary Fund (IMF) have offered prescriptions for improving efficiency and quality of education systems, while international organizations such as the Organisation for Economic Co-operation and Development (OECD) and the International Evaluation of Educational Achievement (IEA) have emphasized measurement and comparison of school outcomes, with better education outcomes considered integral to economic and social productivity (Arnove, 2007).

The purpose of this study is to explore the relationship between levels of economic performance and mathematics and science achievement in international education systems. This is important as one influences the other in meaningful ways. On the one hand, research that examined the impact of mathematics and science on development have concluded that better education outcomes, particularly in mathematics and science, are considered integral to economic and social productivity (Schofer, Ramirez, & Meyer, 2000). This is especially salient in the globalized era in which the world economy is becoming increasingly integrated, and proficiency in the two subject areas is deemed necessary to respond to technological and scientific changes.

On the other hand, and more importantly, national school systems can also focus on extending the school inputs necessary to develop the essential sets of mathematics and science skills to produce an optimal achievement outcome that corresponds to economic growth. In addition to assessing the relationship between national economy and mathematics and science achievement, other within-school factors that enhance achievement in these subject areas are explored. One role of international studies such as the IEA is to provide individual countries with the impetus to improve students' academic achievement in different subject areas through information derived from cross-national scales of comparison. Studies that have examined mathematics and science achievement have reported that differences in national curricula – in the extent to which the intended, potentially implemented and implemented curricula reflect the culture of a country – explained much of the variation in achievement outcomes (Cogan & Schmidt, 2002; Papanastasiou, 2000). Other studies have shown that school resources contribute to variations in student achievement in developing countries, and are better predictors of mathematics than other achievement measures (Marks, Cresswell, & Ainley, 2006; Reddy, 2005).

In this study, the relationship between Gross Domestic Product (GDP) per capita and achievement in mathematics and science is examined. GDP per capita is often used as an indicator of national economy, especially in cross-national achievement studies, based on the assumption that advanced economies also tend to be high performers in mathematics and science (Baker, Goesling, & LeTendre, 2002; Chudgar & Luschei, 2009; Ramirez et al., 2006). Two research questions are raised. First, is there an increase in mathematics and science achievement over time across the different countries, and if so, does the increase in achievement correlate with GDP per capita across the years? Second, how do school level factors – such as instructional time spent in school, teacher's formal education, and teaching experience – affect mathematics and science achievement across the two groups of economies? Additionally, do these effects vary over time?

Theoretical Framework

This study subscribes to the education production function model in establishing the possible relationship between national economy and achievement in mathematics and science. The production function framework of economics explains the production of education as a function of different inputs that are important for a given context or country (Chudgar & Luschei, 2009). Most production function studies measure educational outcomes in terms of student achievement, although some studies have used alternative quantitative measures to assess outcomes, such as attendance rates and attitudinal scales. Among them, student performance is considered the most direct and measurable indicator of school outcomes. Measured achievement has been employed as a reasonable predictor of success in the labor market, as well as a plausible indicator of economically relevant skills. Educational inputs range from economic to sociological inputs such as investment into school resources, student's family background, and curricular contents. Although Hanushek and Kimko (2000) disputed the impact of direct spending on student achievement, Heyneman and Loxley (1983) found that both school and teacher qualities are key factors that influence student learning in numerous advanced and developing countries. This study examines school factors as educational inputs in relation to mathematics and science achievement.

Criticisms of the education production function model have pointed to the limitations of identifying reliable production functions in education based on three grounds. The first highlights the conceptual limitation of the underlying productivity model as it fails to capture the complex and dynamic nature of education production processes (Monk, 1992). The second criticism is directed at the outcomes-as-standards strategy used to identify the properties of the relevant production functions. Again, the issues focus on the conceptualization of the standards as well as their measurement, which obscure the implications for policy-making by the central authority as knowledge about the precise factors contributing to improved school effects are lacking. The third factor critiques the deficiency of the model that bases productivity on tangible and non-simultaneous possession of material goods, without factoring non-material resources into the production function model (Hodas, 1993).

