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School Infrastructure and Educational Outcomes: A Literature Review, with Special Reference to Latin America

ABSTRACT International development agencies and country governments have called for greater resources to be devoted to education. While previous studies highlight the value of investing in education, they do not shed light on which specific educational investments should be pursued. This paper examines both the economics literature and the education literature published from 1990 to 2012 to assess the extent to which specific types of school infrastructure have a causal impact on student learning and enrollment. There is some evidence that school libraries and the creation of new schools leads to improved learning and enrollment. The literature also provides some evidence that toilets improve student learning, and that laboratories and drinking water facilities increase enrollment. Perhaps the main conclusion of this study is that the evidence base is weak, so more high-quality research is needed on the impact of infrastructure on learning and time in school in developing countries.

JEL classifications: I21, I25, O15, O18

Keywords: education; Latin America; infrastructure; test scores; time in school

Economists and other researchers have shown that education increases workers' productivity and thus raises their incomes. Education also has many other benefits, such as improved health status and lower crime.[1] Recent research shows that education increases countries' economic growth rates.[2] While these studies offer strong support for investments in

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1. Lochner (2011).
2. Hanushek and Woessmann (2015).

education, they shed no light on what types of educational investments are most effective.

Governments in developing countries generally accept that education provides many benefits, so they have steadily increased their funding of education. In Latin America, public spending on education as a percent of GDP increased from 3.9 percent in 1995 to 4.4 percent in 2010. Some countries spend even more: Costa Rica, Cuba, and Jamaica all spend more than 6 percent of their GDP on education.[3] International development agencies have also called for greater resources to be devoted to education.[4]

This higher spending on education has been accompanied by, and almost certainly has contributed to, higher school enrollment rates. The increases in enrollment over the past two decades, particularly at the secondary level, have been quite dramatic. As shown in table 1, primary and secondary enrollment rates increased in all regions of the developing world from 1990 to 2012. By 2012, gross primary enrollment rates were at or above 100 percent in all regions, and gross secondary enrollment rates were well above 50 percent in all regions except sub-Saharan Africa. In Latin America and the Caribbean, virtually all countries now have gross primary enrollment rates greater than 100 percent and gross secondary enrollment rates well above 60 percent. Similarly, table 2 shows that primary school completion rates increased in most regions from 1990 to 2012, approaching 100 percent in all regions except South Asia and sub-Saharan Africa. Primary school completion rates are close to 100 percent for almost all countries in Latin America and the Caribbean, with some exceptions such as Guyana (85 percent) and Nicaragua (80 percent).[5]

The increased funding for education in Latin America and elsewhere has often been used to build and staff new schools, especially in areas that had no schools. Indeed, several studies show that enrollment increases when there is a reduction in the distance to the nearest school. Even after the distance to the nearest school has been reduced, however, there are other ways by which investing in infrastructure could increase enrollment. For example, while access to paved roads has increased in almost all Latin American countries, only 23 percent of roads are paved in the region.[6] This

3. World Bank (1998, table 2.9; 2012, table 2.11).

4. OECD (2013).

5. It is possible that Haiti's primary completion rate is even lower, but there are no reliable data from Haiti on most education indicators.

6. World Bank (2012, table 5.10).

TABLE 1. Primary and Secondary Gross Enrollment Rates, 1990–2012

	Primary			Secondary		
Region or country	*1990*	*2000*	*2012*	*1990*	*2000*	*2012*
World region						
Latin America and the Caribbean	116	119	109	60	82	88
East Asia and Pacific	120	105	118	39	57	83
Middle East and North Africa	95	99	110	56	68	78
South Asia	87	92	111	36	44	63
Sub-Saharan Africa	72	82	100	23	26	41
Latin America and the Caribbean						
Argentina	106	114	118[a]	71	87	92[a]
Bahamas	98	97	108	86	78	93[b]
Barbados	116	102	105[a]	86	105	105[a]
Belize	113	120	121	61	68	84
Bolivia	104	112	94[a]		78	77[a]
Brazil	141					
Chile	105	100	101	78	82	89
Colombia	105	119	107	52	72	93
Costa Rica	102	110	105	43	61	104
Dominican Republic	100	113	103		59	76
Ecuador	125	113	114	59	59	87
El Salvador	94	104	113	38	54	69
Guatemala	77	104	114[a]	23	38	65[a]
Guyana	105	104	75		97	101
Haiti	75					
Honduras	107	107	109	33		73
Jamaica	104	97		70	87	89[a]
Mexico	111	106	105[b]	53	70	86
Nicaragua	87	101	117[b]	37	53	69
Panama	100	105	100	59	65	84
Paraguay	104	120	95[a]	31	61	70[a]
Peru	119	122	100	67	85	90
Suriname	117	118	114[a]	56	73	85[a]
Trinidad and Tobago	96	105	106[b]	83		
Uruguay	109	109	112	81	98	90
Venezuela	105	101	102	56	60	85

Source: World Bank, *World Development Indicators.*
a. Latest available data are for 2011.
b. Latest available data are for 2010.

TABLE 2. Primary School Completion Rates

Region or country	*1990*	*2012*
World region		
Latin America and the Caribbean	82	95
East Asia and Pacific	99	105[a]
Middle East and North Africa	76	95
South Asia	64	91
Sub-Saharan Africa	54	70
Latin America and the Caribbean		
Argentina		109[b]
Bahamas		93[a]
Barbados		104[b]
Belize		116
Bolivia	70	92[b]
Brazil		
Chile		97
Colombia	74	105
Costa Rica	75	95
Dominican Republic		90
Ecuador		111
El Salvador	63	101
Guatemala		88[b]
Guyana		85
Haiti		
Honduras	64	100
Jamaica	97	
Mexico	87	99
Nicaragua	39	80[a]
Panama		98
Paraguay	65	86[b]
Peru		91
Suriname		88[b]
Trinidad and Tobago	100	95[a]
Uruguay	95	104[a]
Venezuela	78	96

Source: World Bank, *World Development Indicators*.
a. Latest available data are for 2010.
b. Latest available data are for 2011.

raises the possibility that paving unpaved roads in these countries could increase access to schools even if there are no reductions in the distance to the nearest school.

Another way to increase enrollment is to increase spending on existing schools, either by reducing school fees and other direct costs or by improving school quality, including infrastructure improvements. Tables 3 and 4 present data on school infrastructure in Latin America and the Caribbean in

TABLE 3. School Infrastructure in Latin America, 1997
Share of schools with different school facilities

School sample and country	*Sports facilities*	*Science lab*	*Computer lab*	*Dining hall*	*Nurse station*	*Library*
All schools						
All countries	0.68	0.17	0.23	0.26	0.10	0.20
Argentina	0.65	0.21	0.33	0.18	0.05	—
Bolivia	0.70	0.24	0.24	0.10	0.11	0.49
Brazil	0.67	0.29	0.20	0.42	0.02	0.26
Chile	0.78	0.23	0.46	0.78	0.18	—
Colombia	0.70	0.14	0.18	0.31	0.12	0.32
Cuba	0.92	0.14	0.27	0.62	0.43	0.10
Dominican Republic	0.65	0.18	0.18	0.09	0.06	0.18
Honduras	0.60	0.09	0.09	0.11	0.03	0.41
Mexico	0.68	0.06	0.28	0.01	0.02	0.41
Paraguay	0.62	0.10	0.14	0.13	0.05	—
Peru	0.79	0.34	0.30	0.11	0.09	0.32
Venezuela	0.42	0.10	0.05	0.15	0.04	—
Urban schools						
Argentina	0.71	0.25	0.37	0.18	0.06	—
Bolivia	0.79	0.40	0.40	0.17	0.19	0.38
Brazil	0.70	0.33	0.24	0.41	0.03	0.20
Chile	0.85	0.28	0.56	0.70	0.19	—
Colombia	0.79	0.28	0.38	0.29	0.26	0.27
Cuba	0.90	0.15	0.34	0.75	0.60	0.06
Dominican Republic	0.76	0.27	0.26	0.08	0.08	0.18
Honduras	0.67	0.22	0.20	0.09	0.07	0.17
Mexico	0.76	0.08	0.37	0.00	0.02	0.43
Paraguay	0.67	0.15	0.22	0.14	0.06	—
Peru	0.80	0.41	0.40	0.11	0.11	0.26
Venezuela	0.44	0.12	0.07	0.13	0.05	—
Rural schools						
Argentina	0.33	0.00	0.11	0.22	0.00	—
Bolivia	0.57	0.00	0.00	0.00	0.00	0.64
Brazil	0.55	0.09	0.00	0.45	0.00	0.55
Chile	0.63	0.12	0.24	0.93	0.15	—
Colombia	0.63	0.03	0.03	0.32	0.00	0.35
Cuba	0.97	0.12	0.12	0.36	0.09	0.18
Dominican Republic	0.46	0.00	0.03	0.11	0.03	0.17
Honduras	0.55	0.00	0.02	0.13	0.00	0.58
Mexico	0.53	0.03	0.13	0.02	0.02	0.38
Paraguay	0.52	0.02	0.02	0.11	0.02	—
Peru	0.74	0.17	0.06	0.11	0.03	0.46
Venezuela	0.33	0.00	0.00	0.21	0.00	—

Source: Authors' estimations, based on data from the First Regional Comparative Explanatory Study (PERCE), carried out by the Latin American Laboratory for Assessment of the Quality of Education (LLECE).

TABLE 4. School Infrastructure in Latin America, 2006
Share of schools with different school facilities and utilities

School sample and country	*Electricity*	*Water*	*Sewage*	*Landline*	*Enough restrooms*	*Sports facilities*	*Science lab*	*Computer lab*	*Dining hall*	*Nurse station*	*Library*
All schools											
All countries	0.89	0.80	0.61	0.49	0.69	0.64	0.13	0.37	0.29	0.06	0.53
Argentina	0.95	0.82	0.55	0.71	0.75	0.47	0.31	0.47	0.42	0.05	0.72
Brazil	0.95	0.88	0.62	0.58	0.81	0.69	0.13	0.39	0.33	0.02	0.52
Colombia	0.92	0.73	0.75	0.55	0.54	0.64	0.32	0.54	0.48	0.16	0.57
Costa Rica	0.97	0.88	0.72	0.72	0.61	0.48	0.03	0.30	0.93	0.06	0.24
Cuba	0.99	0.95	0.71	0.34	0.91	0.62	0.04	0.94	0.34	0.13	0.82
Chile	0.99	0.92	0.82	0.84	0.90	0.79	0.37	0.90	0.94	0.39	0.79
Dominican Republic	0.75	0.61	0.48	0.33	0.74	0.41	0.17	0.16	0.10	0.06	0.39
Ecuador	0.97	0.58	0.58	0.42	0.54	0.74	0.17	0.38	0.25	0.10	0.31
El Salvador	0.94	0.67	0.51	0.46	0.67	0.29	0.09	0.22	0.12	0.03	0.50
Guatemala	0.68	0.78	0.38	0.16	0.52	0.39	0.02	0.10	0.17	0.03	0.61
Mexico	0.97	0.80	0.67	0.41	0.66	0.70	0.02	0.31	0.13	0.04	0.53
Nicaragua	0.44	0.48	0.24	0.19	0.28	0.24	0.01	0.09	0.06	0.01	0.23
Panama	0.66	0.61	0.46	0.33	0.50	0.48	0.19	0.31	0.69	0.05	0.38
Paraguay	0.89	0.64	0.30	0.22	0.60	0.77	0.04	0.13	0.10	0.03	0.32
Peru	0.55	0.64	0.44	0.29	0.51	0.69	0.11	0.28	0.11	0.06	0.50
Uruguay	1.00	0.98	0.96	0.99	0.82	0.57	0.17	0.42	0.78	0.04	0.75
Urban schools											
Argentina	1.00	0.94	0.75	0.92	0.81	0.39	0.41	0.60	0.42	0.05	0.83
Brazil	1.00	0.95	0.84	0.86	0.90	0.86	0.22	0.64	0.46	0.04	0.74
Colombia	0.98	0.92	0.91	0.88	0.67	0.64	0.46	0.80	0.46	0.28	0.67
Costa Rica	0.99	0.96	0.84	0.98	0.77	0.61	0.09	0.77	0.92	0.18	0.57
Cuba	1.00	0.99	0.97	0.65	0.89	0.70	0.04	0.99	0.61	0.26	0.97
Chile	1.00	0.99	0.96	0.99	0.96	0.80	0.47	0.99	0.92	0.45	0.86

Dominican Republic	0.85	0.79	0.72	0.63	0.83	0.52	0.25	0.29	0.15	0.11	0.56
Ecuador	1.00	0.88	0.82	0.71	0.68	0.80	0.22	0.65	0.16	0.18	0.49
El Salvador	1.00	0.93	0.91	0.93	0.85	0.48	0.25	0.61	0.06	0.09	0.77
Guatemala	0.94	0.97	0.93	0.67	0.81	0.67	0.04	0.43	0.54	0.07	0.50
Mexico	0.97	0.97	0.89	0.70	0.77	0.77	0.04	0.46	0.11	0.08	0.57
Nicaragua	0.93	0.93	0.76	0.74	0.66	0.52	0.07	0.38	0.14	0.07	0.53
Panama	0.96	0.96	0.88	0.86	0.76	0.65	0.52	0.78	0.70	0.17	0.70
Paraguay	0.96	0.93	0.55	0.61	0.75	0.69	0.09	0.30	0.11	0.03	0.53
Peru	0.97	0.97	0.89	0.63	0.85	0.61	0.27	0.63	0.11	0.16	0.64
Uruguay	1.00	1.00	0.97	1.00	0.82	0.48	0.19	0.41	0.76	0.05	0.76
Rural schools											
Argentina	0.85	0.54	0.06	0.22	0.61	0.64	0.08	0.21	0.40	0.04	0.50
Brazil	0.88	0.79	0.33	0.20	0.70	0.45	0.02	0.06	0.16	—	0.22
Colombia	0.85	0.54	0.57	0.20	0.41	0.65	0.17	0.27	0.50	0.03	0.47
Costa Rica	0.96	0.83	0.67	0.60	0.53	0.42	—	0.08	0.93	—	0.08
Cuba	0.98	0.91	0.48	0.07	0.93	0.56	0.04	0.90	0.10	0.03	0.70
Chile	0.98	0.78	0.55	0.55	0.78	0.76	0.17	0.72	0.97	0.26	0.65
Dominican Republic	0.67	0.47	0.29	0.09	0.66	0.32	0.09	0.05	0.05	0.02	0.24
Ecuador	0.94	0.32	0.36	0.16	0.42	0.69	0.14	0.16	0.32	0.03	0.14
El Salvador	0.91	0.56	0.34	0.26	0.59	0.22	0.03	0.07	0.15	—	0.39
Guatemala	0.61	0.73	0.24	0.03	0.44	0.33	0.02	0.02	0.07	0.02	0.64
Mexico	0.97	0.63	0.44	0.09	0.53	0.63	—	0.15	0.16	—	0.48
Nicaragua	0.32	0.37	0.12	0.06	0.19	0.18	—	0.02	0.05	—	0.16
Panama	0.53	0.47	0.28	0.10	0.39	0.41	0.05	0.11	0.68	—	0.25
Paraguay	0.86	0.51	0.19	0.05	0.53	0.81	0.02	0.06	0.10	0.03	0.23
Peru	0.25	0.42	0.15	0.06	0.28	0.74	0.01	0.06	0.11	—	0.41
Uruguay	0.98	0.92	0.93	0.94	0.80	0.95	0.06	0.45	0.87	0.02	0.70

Source: Authors' estimations, based on data from the Second Regional Comparative Explanatory Study (SERCE), carried out by the Latin American Laboratory for Assessment of the Quality of Education (LLECE).

1997 and 2006.[7] The 2006 data are more comprehensive in that they include five additional infrastructure variables and four additional countries. These tables highlight several different characteristics of school infrastructure in Latin America. First, there is a gap between urban and rural schools in both years. For example, no rural schools had computer labs in Brazil in 1997, yet 24 percent of urban schools had them; and while the number increased to 6 percent for rural schools in 2006, it increased much more (to 64 percent) for urban schools. Second, several types of infrastructure increased over time from 1997 to 2006. For example, averaging over all countries, the share of schools with computer labs increased from 23 percent to 37 percent, and the share with a library increased from 20 percent to 53 percent. Third, there is wide variation in many types of school infrastructure. For example, in 2006, 94 percent of schools in Cuba had access to a computer lab, while Nicaragua and Guatemala were far behind with only nine and ten percent, respectively. Another example is electricity: 100 percent of schools in Uruguay have electricity, but this is true for only 44 percent of Nicaraguan schools and 55 percent of Peruvian schools.