Modernization and human capital theories, on the other hand, focus on the role of education in advancing economic growth. They specifically examine the effect of human capital on economic growth, which this study does not intend to cover. The premise of their arguments also acknowledges the importance of mathematics and science as core subjects that contribute to the expansion of industrial production (Kamens, Meyer, & Benavot, 1996), and to the improvement of individual and national productivity (Schofer, Ramirez, & Meyer, 2000). A more recent study (Ramirez et. al., 2006), however, empirically supports that the established confidence of the positive effects of educational attainment on economic growth is unwarranted. Nonetheless, the study demonstrates that there is a positive relationship between national economy and mathematics and science achievement in the four Asian Tigers (South Korea, Taiwan, Hong Kong, and Singapore) that have achieved remarkable economic growth between the 1960s and 1990s. It is not surprising, therefore, that mathematics and science have been the most prevalent school subjects in reform efforts, especially in the lower secondary levels, to educate a more technically and scientifically literate population. Since the 1960s, developing nations have also adopted policy reforms incorporating mathematics and science into their primary school curricula as a means to achieve economic prosperity (Benavot, 2004).

School factors. School resources explain a larger proportion of variance in achievement for developing than for advanced economies. Heyneman and Loxley (H-L) (1983) proposed that variations in school resource quality can matter more than variations in family SES in affecting overall student achievement in less-developed nations, while the reverse holds true for developed nations. While the H-L findings have specifically been disputed in replicated studies on school effects (Baker, Goesling, & LeTendre, 2002; Hanushek & Luque, 2003), the literature on production function studies generally indicate that school resources are important and significant for student achievement in developing countries (Hanushek, 1995; Buchmann & Hannum, 2001).

Raising teacher quality was found to be critical to improving student learning outcomes (Rockoff, 2005), as student achievement is affected more by the teacher than by other factors such as class size or composition (Darling-Hammond & Sykes, 2003). This has been affirmed early on by the Coleman Report that highlighted teacher characteristics to account for more variance in student achievement than any other school resources (Coleman et al., 1966). Evidence from the U.S. showed that indicators of teacher quality, such as teacher certification and degree in the field to be taught, were the strongest predictors of student outcomes; while uncertified teachers were a weak predictor of student achievement (Darling-Hammond, 2000). Beginning teachers also performed significantly worse than more experienced teachers, which implied important gains in teaching quality for novice teachers in their first years of teaching (Rivkin, Hanushek, & Kain, 2005). Teacher qualifications and teaching experience were also positively associated with student achievement, especially in the lower grades (Hanushek & Luque, 2003). Teacher certification in science, that trained teachers to present scientific concepts and acquire mastery of content knowledge, was also highly correlated to student achievement in TIMSS (Vlaardingerbroek & Taylor, 2003).

In developing countries, teachers in general lack adequate academic qualifications, training and mastery of content compared to teachers in advanced economies (UNESCO, 2004). Research has shown mixed evidence on the relationship between teacher quality and student achievement in developing contexts. Students performed better in mathematics and English when taught by qualified teachers than otherwise in rural Kenya (Oneri & Goll, 2008), while students tended to score lower in science if the teachers majored in the subject in Romanian schools (Istrate et al., 2006). However, teacher education in developing countries was found to be effective in enhancing student performance as evidenced in 35 out of 63 studies conducted in the 1980s and early 1990s (Hanushek, 1995). This also supports the argument that achievement in developing nations is less affected by socioeconomic differences than by within-school factors. Furthermore, there was a notable difference in the way trained teachers taught more advanced grades and more difficult subjects, mainly in mathematics and science (Heyneman & Loxley, 1983).

When school systems allocated a greater amount of time on any given subject, Inkeles (1979) reported that it yielded national differences in academic performance. Subsequent studies have affirmed the positive effects of instructional time on student achievement, especially time spent on subject-specific instructions (Frederick & Walberg, 1980; Benavot & Gad, 2004). Instructional time is often discussed in conjunction with instructional quality and content, and is an essential component of school resources (Baker et al., 2004a). According to the economic analysis of time spent on school learning (Millot & Lane, 2002), instructional time is optimal as an educational input when it produces classroom learning as output, as measured by achievement tests. A comprehensive review of school effectiveness studies cited length of instructional time to be an important factor in influencing student achievement (Lewin, 1993). The actual amount of instructional time the students receive, as opposed to the intended instructional time that is often reported in large data surveys, matters more for learning outcomes, given the discrepancy between the intended and enacted curriculum in both developed and developing countries (Benavot & Gad, 2004).

In earlier studies, the length of time spent on subject content in developing countries was a consistent predictor of student achievement, with instructional time being comparable in magnitude to other school factors (Fuller, 1987). Subsequent studies (Baker, Goesling, & LeTendre, 2002; Baker et al., 2004a) have critiqued this on two grounds: the findings pertain to a period when the discrepancies in educational resources were greater than they are at present among developing economies, with the overall association between instructional time and achievement across countries being relatively small. Nonetheless, instructional time did account for more variances in science than in mathematics achievement (Baker et al., 2004a). In addition, developing nations allocated an extensive amount of instructional time to both subjects for their relevance to economic development (Kamens, Meyer, & Benavot, 1996). Cross-national research conducted between 1925 and 1985 showed that expanded time was given to mathematics in developing countries (Kamens & Benavot, 1991), but this trend was ambiguous between 1985 and 2000 with mathematics emphasized only in selected parts of the world, such as Latin America and the Caribbean (Benavot, 2004).

Methodology

Data

For the TIMSS data collection, 42, 38, 48 and 59 countries participated in the eighth grade test-taking in 1995, 1999, 2003 and 2007, respectively (Beaton et al., 1996; Olsen et al., 2008; see Table 1). In addition to the mathematics and science tests, TIMSS also collected extensive information about home and school factors that influenced students' learning in these subjects. The database contains student achievement scores in mathematics and science, as well as large-scale responses to background questionnaires from students, mathematics and science teachers, and school principals in the participating countries (Gonzalez & Miles, 2001; Olsen et al., 2008). Table 1 shows the number of items in eighth grade mathematics and science assessment across the four years. To ensure reliable measurement of trends over time, items that had been used in 1995 and 1999 were also included in the 2003 and 2007 assessments (Olsen et al., 2008). The data used in this study was aggregated by country as the measurement unit in the analyses. The sampling population included all the data available for the 18 countries for the four variables examined (student achievement, teaching experience, academic qualification, instructional days; see Tables 2a and 2b). In the 8th grade sampling population for Korea in TIMSS 1995 (Table 2a), for example, 5827 students participated in the mathematics assessments (variable a); 288 mathematics teachers indicated the number of years they had taught (variable b) and 290 mathematics teachers had academic qualifications (variable c). There was an average of 143 full instructional days in the school year (variable d).

Table 1

Number of Participating Countries and Items in Mathematics and Science in Grade 8 for 1995, 1999, 2003 and 2007

Year / *Data Type*	1995	1999	2003	2007
Countries	42	38	48	59
Mathematics	151	162	194	215
Science	135	146	189	214

Table 2a

Distribution of Sampling Population by Country and Variables in Mathematics for 1995, 1999, 2003 and 2007

Group	Variables / Countries	1995				1999				2003				2007			
		a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
1	Australia	12852	486	489	131	4032	159	158	133	4791	217	226	173	4069	233	240	195
	Canada	10456	729	723	331	8770	383	378	353	8628	347	361	327	7404	392	403	314
	Cyprus	5852	185	187	37	3116	111	112	48	4002	158	158	50	4399	231	237	55
	England	3579	472	468	99	2960	336	336	102	2830	97	96	47	4025	218	224	122
	Hong Kong	6752	163	159	71	5179	150	150	116	4972	144	145	94	3470	128	139	100
	Israel	1415	54	55	16	4195	292	278	67	4318	306	309	76	3294	310	328	79
	Italy	4836	264	266	134	3328	183	180	180	4278	203	215	164	4408	287	287	170
	Japan	10271	297	m	146	4745	142	144	131	4856	146	146	131	4312	214	215	135
	Korea	5827	288	290	143	6114	193	193	142	5309	260	263	144	4240	237	241	145
	Singapore	8285	271	268	137	4966	144	144	145	6018	319	329	161	4599	399	409	159
	Slovenia	5606	206	208	94	3109	149	149	147	3578	221	222	154	4043	754	760	133
	United States	10973	450	449	152	9072	412	407	175	8912	397	400	196	7377	609	615	206
2	Bulgaria	3771	n/a	n/a	n/a	3272	160	153	148	4117	182	183	154	4019	231	245	141
	Hungary	5978	274	277	143	3183	192	192	144	3302	192	194	139	4111	269	m	132
	Iran	7429	353	355	145	5301	168	168	123	4942	172	178	152	3981	204	208	141
	Lithuania	5056	244	261	122	2361	149	147	149	4964	248	246	129	3991	257	241	129
	Romania	7471	308	326	151	3425	146	145	135	4104	170	174	135	4198	255	263	137
	Russia	8160	169	170	169	4332	186	187	179	4667	208	215	211	4472	269	271	200

Note. Group 1 = Advanced economies; Group 2 = Developing economies.
Variable labels for sampling population: a = Student achievement; b = Number of teaching years; c = Teacher's academic qualifications; d = Number of full instructional days in a year.
n/a = Data has not been included in the TIMSS International Database.
m = Missing data as items were omitted or not administered.