While the improvements over time in school infrastructure are encouraging, in recent years increased attention has been given to school quality and to student learning—and here, unfortunately, there is less evidence of progress. Student performance on the tests developed by the Program for International Student Assessment (PISA) is comparable over time starting in 2000. Student learning appears to be stagnant or even falling among fifteen-year-old students in seven Latin American countries (see table 5). From 2000 to 2012, two countries show clear upward trends in math scores (Brazil and Chile), while the rest show either mixed or even decreasing trends. For reading scores, the only Latin American country that experienced an increase in scores was Peru. One possible explanation is that expanded enrollment brings in less prepared students, reducing the average score. Yet there are several countries with mixed or declining trends that did not experience large increases in school enrollment, despite increasing real expenditures per student in the period. For example, in Argentina the gross secondary school enrollment rate was about 85 percent from 1998 to 2007, and spending per pupil was somewhat higher in

7. These data are from the Latin American Laboratory for Assessment of the Quality of Education (LLECE), which has implemented two comparative studies that collected data on school infrastructure in the region. PERCE (First Regional Comparative Explanatory Study) was implemented in 1997 and collected data from 1,435 schools in twelve countries on six school infrastructure variables. SERCE (Second Regional Comparative Explanatory Study) was implemented in 2006 and collected data from 2,872 schools in sixteen countries on eleven infrastructure variables.

TABLE 5. Scores on International Comparable Tests by Fifteen-Year-Old Students, 2000 to 2012

Country and subject	*2000*	*2003*	*2006*	*2009*	*2012*
Argentina					
Reading	418	n.a.	374	398	396
Mathematics	n.a.	n.a.	381	388	388
Brazil					
Reading	396	403	393	412	410
Mathematics	n.a.	356	370	386	391
Chile					
Reading	410	n.a.	442	449	441
Mathematics	n.a.	n.a.	411	421	423
Colombia					
Reading	n.a.	n.a.	385	413	403
Mathematics	n.a.	n.a.	470	481	376
Mexico					
Reading	422	400	410	425	424
Mathematics	n.a.	385	406	419	413
Peru					
Reading	327	n.a.	n.a.	370	384
Mathematics	n.a.	n.a.	n.a.	n.a.	368
Uruguay					
Reading	n.a.	434	413	426	411
Mathematics	n.a.	422	427	427	409

Source: Program for International Student Assessment (PISA) results, U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics (http://nces.ed.gov/surveys/pisa/).
n.a. Not available.

2004–06 than in 1998–2000; yet reading test scores in 2006 were much lower than in 2000. Similarly, Brazil's progress in reading was uneven from 2000 to 2006, although it experienced only a moderate increase in secondary school enrollment (7–13 percentage points) from 2000 to 2007, and real spending on education increased steadily over that period.

Policymakers and researchers in both developed and developing countries have interpreted this stagnation in test scores as evidence that progress can be achieved only by changing the way schools are run. Nevertheless, it is still possible that spending that changes basic school and classroom infrastructure characteristics could improve the educational outcomes of students in developing countries. This paper reviews the literature since 1990 on the impact of school infrastructure on students' educational outcomes. Building on an earlier review, this paper focuses on the impact of infrastructure on educational outcomes, particularly for Latin America.[8] Given the different focus

8. The earlier review was conducted by Glewwe and others (2013).

of this study and its extension of the time horizon from 2010 to 2012, this paper includes sixteen studies that were not covered in the earlier survey. The inclusion of these studies and the focus on classroom- and school-level infrastructure, as well as utilities, are distinguishing features of the present study.

This paper examines both the economics literature and the education literature published from 1990 to 2012 to assess the extent to which school infrastructure characteristics have a causal impact on student learning and enrollment. School infrastructure includes classroom-level infrastructure and other classroom characteristics (such as natural light, temperature, and acoustics), as well as school-level infrastructure, which includes school utilities (such as availability of electricity, potable water, and the condition of the building) and other features of the school (such as the existence of a library, a computer lab, or science labs). The definition of infrastructure used in this study excludes textbooks, other pedagogical materials, and information and communications technology (ICT).[9]

The rest of the paper is organized as follows. The next section describes the methodology used to identify the studies to include in this review. In the following section, the results of this literature review for developing and developed countries are presented, with a special focus on Latin American countries. The paper then summarizes the results and draws several conclusions.

Methodology for Reviewing the Literature

This paper reviews the literature that estimates the impact of school infrastructure on student learning and time in school in both developing and developed countries. We focus on papers published in peer-reviewed journals between 1990 and 2012, but we also include working papers from 2008 to 2012. Studies published before 1990 are excluded. The review includes studies of pre-primary, primary, secondary, and vocational education, while excluding tertiary-level education. The outcomes of interest include test scores in different subjects, enrollment, dropping out, years of schooling, and daily attendance.[10] This review of the literature focuses on the impact of school infrastructure variables, which include the condition of the walls, floors, and

9. The physical presence of a computer was included in this study, but software or programs related to information and communications technology were excluded.

10. Unlike previous studies, this analysis searched for impacts on other educational outcomes, such as school bullying, cheating, conflict, crime, security, and delinquency. However, we found no studies on these outcomes that met our minimum criteria for quality.

roofs; instructional materials in the classroom (such as flip charts and blackboards, but excluding textbooks); the availability of electricity, water, and toilets; and the availability of laboratories (science and computer), libraries, desks, and blackboards.[11]

Before explaining how we conducted the literature review, it is important to clarify the relationships the literature attempts to estimate and to briefly discuss problems that arise when estimating these relationships.[12] To begin, assume that children's parents maximize, subject to constraints, a (life-cycle) utility function. The main arguments in the utility function are consumption of goods and services (including leisure) at different points in time and each child's years of schooling and learning. The constraints faced are the production function for learning, the impacts of years of schooling and of skills obtained on the future labor incomes of children, a life-cycle budget constraint, and perhaps some credit constraints or an agricultural production function. The production function for learning is a structural relationship that can be depicted as

$$A = a(S, \mathbf{Q}, \mathbf{C}, \mathbf{H}, \mathbf{I}), \tag{1}$$

where A is skills learned (*achievement*); S is years of schooling; $\mathbf{Q}$ is a vector of school and teacher characteristics (inputs that raise school *quality*), which include school infrastructure variables; $\mathbf{C}$ is a vector of child characteristics (including "innate ability"); $\mathbf{H}$ is a vector of household characteristics; and $\mathbf{I}$ is a vector of school inputs under the control of parents, such as children's daily attendance and purchases of textbooks and other school supplies.

For a given school, parents choose S and $\mathbf{I}$ (subject to the above-mentioned constraints) to maximize household utility. Both years of schooling, S, and schooling inputs, $\mathbf{I}$, are general functions of $\mathbf{Q}$, $\mathbf{C}$, and $\mathbf{H}$, as well as prices related to schooling (such as tuition, other fees, and prices of textbooks and uniforms), which are also exogenous and can be denoted by the vector $\mathbf{P}$. Inserting these equations for S and $\mathbf{I}$ into equation 1 yields a reduced-form equation for A:

$$A = h(\mathbf{Q}, \mathbf{C}, \mathbf{H}, \mathbf{P}). \tag{2}$$

11. The complete list of school infrastructure variables is available from the authors on request.

12. The following paragraphs summarize a more detailed exposition given in Glewwe and others (2013).

This reduced-form equation is a causal relationship, but it is not a textbook production function because it reflects household preferences and includes prices among its arguments.

Turning to the impact of infrastructure and other school quality variables (**Q**) on student learning, there are two distinct relationships. To see this, consider a change in one element of **Q**, which we call Q_i. Equation 1 shows how changes in Q_i affect A when all other explanatory variables are held constant and thus provides the *partial* derivative of A with respect to Q_i. In contrast, equation 2 provides the *total* derivative of A with respect to Q_i because it allows for changes in S and **I** in response to the change in Q_i. For example, parents may respond to higher school quality by increasing their provision of educational inputs such as textbooks. Alternatively, if they consider higher school quality a substitute for those inputs, they may decrease those inputs.

Many studies attempt to estimate the impact of school and teacher characteristics, including school infrastructure, on enrollment and learning, yet these attempts face a number of serious estimation challenges. The most common generic concerns are omitted-variable bias, sample selection, endogenous program placement, and measurement errors. With regard to the first concern, if major inputs to achievement are omitted from the estimation of equation 1, they may be correlated with the included variables, which results in biased estimates of the impacts of the included variables. School quality could also be correlated with unobserved variables if governments improve schools that have unobserved education problems.[13] Governments may also raise school quality in areas with good educational outcomes, if those areas have political influence.[14] The former causes underestimation of school quality variables' impacts on learning, while the latter causes overestimation. Finally, measurement error—a ubiquitous problem that can be particularly severe in developing countries—can bias estimates, often pushing estimates toward zero and making factors appear to be insignificant.