Table 2b

Distribution of Sampling Population by Country and Variables in Science for 1995, 1999, 2003 and 2007

Group	Variables / Countries	1995				1999				2003				2007			
		a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
1	Australia	12852	885	886	131	4032	471	461	133	4791	384	399	173	4069	422	445	195
	Canada	10456	735	735	331	8770	442	440	353	8628	504	515	327	7404	349	368	314
	Cyprus	5852	209	222	37	3116	223	222	48	4002	459	471	50	4399	652	670	55
	England	3579	578	574	99	2960	366	364	102	2830	260	269	47	4025	506	533	122
	Hong Kong	6752	157	153	71	5179	135	135	116	4972	123	131	94	3470	118	120	100
	Israel	1415	37	35	16	4195	233	233	67	4318	286	279	76	3294	310	328	79
	Italy	4836	264	266	134	3328	183	180	180	4278	203	215	164	4408	287	287	170
	Japan	10271	295	m	146	4745	144	144	131	4856	145	145	131	4312	175	177	135
	Korea	5827	400	400	143	6114	186	186	142	5309	256	255	144	4240	179	178	145
	Singapore	8285	265	265	137	4966	144	145	145	6018	325	329	161	4599	388	397	159
	Slovenia	5606	603	609	94	3109	221	220	147	3578	484	491	154	4043	754	760	133
	United States	10973	900	912	152	9072	944	935	175	8912	924	916	196	7377	609	615	206
2	Bulgaria	3771	n/a	n/a	n/a	3272	567	531	148	4117	580	589	154	4019	614	682	141
	Hungary	5978	762	781	143	3183	580	577	144	3302	601	605	139	4111	762	781	132
	Iran	7429	358	341	145	5301	167	167	123	4942	169	180	152	3981	358	341	208
	Lithuania	5056	715	760	122	2361	442	419	149	4964	912	916	129	3991	715	760	129
	Romania	7471	1114	1180	151	3425	563	554	135	4104	668	693	135	4198	1114	1180	137
	Russia	8160	327	329	169	4332	751	753	179	4667	814	842	211	4472	327	329	200

Note. Group 1 = Advanced economies; Group 2 = Developing economies.
Variable labels for sampling population: a = Student achievement; b = Number of teaching years; c = Teacher's academic qualifications;
d = Number of full instructional days in a year.
n/a = Data has not been included in the International Database.
m = Missing data as items were omitted or not administered.

Hypotheses

There are two hypotheses in this study. The first hypothesis assumes there is a relationship between GDP per capita and mathematics and science achievement, with corresponding changes in the relationship between the two variables across time.

The second hypothesis posits that school factors – teaching experience, teachers' academic qualification, and time spent on instruction – are predictors of student achievement in the two subject areas.

Variables

Dependent variable. The TIMSS International Database contains achievement data for students in mathematics and science and related background data for 1995, 1999, 2003 and 2007. As dependent variables, student achievement in mathematics and science are taken from the 18 countries across the years. Each subject has five sets of plausible values based on which analyses are replicated five times per subject in this study. Plausible values are derived from five imputed values per student response to account for the error inherent in the multiple imputation process (Martin et al., 2004).

Independent variables. The TIMSS International Database includes data for school and student level variables. Teacher quality and instructional time variables are pertinent to this study at the school level. The data used to indicate teacher quality are teaching experience and teachers' academic qualification. For both subjects in 1999, teaching experience was expressed in terms of the number of years taught (open-ended numerical response) and academic qualification in terms of four categorical responses:

1 = Did not complete secondary school;
2 = Secondary school only;
3 = BA or equivalent; and
4 = MA/PhD

In some cases, the variable for teacher's academic qualification expanded to six categories:

1=Did not complete ISCED 3;
2=Finished ISCED 3;
3=Finished ISCED 4;
4=Finished ISCED 5B;
5=Finished ISCED 5A, first degree; and
6=Finished ISCED 5A, second degree or higher.

ISCED denotes International Standard Classification of Education and the levels indicate the following (UNESCO, 1997):

ISCED 3=Upper secondary education;
ISCED 4=Post-secondary non-tertiary education;
ISCED 5A=Tertiary programs that are largely theoretically based and intended to provide sufficient qualifications for gaining entry into advanced research programs and professions with high skills requirements, last 3-4 years full-time (e.g. higher education);
ISCED 5B=Tertiary programs that are shorter than 5A that focus on occupationally specific skills geared for entry into the labor market.

For the purpose of consistency across the years, the six categories were collapsed into 1, 2-4, 5 and 6 to correspond to the four categorical responses used in 1999.

Instructional time is measured in terms of the number of full instructional days in the school year.