Considerable effort has gone into addressing these problems in recent decades. Most significant is the implementation of randomized experiments through the use of randomized control trials (RCTs). Other methods include regression discontinuity (RD) designs and panel data methods. In general, RCTs and RD methods estimate the impacts as given in equation 2, rather than the production function of equation 1. Other methods often attempt to

13. Pitt, Rosenzweig, and Gibbons (1993).
14. World Bank (2001).

estimate equation 1. Unfortunately, many studies do not clarify which of the two types of relationships they are estimating, and we do not attempt to make this distinction here.

The remainder of this section describes how the very large literature available was searched and categorized by quality of analysis. The first step was to classify studies into three categories: medium quality, high quality, and randomized controlled trials (RCTs). Medium-quality papers are those studies whose estimation strategy includes ordinary least squares (OLS), as well as some studies that used hierarchical linear model (HLM) methods. The high-quality papers use other, more sophisticated estimation methods, such as instrumental variables (IV), regression discontinuity, matching methods, difference in differences, or panel data methods such as fixed-effects regression. All RCTs were classified as a separate "very high quality" method because this method minimizes the estimation problems discussed above. While this paper presents evidence for all developing countries, a particular focus was placed on Latin American countries. For Latin America, the review includes all studies that meet the medium-quality requirement. When all developing countries are considered, including Latin American countries, results are presented for all studies, then only for high-quality studies (including RCTs), and finally only for RCTs. For studies conducted in developed countries, only those that meet the high-quality criteria, including RCTs, are included.

In searching for relevant studies, we searched for papers that included a list of keywords that included education, a list of eighty-six infrastructure inputs, and a list of thirty-five educational outcomes. For a study to appear in our search, it needed to have the word education, at least one of the infrastructure inputs, and at least one of the educational outcomes from this list of keywords. This list of keywords was created from analyzing all the keywords in the Education Resources Information Center (ERIC) to choose those that are relevant for the scope of this study. To further refine the search, a list of developing country names was included. These developing countries came from the International Monetary Fund's list of emerging and developing countries. We searched both the educational and economic academic literatures (using ERIC and EconLit, respectively) for peer-reviewed articles.

Table 6 provides a summary of the search process and the number of articles reviewed in each phase. The initial search of studies on developing countries yielded nearly 9,000 articles. These articles were reviewed individually, keeping the articles that appeared to be relevant to the study based on information found in the abstract. In the search for developing country articles, we excluded papers that analyzed developed countries or tertiary

TABLE 6. Steps to Select Papers Used in the Literature Review: Developing Countries

Review phase	*Procedures used*	*No. papers*
First phase	Search EconLit and ERIC databases	8,820
	—Potential studies kept (round 1)	382
	—Potential studies with our quality criteria	82
	—Add papers included in Glewwe and others (2013) that were not in our list	27
	—Add working papers written after 2010	13
Second phase	Review 122 full papers; eliminate papers based on lack of relevance or lack of quantitative analysis.	58
Third phase	Eliminate papers based on methodology: lack of basic covariates. These 39 papers are the full sample.	39
Fourth phase	Exclude papers that used OLS only. The remaining 19 papers are the high-quality sample and include four RCTs.	19

education, as well as papers that focused on information and communications technologies (ICTs).[15] Based on this initial review, 382 papers were retained for the next phase of the selection process.

After eliminating papers whose estimation strategies were not of medium or high quality, which was based on an initial review of the paper's methodology section, only eighty-two papers remained. In addition, twenty-seven studies from Glewwe and others' meta-analysis study were added to the review.[16] To include more recent studies, thirteen working papers that appeared from 2008 to 2012 in prominent working paper series were included. These included the Inter-American Development Bank working papers, Abdul Latif Jameel Poverty Action Lab (J-PAL) working papers, World Bank Policy Research working papers, and National Bureau of Economic Research (NBER) working papers.

Two of the authors reviewed the full text of each of these 122 papers; this step revealed further analytical weaknesses or lack of relevance, so that only fifty-eight papers were retained. These fifty-eight were then reviewed for the adequacy of their basic covariates; to be retained, a study was required to include at least one school variable, at least one family variable, and at least one teacher variable (or another school variable). Examples of school

15. This was done because this paper focuses on the presence of physical infrastructure, such as computer hardware, but not software or programs that are used as instructional or pedagogical materials.

16. Glewwe and others (2013). These studies were dropped from the initial search because some of the infrastructural variables were used as controls, and the abstracts did not reveal the paper to be relevant in the initial search. They were not dropped from Glewwe and others (2013) because of the wider scope of that study.

variables are the availability of electricity and the presence of adequate desks in the classroom. Examples of family variables include household income, parental education levels, and family size. A teacher-level variable could include teacher salary level, teacher education or experience, or the teacher's race. After dropping papers that did not meet these criteria, the final sample of both medium- and high-quality studies consisted of thirty-nine papers on developing countries. These papers were then divided into the three categories: all thirty-nine meet the medium-quality criteria, nineteen meet the higher-quality criteria (that is, they use a more sophisticated estimation method), and four are RCTs.

We used the same search process for developed country articles, but we retained only studies that employ high-quality statistical methods. This search yielded approximately 350 articles from the educational academic literature (ERIC database) and 150 articles from the economics literature (EconLit database). These articles were reviewed in detail and, based on their relevance and the rigor of their methodology, only four papers were included in this review.

Using the same criteria as for developing countries (medium-quality papers), we also checked twenty-three well-regarded Latin American and Caribbean research institutions for working paper series from 1990 to 2012. These included working papers written in English, Spanish, or Portuguese. From this additional search, we added three papers to the thirteen Latin American studies discovered during the initial search of the economic and educational academic literatures.

Results

This section presents the findings of this literature. Table 7 summarizes the number of studies available, classified by quality of study and type of infrastructure. The three types of infrastructure are defined as follows. First, classroom-level infrastructure refers to furniture, such as desks; basic materials such as blackboards, flip charts, and chalk; and other types of classroom infrastructure such as a classroom library. Second, school-level infrastructure includes general building characteristics, such as the type and condition of the walls, floors, and roofs; the presence of a school library; and school amenities, defined as general school-level indexes of items such as walls to separate classrooms, equipment available at the school, the number of specialized rooms (such as libraries or science labs), the reliability of electricity, a compilation of available writing materials (pens, pencils, paper, notebooks, a complete set

TABLE 7. Number of Papers Analyzing Impacts of Infrastructure Variables on Educational Outcomes

Infrastructure variable	*Medium-quality*	*High-quality*	*RCTs*
Classroom			
Desk, tables, chairs	4	2	—
Blackboards, flip charts, chalks	9	5	1
Roofs, walls, floors	5	4	—
Classroom library	2	2	—
School			
Overall school infrastructure	15	5	—
Library	8	6	1
Computers, laptops, Internet	6	4	2
School amenities	8	4	—
Laboratories	2	2	—
Creation of new schools	3	3	—
Utilities			
Electricity	7	3	—
Drinking water facilities	4	3	—
Toilet facilities	4	3	—

of required textbooks, and dictionaries), ventilated classrooms, noise level, or computers for administrative use. Third, utilities refer to water, electricity, and sanitation facilities (such as toilets) within the school. For each of these types of infrastructure, results are presented for the impacts both on student test scores and on students' time in school. In addition to the results for developing countries, findings from developed-country studies are briefly discussed. Finally, each section highlights findings from studies on Latin American countries, based on sixteen studies that examine the impact of school infrastructure on educational outcomes in Latin America and the Caribbean.

Within each type of infrastructure, the studies from developing countries are classified by analytical rigor into three types: medium quality, high quality and RCTs. RCTs are arguably the best methodology for analyzing the impact of school infrastructure on educational outcomes. Unfortunately, very few RCTs have examined the impacts of different types of school infrastructure on student outcomes.