Analyses

Consistent with the first hypothesis, repeated measures was used to determine the relationship between GDP per capita and 8th grade mathematics and science achievement across the years. Repeated measures analysis provides information on the time trend of the dependent variable under different conditions, with the responses to individual conditions over time an important element of analysis (Kuehl, 1994). This study used a quasi-repeated measures design since the mathematics and science tests were cross-nationally administered to a cohort group of 8th grade students across the four years. As dependent variables, mathematics and science achievement were measured for all 18 countries that participated in TIMSS studies in 1995, 1999, 2003 and 2007. Hence, the five plausible scores for each subject were observed at each time point. The 18 countries were categorized into advanced and developing economies, with changes in both categories assessed over time. The two categories were derived from the classification of advanced and developing economies used by the IMF World Economic Outlook (IMF, October 2010): Bulgaria, Hungary, Iran, Lithuania, Romania and Russia are categorized as the six developing economies, while the remaining 12 are advanced economies.

For the second hypothesis, multiple regression was conducted to test the relationship between the school factors and student achievement. As the TIMSS 1995 data for Bulgaria was missing, a total of 17 countries were examined in the regression analysis for 1995. The regression model conveyed the level of significance of each variable on mathematics and science achievement across the two groups of countries over time.

Results

In both subjects, advanced economies (Group 1) performed better in mathematics and science than developing economies (Group 2) in 1995, 1999, 2003 and 2007 (see Tables 3a and 3b). Developing countries also showed a consistent improvement in both mathematics and science performance across the four points in time.

Table 3a

Descriptive Statistics for Mathematics Achievement: Plausible Values 1-5

Year	Group	PV1		PV2		PV3		PV4		PV5	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1995	1	519.72	91.41	519.48	91.65	519.55	91.23	519.58	91.09	519.45	91.40
	2	471.15	95.04	471.11	95.14	471.14	94.97	470.94	95.03	471.19	94.83
1999	1	532.72	92.29	532.47	92.81	532.67	92.71	532.18	92.48	532.65	93.19
	2	489.75	94.81	489.14	95.38	489.40	94.78	489.46	94.86	532.65	93.19
2003	1	529.01	88.59	529.86	89.85	529.99	89.63	529.64	89.61	529.80	88.86
	2	485.01	88.25	485.30	89.13	485.27	89.70	485.14	88.95	485.49	89.26
2007	1	522.66	92.97	523.66	93.67	523.74	94.12	523.23	93.92	523.96	93.42
	2	487.25	95.64	487.81	96.95	487.60	97.30	487.43	97.41	488.37	96.32

Table 3b
Descriptive Statistics for Science Achievement: Plausible Values 1-5

Year	Group	PV1		PV2		PV3		PV4		PV5	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1995	1	507.62	93.21	507.66	93.34	507.78	93.27	507.56	93.26	507.58	93.25
	2	477.65	95.19	477.43	94.98	477.49	95.13	477.55	95.03	477.13	95.36
1999	1	524.34	91.81	523.43	92.05	523.17	91.16	523.27	91.92	523.35	91.70
	2	500.97	97.07	499.08	96.05	500.84	96.45	500.24	96.55	500.64	95.35
2003	1	527.22	82.71	527.47	83.30	527.72	82.07	527.76	82.97	527.96	82.24
	2	496.71	84.99	496.95	85.41	497.47	84.23	496.80	85.51	497.62	84.72
2007	1	520.40	88.13	520.92	87.50	520.58	87.45	520.23	88.32	520.85	87.81
	2	505.10	89.63	504.42	89.60	505.61	88.37	504.63	89.91	505.70	88.30

For the first hypothesis, repeated measures analysis indicated that there was considerable growth in achievement within the two groups of countries from 1995 to 2007 even though the variation in the mean scores was small between the two groups. As shown in Tables 4a and 4b, the interaction effect was not statistically significant between GDP per capita and 8th grade mathematics and science achievement. However, achievement was significant across the years for all mathematics plausible scores, $F(3, 88) = 3.96, 4.08, 3.93, 4.02$ and 3.92, $p < 0.05$ (see Table 4a); and all science plausible scores, $F(3, 88) = 4.73, 5.16, 5.37, 5.27$ and 5.73, $p < 0.05$ (see Table 4b).

Table 4a
Repeated Measures Analyses for Mathematics Achievement: Plausible Values 1-5

Plausible Value	Source	df	F	p
1	Year	3	3.96	.01*
	Year x Group	3	0.38	.77
	Error	48	(170.90)	
2	Year	3	4.08	.01*
	Year x Group	3	0.33	.80
	Error	48	(173.66)	
3	Year	3	3.93	.01*
	Year x Group	3	0.33	.80
	Error	48	(176.50)	
4	Year	3	4.02	.01*
	Year x Group	3	0.41	.74
	Error	48	(171.72)	
5	Year	3	3.92	.01*
	Year x Group	3	0.31	.82
	Error	48	(174.35)	

Note: Values enclosed in parentheses represent mean square errors.
*p < .05.