Classroom-Level Infrastructure

Table 8 summarizes the findings of eleven studies that examine the impact of classroom infrastructure on student learning as measured by test scores, and table 9 summarizes the findings from six studies of the impact of classroom infrastructure on time in school variables (namely, enrollment, attendance,

TABLE 8. Summary of Impacts of Classroom Infrastructure on Test Scores

Set of studies	*Negative, significant*	*Negative, insignificant*	*Zero or missing and no sign given*	*Positive, insignificant*	*Positive, significant*	*Total papers*
All studies						
Desk, tables, chairs	2 (1)	2 (1)	—	3 (2)	1 (1)	4
Blackboards, flip charts, chalk	1 (1)	17 (5)	—	22 (6)	8 (3)	8
Roofs, walls, floors	—	3 (2)	—	1 (1)	2 (1)	3
Classroom library	—	—	—	2 (1)	—	1
High-quality studies						
Desk, tables, chairs	—	2 (1)	—	2 (2)	—	2
Blackboards, flip charts, chalk	1 (1)	6 (2)	—	7 (3)	1 (1)	4
Roofs, walls, floors	—	—	—	—	2 (1)	1
Classroom library	—	—	—	2 (1)	—	1
RCTs						
Desk, tables, chairs	—	—	—	—	—	0
Blackboards, flip charts, chalk	—	—	—	1 (1)	—	1
Roofs, walls, floors	—	—	—	—	—	0
Classroom library	—	—	—	—	—	0
Latin America						
Desk, tables, chairs	—	—	—	1 (1)	1 (1)	1
Blackboards, flip charts, chalk	—	2 (1)	—	—	—	1
Roofs, walls, floors	—	1 (1)	—	1 (1)	—	1
Classroom library	—	—	—	—	—	0

TABLE 9. Summary of Impacts of Classroom Infrastructure on Time in School

Set of studies	*Negative, significant*	*Negative, insignificant*	*Zero or missing and no sign given*	*Positive, insignificant*	*Positive, significant*	*Total papers*
All studies						
Desk, tables, chairs	—	2 (1)*	—	—	—	1
Blackboards, flip charts, chalk	—	12 (1)	—	14 (2)*	2 (2)	2
Roofs, walls, floors	1 (1)	12 (3)	—	16 (2)	3 (2)	4
Classroom library	—	—	—	—	—	—
High-quality studies						
Desk, tables, chairs	—	2 (1)	—	—	—	1
Blackboards, flip charts, chalk	—	12 (1)	—	14 (2)*	2 (2)	2
Roofs, walls, floors	3 (1)	17 (3)	—	11 (1)	1 (1)	4
Classroom library	—	—	—	—	—	—
RCTs						
Desk, tables, chairs	—	—	—	—	—	0
Blackboards, flip charts, chalk	—	—	—	—	—	0
Roofs, walls, floors	—	—	—	—	—	0
Classroom library	—	—	—	—	—	0
Latin America						
Desk, tables, chairs	—	—	—	—	—	0
Blackboards, flip charts, chalk	—	—	—	—	—	0
Roofs, walls, floors	—	—	—	—	—	0
Classroom library	—	—	—	—	—	0

* We flipped one of the signs.

years of schooling, and dropping out).[17] The tables also show findings from the high-quality studies, followed by RCTs, and studies specific to Latin America and the Caribbean.

CLASSROOM FURNITURE. Four studies estimate the impact of the availability of classroom furniture (desks, tables, chairs) on test scores in developing countries, with somewhat ambiguous results. Of the eight estimates in these four studies, five are statistically insignificant. Of the three statistically significant estimates, two are negative and one is positive (all at the elementary or secondary level). Of the four studies, one finds significantly negative results of classroom furniture on the reading and math scores of grade 5 students in urban and rural areas of Vietnam, one study finds a significant positive effect in urban and rural areas of Jamaica on primary school students' reading test scores, and the other two find no significant effects.[18]

When the evidence is limited to high-quality studies conducted in developing countries, there are only two: the study of urban and rural areas of Ghana by Glewwe and Jacoby and the study of rural areas in Pakistan by Khan and Kiefer.[19] These two high-quality studies provide four estimates of the impact of classroom furniture on student learning, all of which are statistically insignificant. Thus there is no evidence from high-quality studies that classroom furniture increases students' test scores. Finally, there are no RCT estimates of the impact of classroom furniture on learning in developing countries.

The Jamaica study was the only one of the four studies that was conducted in Latin America and the Caribbean; it yielded only one significant result, showing a positive impact of classroom furniture on test scores.[20] Since this result is from a single paper, it is insufficient for drawing general conclusions on the impact of classroom infrastructure on test scores in Latin America.

With regard to time in school (table 9), only one study examines the impact of the availability of furniture (desks, tables, chairs) on time in school.[21] This high-quality study found no significant impacts. There are no RCT studies in developing countries that examine the impact of classroom furniture on students' time in school. Unfortunately, there are no studies analyzing the impacts of any classroom infrastructure variables on time in school for Latin American countries.

17. While it may seem that there are sixteen (4 + 8 + 3 + 1) studies of classroom infrastructure in the top four lines of table 8, there are actually only eleven: some studies appear in more than one line because they are regression analyses with multiple explanatory variables.

18. On Vietnam, see Hungi (2008); on Jamaica, see Glewwe and others (1995).

19. Glewwe and Jacoby (1994); Khan and Kiefer (2007).

20. Glewwe and others (1995).

21. Glewwe and Jacoby (1994).

TABLE 10. Summary of Impacts of Infrastructure Variables on Educational Outcomes: Four Studies from Developed Countries

Set of studies	*Negative, significant*	*Negative, insignificant*	*Zero or missing and no sign given*	*Positive, insignificant*	*Positive, significant*	*Total papers*
Classroom						
Desk, tables, chairs	—	3 (1)	—	3 (1)	—	1
Blackboards, flip charts, chalk	—	—	—	—	—	—
Roofs, walls, floors	—	—	—	—	—	—
Classroom library	—	—	—	—	—	—
School						
Overall school infrastructure	—	—	—	—	—	—
Library	—	—	3 (1)	1 (1)	2 (1)	1
Computers, laptops, Internet	1 (1)	—	—	3 (1)	—	2
School amenities	—	—	—	—	—	—
Laboratories	—	—	3 (1)	—	3 (1)	1
Creation of new schools	—	—	—	—	—	—
Utilities						
Electricity	—	—	—	—	—	—
Drinking water facilities	—	—	—	—	—	—
Toilet facilities	—	—	—	—	—	—

As shown in table 10, one developed-country study analyzes the impact of classroom furniture on student learning in the United States. Harter presents six estimates, all insignificant, on reading and math test scores.[22] There are no high-quality studies that estimate the impact of other types of classroom-level infrastructure variables (namely, class library, blackboards, or the quality of roofs, walls, or floors) in developed countries.

BLACKBOARDS, FLIP CHARTS, OR CHALK. In contrast, the evidence on the availability of blackboards, flip charts, or chalk in the classroom is more extensive: forty-eight estimates from eight studies. When medium-quality studies are included, this type of classroom infrastructure often appears to increase students' test scores at both the elementary and secondary school levels. More specifically, eight of the nine statistically significant results are positive. Most of these significant results are from studies conducted in African countries.[23]

22. Harter (1999).

23. Glewwe and Jacoby (1994) in Ghana; Glick, Randrianarisoa, and Sahn (2011) in urban and rural areas of Madagascar; and Lee, Zuze, and Ross (2005) for urban and rural areas of fourteen sub-Saharan countries.

However, when the evidence is limited to the high-quality studies, we find little or no support for this type of infrastructure. Of the fifteen estimates of the impact of the availability of blackboards, flipcharts, or chalk in the classroom on students' test scores in elementary and secondary schools, thirteen are statistically insignificant, one is significantly negative, and one is significantly positive. The one positive result is for math test scores in Ghana at the secondary level.[24] The only negative significant result is for dictation test scores at the primary level in urban and rural areas of Indonesia.[25]

Only one paper uses a randomized control trial to examine the impact of classroom infrastructure on test scores.[26] The paper reports a positive but insignificant impact of flipcharts on students' test scores in a rural area of Kenya. Overall, the evidence suggests that blackboards and flip charts have little or no effect on student learning.

Regarding time-in-school outcomes, table 9 shows that there is weak evidence that blackboards or flipcharts in the classroom have a positive impact. Of the twenty-six estimates of these relationships from two studies, only two are significant, but both are positive.[27] More specifically, both studies report one specification with a significant impact of blackboards (as well as many insignificant specifications). These two studies examine attendance in rural India and grade attainment in urban and rural areas of Ghana.[28]

CONDITION OF ROOFS, WALLS, AND FLOORS. There is some evidence that the condition of classroom roofs, walls, and floors increases student learning as measured by test scores. While the three studies yield three negative and three positive estimates, two of the three positive estimates are statistically significant, while none of the negative estimates is statistically significant.[29] When the evidence is limited to high-quality studies, only one study provides consistently positive and significant evidence, which pertains to the condition of school roofs.[30]

Four studies examine the impact of the condition of roofs, walls, and floors on time in school. Only four of the thirty estimates are statistically significant:

24. Glewwe and Jacoby (1994).
25. Suryadarma and others (2006).
26. Glewwe and others (2004).
27. Afridi (2011) estimates the impact on attendance rates for children in India in grades 1–5 separately for each grade and by gender, leading to the large number of estimates.
28. Afridi (2011) on India; Glewwe and Jacoby (1994) on Ghana.
29. The significant positive estimates are both from Glewwe and Jacoby (1994).
30. Glewwe and Jacoby (1994).

one is significantly positive, and three are significantly negative.[31] Two of these studies examine students in rural areas of China. Overall, the results generally suggest no systematic impact of the condition of roofs, walls, and floors on students' time in school. This is also the case when the evidence is limited to high-quality studies. Similarly, no conclusions can be drawn regarding the impact of the condition of walls or floors in the classroom, since no high-quality studies examined these conditions. However, one study has two positive and significant estimates of the impact of roofs on student learning.[32] There are no RCT studies on this type of school infrastructure.