Table 4b.
Repeated Measures Analyses for Science Achievement: Plausible Values 1-5

Plausible Value	Source	df	F	p
1	Year	3	4.73	.00*
	Year x Group	3	0.27	.85
	Error	48	(324.59)	
2	Year	3	5.16	.00*
	Year x Group	3	0.34	.80
	Error	48	(258.59)	
3	Year	3	5.37	.00*
	Year x Group	3	0.49	.69
	Error	48	(258.85)	
4	Year	3	5.27	.00*
	Year x Group	3	0.44	.73
	Error	48	(260.14)	
5	Year	3	5.73	.00*
	Year x Group	3	0.48	.70
	Error	48	(254.45)	

Note: Values enclosed in parentheses represent mean square errors.
*$p < .05$.

For the second hypothesis, three school inputs (teaching experience, academic qualifications, and number of instructional days in the school year) were used to identify educational production processes and their influences on student achievement. Multiple regression was conducted to examine the effect of these school variables on mathematics and science achievement in both groups of countries: teaching experience (in terms of the number of years taught), academic qualification, and the number of full instructional days in the school year. The regression analyses showed significant effects of school variables on mathematics achievement in developing countries, and on both subjects in advanced economies, across the years.

Table 5a
Summary of Regression Analysis for Variables Predicting Mathematics Achievement for Group 1 (Developed Economies) from 1995 to 2007: Plausible Values 1-5

PV	Variable	B	SE B	β
1	A	-33.08	19.04	-.25
	B	-6.47	2.33	-.43*
	C	1.01	0.44	.33*
2	A	-33.49	19.24	-.25
	B	-6.57	2.36	-.43*
	C	1.03	0.45	.34*
3	A	-32.78	19.20	-.25
	B	-6.46	2.35	-.42*
	C	1.01	0.45	.33*
4	A	-32.98	19.14	-.25
	B	-6.47	2.34	-.42*
	C	1.02	0.45	.34*
5	A	-32.53	19.19	-.25
	B	-6.42	2.35	-.42*
	C	1.02	0.45	.33*

Note. Variable labels: A = Teacher's academic qualifications; B = Number of years taught; C = Number of full instructional days.
R^2 = .14 for all Plausible Values 1 to 5.
*$p < .05$.

Table 5b
Summary of Regression Analysis for Variables Predicting Mathematics Achievement for Group 2 (Developing Economies) from 1995 to 2007: Plausible Values 1-5

PV	Variable	B	SE B	β
1	A	8.97	12.52	.15
	B	7.40	2.76	.68*
	C	0.18	0.78	.06
2	A	8.46	12.58	.14
	B	7.62	2.77	.69*
	C	0.21	0.78	.07
3	A	8.34	12.68	.13
	B	7.60	2.80	.68*
	C	0.18	0.79	.06
4	A	8.57	12.62	.14
	B	7.62	2.78	.69*
	C	0.20	0.79	.06
5	A	8.78	12.51	.14
	B	7.50	2.76	.68*
	C	0.18	0.78	.06

Note. Variable labels: A = Teacher's academic qualifications; B = Number of years taught; C = Number of full instructional days.
R^2 = .46, .47, .47, .47, .47 respectively for Plausible Values 1 to 5.
*$p < .05$.

Table 5c

Summary of Regression Analysis for Variables Predicting Science Achievement for Group 1 (Developed Economies) from 1995 to 2007: Plausible Values 1-5

PV	Variable	B	SE B	β
1	A	-20.24	16.43	-.18
	B	-1.79	1.68	-.17
	C	0.77	0.35	.34*
2	A	-20.55	16.46	-.18
	B	-1.81	1.68	-.17
	C	0.76	0.35	.33*
3	A	-20.24	16.42	-.18
	B	-1.82	1.68	-.17
	C	0.76	0.35	.33*
4	A	-20.41	16.65	-.18
	B	-1.74	1.70	-.16
	C	0.74	0.36	.32*
5	A	-20.56	16.38	-.18
	B	-1.79	1.67	-.17
	C	0.76	0.35	.33*

Note. Variable labels: A = Teacher's academic qualifications; B = Number of years taught; C = Number of full instructional days.

R^2 = .07, .07, .07, .06, .07 respectively for Plausible Values 1 to 5.

*$p < .05$.