CLASSROOM LIBRARY. Finally, there is no evidence that the availability of a classroom library increases student learning. The sole study is by Zhao and Glewwe, which is a high-quality study but not an RCT.[33] They find no significant results. There are no studies of the impact of classroom libraries on students' time in school.

School-Level Infrastructure

The section explores the impact of school-level infrastructure, such as libraries, science laboratories, computers, and even the construction of new schools, on students' educational outcomes. Table 11 presents the findings for test scores, and table 12 presents the results for time in school.

OVERALL SCHOOL INFRASTRUCTURE. Sixty-one estimates from fourteen studies estimate the impact of overall school infrastructure on test scores; of these, twenty-six estimates are insignificant, five are significantly negative, and thirty are significantly positive. The definition of overall school infrastructure varies by study, but can include any of the following: the overall condition of the school; the average condition of the classrooms based on space, lighting, noise, and desks; the proportion of usable rooms; an index of school quality; physical facilities and teaching materials; the reliability of electricity; and the number of specialized instructional rooms.[34] In general, the evidence indicates that overall school infrastructure increases student learning outcomes.

31. The significant positive estimate is from Brown and Park (2002); the negative estimates are from Glewwe and Jacoby (1994) and Zhao and Glewwe (2010).

32. Glewwe and Jacoby (1994).

33. Zhao and Glewwe (2010).

34. On average classroom condition, see Marshall (2009); for an index of school quality, see Anderson (2000); on physical facilities and teaching materials, see Aslam and Siddiqui (2003); on specialized instructional rooms, see Engin-Demir (2009).

TABLE 11. Summary of Impacts of School Infrastructure on Test Scores

Set of studies	*Negative, significant*	*Negative, insignificant*	*Zero or missing and no sign given*	*Positive, insignificant*	*Positive, significant*	*Total papers*
All studies						
Overall school infrastructure	5 (5)	7 (6)	—	19 (8)	30 (7)	14
Library	2 (2)	11 (4)	—	6 (3)	7 (5)	7
Computers, laptops, Internet	3 (2)	15 (3)	—	41 (4)	20 (5)	6
School amenities	7 (4)	6 (4)	—	4 (3)	7 (2)	7
Laboratories	1 (1)	—	—	—	1 (1)	1
Creation of new schools	—	—	—	—	4 (1)	1
High-quality studies						
Overall school infrastructure	2 (2)	4 (2)	—	2 (1)	6 (2)	4
Library	1 (1)	9 (3)	—	6 (3)	4 (3)	5
Computers, laptops, Internet	3 (2)	15 (3)	—	36 (2)	18 (3)	4
School amenities	3 (1)	4 (2)	—	3 (2)	5 (1)	4
Laboratories	1 (1)	—	—	—	1 (1)	1
Creation of new schools	—	—	—	—	4 (1)	1
RCTs						
Overall school infrastructure	—	—	—	—	—	0
Library	—	4 (1)	—	—	—	1
Computers, laptops, Internet	3 (2)	13 (2)	—	36 (2)	16 (2)	2
School amenities	—	—	—	—	—	0
Laboratories	—	—	—	—	—	0
Creation of new schools	—	—	—	—	—	0
Latin America						
Overall school infrastructure	2 (2)	2 (2)	—	6 (3)	21 (3)	5
Library	1 (1)	2 (1)	—		3 (2)	2
Computers, laptops, Internet	2 (1)	9 (2)	—	30 (2)	31 (3)	5
School amenities	2 (2)	3 (3)	—	2 (2)	4 (2)	4
Laboratories	1 (1)	—	—	—	1 (1)	1
Creation of new schools	—	—	—	—	—	0

Four high-quality studies examine the impact of overall school infrastructure on test scores; six of the fourteen estimates are insignificant. Of the eight statistically significant estimates, six are positive and two are negative, which suggests a positive impact of school infrastructure on student learning.[35] None of the four high-quality studies is an RCT.

Turning to Latin America, there are thirty-one estimates from five studies of the impact of overall school infrastructure on test scores: twenty-seven are

35. The significantly positive estimates are from Fehrler, Michaelowa, and Wechtler (2009) and Yamauchi and Liu (2013); the significant negative estimates are from Glewwe and Jacoby (1994) and Suryadarma and others (2006).

TABLE 12. Summary of Impacts of School Infrastructure on Time in School

Set of studies	*Negative, significant*	*Negative, insignificant*	*Zero or missing and no sign given*	*Positive, insignificant*	*Positive, significant*	*Total papers*
All studies						
Overall school infrastructure	—	6 (3)*	2 (1)	3 (3)*	1 (1)*	4
Library	1 (1)	2 (1)	1 (1)	7 (2)*	4 (1)	3
Computers, laptops, Internet	1 (1)	2 (1)	—	2 (1)	—	1
School amenities	—	—	—	1 (1)	1 (1)	1
Laboratories	—	2 (1)	—	4 (1)	6 (1)	1
Creation of new schools	2 (2)	4 (1)	—	1 (1)	9 (2)	2
High-quality studies						
Overall school infrastructure	—	5 (2)*	—	2 (2)*	1 (1)*	2
Library	1 (1)	2 (1)	1 (1)	7 (2)*	4 (1)	3
Computers, laptops, Internet	1 (1)	2 (1)	—	2 (1)	—	1
School amenities	—	—	—	1 (1)	1 (1)	1
Laboratories	—	2 (1)	—	4 (1)	6 (1)	1
Creation of new schools	2 (2)	4 (1)	—	1 (1)	9 (2)	2
RCTs						
Overall school infrastructure	—	—	—	—	—	0
Library	—	—	1 (1)	—	—	1
Computers, laptops, Internet	1 (1)	2 (1)	—	2 (1)	—	1
School amenities	—	—	—	—	—	0
Laboratories	—	—	—	—	—	0
Creation of new schools	—	—	—	—	—	0
Latin America						
Overall school infrastructure	—	—	—	1 (1)	—	1
Library	—	—	—	—	—	0
Computers, laptops, Internet	1 (1)	2 (1)	—	1 (1)	—	1
School amenities	—	—	—	1 (1)	1 (1)	1
Laboratories	—	—	—	—	—	0
Creation of new schools	2 (2)	4 (1)	—	1 (1)	9 (2)	2

* We flipped one of the signs.

positive, of which twenty-one are significant, and four are negative, of which two are significant. Most of these results come from the Second Regional Comparative and Explanatory Study (SERCE), which covers sixteen countries across Latin America and the Caribbean.[36] Thus, the evidence indicates that general school-level infrastructure in Latin America seems to increase student learning.

Finally, the impact of overall school infrastructure on time in school is shown in the first line of table 12. Twelve estimates from four studies examine these impacts; of these, eleven are insignificant and one is significantly

36. Treviño and others (2010).

positive. Thus there is at most only weak evidence that the general condition of school infrastructure increases students' time in school. For overall school infrastructure, there are only two high-quality studies examining the impacts on time in school.[37] Seven of the eight estimates are statistically insignificant, and the one that was significant was positive. This offers only weak support for a general impact of school infrastructure on time in school.

SCHOOL LIBRARIES. Seven studies provide twenty-six estimates of the impact of a school library on test scores. Of these twenty-six estimates, seventeen are insignificant, two are significantly negative, and seven are significantly positive, which provides some evidence that school libraries increase student learning. Five of these seven studies are of high quality, providing twenty estimates of the impact of a school library on test scores. Of these, fifteen are statistically insignificant, four are significantly positive, and one was significantly negative, providing some, but rather weak, evidence that a school library increases students' learning.[38] Each of the four studies with statistically significant results included both urban and rural areas. One is an RCT study that estimates the impact of school libraries on test scores in India; all four estimates are negative and statistically insignificant.[39]

One developed-country study analyzes the impact of library books per student on student learning in secondary schools in the United States.[40] Of the six estimates, four are insignificant and two have significantly positive impacts (see table 10). Thus there is some evidence that library books increase student learning in secondary schools in developed countries.

For the impact of the presence of a school library on test scores in Latin America, we find six estimates from two studies: three are positive and statistically significant, two are negative but insignificant, and one is significantly negative. These findings are from an analysis of rural primary schools in Colombia and a study of urban and rural secondary schools in Brazil.[41] These studies suggest that school libraries in Latin America can increase student learning at both the primary and secondary levels.

37. Glewwe and Jacoby (1994; Lloyd and others (2003).

38. The significant positive estimates are from Fehrler, Michaelowa, and Wechtler (2009), Glewwe and Jacoby (1994), and Sprietsma (2012); the significant negative estimate is from Suryadarma and others (2006).

39. Borkum, He, and Linden (2013).

40. Konstantopoulos and Borman (2011).

41. McEwan (1998) on Colombia; Sprietsma (2012) on Brazil.

Finally, three high-quality studies estimate the impact of a school library on time in school, with somewhat ambiguous results (see table 12). Of the fifteen estimates, ten are insignificant, one is significantly negative and four are significantly positive (all four of which are from the same study). Borkum, He, and Linden conducted an RCT on the impact of a school library on time in school, collecting data from urban and rural schools in India.[42] Their results are disappointing, however, since the estimated impact is statistically insignificant.

COMPUTERS. There are many proponents of the benefits of providing computers and other types of information technology hardware to schools. Six studies analyze the impact of computers on student test scores; fifty-six estimates are insignificant, three are significantly negative, and twenty are significantly positive, which suggests that, in many cases, computers can increase student learning. Four of these studies were high quality.[43] Fifty-one of the seventy-two estimates from three different high-quality studies are insignificant, three are significantly negative, and eighteen are significantly positive. While these results indicate that computers can increase student learning, the eighteen significantly positive estimates are from only three different studies, and the three significantly negative estimates are from two different studies. If we give equal weight to each study, there is only weak support for computers. If we limit the evidence to the two RCT studies, we find very similar results to the four high-quality studies, since most of the estimates are from these two RCT studies.[44]

Two studies in developed countries estimate the impact of computers on student learning. Kotte, Lietz, and Martinez Lopez find a negative and significant impact (of the ratio of computers per student) on reading scores in Germany.[45] On the other hand, Carneiro finds three insignificant results for the impact of computers (number of computers divided by school size) on various test scores in secondary schools in Portugal.[46] Taken together, these two studies from developed countries yield no support for a positive impact of computers on student learning.

42. Borkum, He, and Linden (2013).

43. Banerjee and others (2007); Barrera-Osorio and Linden (2009); Fehrler, Michaelowa, and Wechtler (2009); Sprietsma (2012).

44. Banerjee and others (2007); Barrera-Osorio and Linden (2009).

45. Kotte, Lietz, and Martinez Lopez (2005).

46. Carneiro (2008).

We find seventy-two estimates from studies of Latin American countries that measure the impact of computers on student learning.[47] Of these estimates, thirty-eight are from a randomized control trial in Colombia, which shows positive, but mostly insignificant, impacts of computers on educational outcomes.[48] Most of the remaining estimates come from the SERCE study.[49] Of the total seventy-two estimates, thirty-one are significantly positive, from three different studies. Only two, from a single study, are significantly negative. Thus the results suggest a positive impact of the availability of computers in schools on students' test scores for Latin America.

Only one study analyzes the impact of computers on time in school.[50] That study yields one negative and significant estimate and four insignificant estimates (of which two were negative and two were positive) (see table 12). Thus there is no evidence that computers increase students' time in school.

SCHOOL AMENITIES. Twenty-four estimates from seven studies analyze the impact of school amenities on student test scores. School amenities range from an index of writing and reading materials, such as pens, pencils, paper, notebooks, a complete set of required textbooks, and dictionaries, to computers for administrative use.[51] As shown in table 11, ten estimates are insignificant, seven are significantly negative, and seven are significantly positive, such that the findings are ambiguous.

Limiting the evidence to four high-quality studies yields fifteen estimates of the impact of school amenities on test scores. Seven of these are insignificant, three (from a study of urban and rural schools in Indonesia) are significantly negative, and five (from a study of urban and rural schools in South Africa) are significantly positive.[52] Thus the impact of school amenities on test scores is ambiguous even for high-quality studies. There are no estimates from RCT studies.

Four studies from Latin America examine the impact of school amenities—including ventilation, lighting, and noise—on test scores. Of the eleven estimates, five are insignificant, four are significantly positive, and two are

47. This includes estimates from a working paper by Treviño and others (2010) that is not included in the set of all studies, high-quality studies, and RCTs, because it is not one of the working paper series selected for the review.

48. Barrera-Osorio and Linden (2009).

49. Treviño and others (2010).

50. Barrera-Osorio and Linden (2009).

51. The amenities index is from Glewwe and others (1995), while Lockheed, Harris, and Jayasundera (2010) study the availability of computers for administrative use.

52. On Indonesia, see Suryadarma and others (2006); on South Africa, see van der Berg (2008).

significantly negative. At best, this provides only weak support that amenities matter.

Only one study analyzes the impact of school amenities on time in school (see table 12). The findings of two estimates are only suggestive, given that they are from a single study: both are positive, but only one is significant. This was a high-quality study, but not an RCT, conducted in Brazil.

SCIENCE LABORATORIES. Only one high-quality study analyzes the impact of science laboratories on students' test scores, with inconclusive findings.[53] The study of urban and rural schools in Brazil presents two estimates, one of which is significantly negative and the other of which is significantly positive. The evidence of the impact of science laboratories on test scores is thus ambiguous.

Konstantopoulos and Borman also analyze the impact of science laboratory facilities on learning, but in a developed-country setting: namely, U.S. secondary schools.[54] Of the six estimates, three are insignificant and three are significantly positive, which provides some evidence that the availability of science laboratory facilities increases student learning in developed countries (see table 10).

A single study provides twelve estimates from rural schools in China of the impact of science laboratories on time in school.[55] As shown in table 12, these estimates suggest a positive effect: of the twelve estimates, six are insignificant and the other six are positive and significant.

CREATION OF NEW SCHOOLS. Finally, four estimates from a single high-quality study show that the creation of a new school has a significantly positive impact on student learning. As shown in table 11, all four estimates are significantly positive, indicating that the creation of a new school increases test scores, perhaps by reducing students' travel time, which frees up more time for studying.[56] This study is from urban and rural areas of the Philippines. We find no evidence from Latin America.

Two high-quality studies analyze the impact of the creation of a new school on time in school, providing some evidence that new schools increase time in school (see table 12). Of the sixteen estimates, five are insignificant, two are significantly negative, and nine are significantly positive. While this evidence seems strong, when equal weight is given to each study, the results are more ambiguous; both studies find significantly positive and significantly

53. Sprietsma (2012).
54. Konstantopoulos and Borman (2011).
55. Zhao and Glewwe (2010).
56. Yamauchi and Liu (2013).

TABLE 13. Summary of Impacts of Utilities on Test Scores

Set of studies	*Negative, significant*	*Negative, insignificant*	*Zero or missing and no sign given*	*Positive, insignificant*	*Positive, significant*	*Total papers*
All studies						
Electricity	1 (1)	7 (4)	—	11 (5)	9 (3)	7
Drinking water facilities	—	6 (3)	—	4 (3)	—	3
Toilet facilities	—	11 (3)	—	6 (4)	16 (3)*	4
High-quality studies						
Electricity	—	5 (3)	—	9 (3)	—	3
Drinking water facilities	—	5 (2)	—	3 (2)	—	2
Toilet facilities	—	1 (1)	—	7 (2)	2 (1)	2
RCTs						
Electricity	—	—	—	—	—	0
Drinking water facilities	—	—	—	—	—	0
Toilet facilities	—	—	—	—	—	0
Latin America						
Electricity	1 (1)	2 (1)	—	2 (2)	8 (2)	3
Drinking water facilities	—	1 (1)	—	1 (1)	—	1
Sanitation facilities	—	—	—	1 (1)	1 (1)	1
Utilities index	—	—	—	—	16 (1)	1

* We flipped one of the signs.

negative effects. Both studies are on Latin American countries, one on Guatemala and one on Argentina, and both focus on the availability of preprimary education facilities.

Utilities

The third and last type of school infrastructure examined in this paper is utilities, which includes electricity, drinking water, and toilet facilities. Table 13 summarizes the findings of the impacts of utilities on test scores, while table 14 does the same for time in school.