Teaching experience and the number of full instructional days were significantly associated with mathematics performance in advanced economies from 1995 to 2007, with the two variables explaining 14 percent of the proportion of the overall mathematics achievement (see Table 5a). Teaching experience and mathematics achievement, however, were inversely related implying that more teaching experience did not necessarily correspond to improved mathematics performance in developed countries. The number of full instructional days was also significantly related to science achievement for all five plausible scores (0.34, 0.33, 0.33, 0.32, 0.33, $p<0.05$; see Table 5c) in developed countries across the years. Instructional days accounted for 7 percent of the variance in science achievement, with positive beta weights that were twice as strong as either of the two teacher quality variables.

Similar to the findings for mathematics achievement in developed countries, teaching experience was also a significant factor that influenced mathematics achievement in developing economies from 1995 to 2007. Moreover, teaching experience was positively related to mathematics performance, as indicated by the five plausible scores for mathematics (0.68, 0.69, 0.68, 0.69, 0.68, $p<0.05$; see Table 5b), explaining 47 percent of the performance variance in the six developing countries.

Table 5d
Summary of Regression Analysis for Variables Predicting Mathematics Achievement for Group 2 (Developing Economies) in 2007: Plausible Values 1-5

PV	Variable	B	SE B	β
1	A	-17.15	6.37	-.59
	B	16.39	3.40	1.27*
	C	2.24	0.88	.65
2	A	-17.18	6.71	-.59
	B	16.48	3.59	1.27*
	C	2.29	0.93	.66
3	A	-17.71	6.42	-.60
	B	16.73	3.43	1.27*
	C	2.34	0.89	.66
4	A	-17.30	6.42	-.59
	B	16.69	3.42	1.27*
	C	2.35	0.89	.67
5	A	-17.13	6.79	-.59
	B	16.32	3.63	1.26*
	C	2.26	0.94	.65

Note. Variable labels: A = Teacher's academic qualifications; B = Number of years taught; C = Number of full instructional days.
R^2 = .54, .53, .53, .53, .53 respectively for Plausible Values 1 to 5.
*$p < .05$.

To further examine the effects of school factors in the developing countries, eight separate multiple regression analyses were conducted by subject per year. While there were no meaningful influences of the school variables on science achievement, teaching experience was again significantly related to mathematics performance in 2007 (1.27, 1.27, 1.27, 1.27, 1.26, $p<0.05$; see Table 5e), a factor that solely accounted for 53 percent of the variance in mathematics achievement in developing economies.

The overall results indicate that achievement variances for the two groups have reduced and the gap in variances between the two groups have narrowed since the H-L (1983) findings. The results nevertheless support their conclusion that school resources continue to be more influential in student outcomes in developing than in developed contexts: 81-90 percent of achievement variance was explained by school factors in the former, while the figures were considerably reduced to 22-27 percent in the latter.

Discussion and Conclusion

The results for the first hypothesis in this study do not support previous findings that national economy accounts for variation in mathematics and science achievement (Baker, Goesling & LeTendre, 2002; Heyneman & Loxley, 1983). Three plausible reasons explain this phenomenon. First, the age groups to which the achievement tests were administered differ. While this study examined results from 8th grade mathematics and science achievement, Heyneman and Loxley's (1983) study was based on primary school academic achievement in 29 high- and low-income countries. Second, mass institutionalization of education in developing countries, supported by the state and international agencies, may explain the diminishing effect of national economy on mathematics and science achievement, as demonstrated by Baker and colleagues (2002) in their follow-up analysis of Heyneman and Loxley's (1983) study. Third, TIMSS does not cover a wide range of economies as the tests were administered to countries that had sufficient available resources to participate in TIMSS. This eliminated countries at the lowest end of the economic spectrum while largely including those from the upper-middle- and high-income economies.

The mean group differences in student achievement indicate that developed countries performed better than developing countries overall, although interesting observations can be made at the country level. Advanced economies like the U.S. and England (mean plausible scores 474, 495, 504, 506 for the U.S. and 484, 500, 507, 515 for England for 1995, 1999, 2003 and 2007 respectively) consistently scored lower in mathematics than developing nations such as Hungary and Russia (mean plausible scores 513, 537, 532, 523 for Hungary and 506, 528, 510, 520 for Russia for 1995, 1999, 2003 and 2007 respectively) across time. Although the two cases from each group are anomalous to the overall group findings, it is evident that Hungary and Russia are cross-nationally better in 8th grade mathematics and science than the U.S. and England, with the pattern persistent across the four years. This can be attributed to the traditionally heavy emphasis placed on mathematics and science education in the former communist states. Conceptions of teaching mathematics were also substantially different in Bulgaria as compared to the conventional pedagogical beliefs and practices found in England (Andrews & Hatch, 2000).

The results for the second hypothesis examining the effects of school variables validate previous research that school factors still exert significant effects on variance in student achievement (Hanushek, 2006). In this study, teaching experience was the strongest predictor of mathematics achievement in developing countries across all years (Tables 5b). This is consistent with the H-L findings in which the impact of teaching experience on student achievement was proportionately greater for developing countries than for developed countries. Teaching experience remained the strongest predictor of mathematics achievement for developing economies in 2007 (Table 5e) explaining slightly more than the achievement variance for all years combined. One possible explanation for the predominance of teaching experience as a predictor of student performance is that at the primary and lower secondary levels, teachers gain greater competence over the years in the subject matter and teaching skills, which contribute to better teaching outcomes as evident in student achievement (Rivkin, Hanushek, & Kain, 2005). In addition, mathematics is a cumulative subject in which the effects of teacher's prior content knowledge on student performance becomes stronger at the advanced levels (Whitehurst, 2002).

The number of full instructional days in a year was significantly related to mathematics and science achievement in developed countries across the years (Tables 5a and 5c). While this concurs with studies that found quantity of instructional time to be a common indicator to assess student achievement (Millot & Lane, 2002; Benavot & Gad, 2004), the strength of the association between the two variables was low indicating that instructional time is a weak predictor of student performance. A plausible explanation may be that the quality of instruction matters more than the quantity of instructional hours, and that time on task is more effective in enhancing student outcomes. Research that studied the percentage of instructional time utilized in various countries found that the actual number of days engaged in learning was considerably lower than the number of days in the school year (Abadzi, 2007).

Teaching experience, in contrast, was negatively associated with mathematics performance in the same group of advanced economies across the four time points. Research on mathematics teaching in three developed countries – U.S., Germany and Japan – has shown the positive effects of teaching experience on student performance when a system of research-and-development has been established within the schools. For example, Japanese mathematics teachers reported that their individual lessons improved gradually as they participated in developing and sharing knowledge based on their own teaching practices (Stigler & Hiebert, 1999).

This study confirms that school resources continue to play an influential role on mathematics and science achievement in both advanced and developing economies. In view of the findings, two policy implications are made. First, teaching experience was a consistent and strong predictor of student performance in mathematics over time in developing economies, which implies that governments in these countries should not only provide teacher training in the subject – whether in the form or pre-service or on-the-job training – but also ensure that the trained teachers stay on in the school system through incentives and continuous professional development. These measures can prevent the attrition rate of teachers that commonly occurs in their first years of teaching. Second, the number of full instructional days was a positive and significant predictor of mathematics and science achievement over time in developed economies. The association, however, was weak implying that the amount of instructional time allocated in the curriculum may not necessarily be critical to achievement. Instead, and more importantly, the effective use of time spent on learning tasks may be a more accurate indicator of student performance. Educational policymakers can, therefore, consider strategies to reduce the gap between the intended and actual time spent on learning tasks in the curriculum to maximize learning outcomes. A few concrete measures may be to train teachers in effective mathematics and science instructional techniques; and to increase teacher accountability through systematic teacher evaluations and regular meetings in which teaching practices are developed and shared during the school year.

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About the Author

Hee Kyung Hong
Hong Kong Institute of Education
Email: hkhong@ied.edu.hk

Hee Kyung Hong is an assistant professor in the Department of Education Policy and Leadership at the Hong Kong Institute of Education. Her research interests include achievement studies, and school finance and policy.

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José Machado Pais Instituto de Ciências Sociais da Universidade de Lisboa, Portugal
Wenceslao Machado de Oliveira Jr. Universidade Estadual de Campinas, Brasil
Jefferson Mainardes Universidade Estadual de Ponta Grossa, Brasil
Luciano Mendes de Faria Filho Universidade Federal de Minas Gerais, Brasil
Lia Raquel Moreira Oliveira Universidade do Minho, Portugal
Belmira Oliveira Bueno Universidade de São Paulo, Brasil
António Teodoro Universidade Lusófona, Portugal
Pia L. Wong California State University Sacramento, U.S.A
Sandra Regina Sales Universidade Federal Rural do Rio de Janeiro, Brasil
Elba Siqueira Sá Barreto Fundação Carlos Chagas, Brasil
Manuela Terrasêca Universidade do Porto, Portugal
Robert Verhine Universidade Federal da Bahia, Brasil
Antônio A. S. Zuin Universidade Federal de São Carlos, Brasil