ELECTRICITY. Seven studies provide twenty-eight estimates of the impact of the availability of electricity on student test scores at the primary and secondary school level. As shown in table 13, eighteen of the estimates are insignificant, nine are significantly positive, and one is significantly negative.[57] Overall, the evidence indicates that in many settings, the provision of

57. The positive and significant results are from three separate studies: Bacalod and Tobias (2006); McEwan (1998); and Psacharopoulos, Rojas, and Velez (1993). The negative and significant result is from Psacharopoulos, Rojas, and Velez (1993).

TABLE 14. Summary of Impacts of Utilities on Time in School

Set of studies	*Negative, significant*	*Negative, insignificant*	*Zero or missing and no sign given*	*Positive, insignificant*	*Positive, significant*	*Total papers*
All studies						
Electricity	—	4 (1)*	—	—	—	1
Drinking water facilities	—	11 (2)*	—	16 (2)	3 (2)*	2
Toilet facilities	1 (1)	4 (1)	—	18 (1)	3 (1)	1
High-quality studies						
Electricity	—	4 (1)*	—	—	—	1
Drinking water facilities	—	11 (2)*	—	16 (2)	3 (2)*	2
Toilet facilities	1 (1)	4 (1)	—	18 (1)	3 (1)	1
RCTs						
Electricity	—	—	—	—	—	0
Drinking water facilities	—	—	—	—	—	0
Toilet facilities	—	—	—	—	—	0
Latin America						
Electricity	—	—	—	—	—	0
Drinking water facilities	—	—	—	—	—	0
Sanitation facilities	—	2 (1)	—	—	—	1
Utilities index	—	—	—	—	—	0

* We flipped one of the signs.

electricity could increase student learning. However, when only high-quality studies are examined, there is no evidence of an impact of electricity on test scores: all fourteen estimates from three different studies are statistically insignificant, with five negative and nine positive results.[58] There are no RCT studies of the impact of electricity on students' educational outcomes.

Three papers from Latin America estimate the impact of electricity on test scores. Of the thirteen estimates, eight estimates, from two different studies of rural areas, are significantly positive, which suggests that the provision of electricity in Latin America increases student learning (see table 13).[59] None of the three papers, however, is a high-quality study. Finally, one Latin American study analyzes the impact of an index of utilities, which includes water, electricity, and a telephone connection. The paper presents sixteen estimates from sixteen countries, all of which were significantly positive. This suggests that utilities may have a strong impact on student learning in Latin America, but caution is in order because this is based on a single study.

58. Fehrler, Michaelowa, and Wechtler (2009); Glewwe and Jacoby (1994); Suryadarma and others (2006).

59. McEwan (1998); Psacharopoulos, Rojas, and Velez (1993).

Only one study examines the impact of the availability of electricity on time in school. As shown in table 14, all four estimates are statistically insignificant.[60]

DRINKING WATER FACILITIES. While adequate drinking water facilities would seem to be desirable for any school, there is no evidence that such facilities promote student learning. Table 13 shows that all ten estimates from the three studies of the impact of the availability of drinking water facilities are statistically insignificant. Similarly, the eight estimates from two high-quality studies of the impact of drinking water are all statistically insignificant.[61] There are no RCT studies of the impact of drinking water facilities on students' educational outcomes.

For Latin America, there is one paper, with two estimates, that analyzes the impact of drinking water facilities on test scores.[62] This paper reaches the same conclusion: both estimates are statistically insignificant, so there is no evidence from Latin American countries that the provision of drinking water facilities increases student learning.

Finally, two studies assess the impact of drinking water facilities on students' time in school.[63] Both are of high-quality studies, providing thirty estimates. Twenty-seven are statistically insignificant, and only three had significantly positive impacts on time in school, which suggests at best a weak impact.

TOILET FACILITIES. The last utility variable to consider is sanitation, namely, toilet facilities. There are thirty-three estimates from four studies that examine the impact of the availability of toilets or separate latrines for boys and girls on student learning. These estimates suggest that having access to adequate sanitation facilities increases student test scores at both the primary and secondary levels. More specifically, of the thirty-three estimates, eleven are insignificantly negative and six are insignificantly positive, while sixteen estimates from three different studies are significantly positive and none is significantly negative. When the evidence is limited to the two high-quality studies, there is only modest evidence that access to adequate sanitation facilities increases student test scores: while nine of the ten estimates from two high-quality studies are positive, only two estimates, both from the study of Indonesia, are significantly positive.[64] There are no RCT studies of the impact of toilet facilities on students' educational outcomes.

60. Glewwe and Jacoby (1994).
61. Fehrler, Michaelowa, and Wechtler (2009); Glewwe and Jacoby (1994).
62. Glewwe and others (1995).
63. Afridi (2011); Glewwe and others (1995).
64. On Indonesia, see Suryadarma and others (2006).

One Latin American study examines the impact of sanitation facilities on educational outcomes, including both test scores and time in school. The study, which tracks students in the city of Puno, Peru, shows that the availability of sanitation facilities leads to increased reading comprehension.[65] Both of the estimates in this study are positive, and one is positive and significant. The same study finds a negative but insignificant effect on time in school, thus providing no support for this intervention.

Finally, one study provides twenty-six estimates of the impact of the availability of toilet facilities on school attendance, at the elementary school level.[66] Of these, twenty-two were statistically insignificant, one was significantly negative, and the other three were significantly positive. All of the estimates are from Afridi, and they provide some rather weak evidence that toilet facilities increase time in school for girls.[67]

Conclusion

This paper has reviewed the results from thirty-nine studies on the impact of school infrastructure on student outcomes. The results from this literature, which span twenty-three years from 1990 to 2012, are summarized in the tables 8–14. Overall, the evidence base is not particularly strong. Focusing on the nineteen high-quality studies from all developing countries, there is limited evidence that having roofs, walls, and floors in good condition improves student learning, but no other classroom-level variables have clear effects. Turning to school-level infrastructure, there is some evidence that school libraries and the creation of new schools (which make schools more accessible) lead to improved learning. The evidence on computers appears strong when each estimate is given equal weight, but it is much weaker when each study is given equal weight. Finally, with the possible exception of toilets, there is no evidence that utilities affect student learning.

The evidence on the impact of infrastructure variables on time in school also tends to be inconclusive. There is weak evidence of a positive impact of blackboards and related items and stronger evidence of the impact of school

65. Cueto and others (2010).

66. The Cueto and others (2010) study in the previous paragraph is excluded because it is a working paper this is not in our set of high-quality working papers.

67. Afridi (2011).

libraries. There is also evidence of positive impacts of science laboratories, the creation of new schools, and drinking water facilities.

When the evidence is limited to the sixteen medium- and high-quality studies from Latin America, the evidence is also mostly inconclusive for both student learning and time in school. At the classroom level, there is evidence from a single study of urban and rural areas of Jamaica that desks, tables, and chairs matter for student learning. With regard to school-level infrastructure, three studies find positive impacts of overall indexes of school infrastructure for both student learning and time in school. These results are not very useful, however, since they give no indication of which components of the index are most important. There is some evidence, from rural areas of Colombia and from urban and rural areas of Brazil, that libraries have a positive effect on learning and even stronger evidence that computers have an effect. There is suggestive evidence that school amenities also have an effect on both learning and time in school, but again, this result is not particularly useful since it does not identify the specific amenities affecting outcomes. As expected, the construction of new schools also increases time in school. Finally, there is some evidence that electricity has positive impacts on learning and weak evidence that sanitation may, as well.

Ideally, the few interventions that appear to be effective should be subjected to cost-effectiveness comparisons or, more ambitiously, cost-benefit analysis. Unfortunately, very few studies provide information on the costs of the interventions, so this was not possible for this review. Future studies should report those costs.

Perhaps the main conclusion of this study is that more high-quality research is needed on the impact of infrastructure on learning and time in school in developing countries. This raises the question of why relatively little research has been conducted on the impact of school infrastructure on educational outcomes. While somewhat speculative, the following explanations seem plausible. First, in developed countries there is little research on basic infrastructure, such as electricity and water, because almost all schools have them, so there is very little variation across schools that can be used to estimate an effect. Second, in most studies, infrastructure is used only as a control variable in the regression analysis, since the main interest is in other variables, and thus there is little discussion of the impacts of infrastructure variables even when they are included in the analysis. Third, many new studies on education in developing countries employ randomized control trials (RCTs). It is often very costly—and contentious—to randomly assign some schools to receive infrastructure improvements while others do not receive them (or receive them at a much later date). Fourth, many infrastructure improvements (such as electricity, potable water, and adequate sanitation) are assumed to be desirable, even if they may not have large impacts on educational outcomes, so there is little demand for research on this topic. Finally, the quality of many types of school infrastructure is likely to deteriorate slowly over time. It may therefore be difficult to measure the decrease in quality, which will generate noisy data and statistically insignificant estimates.

There is a dearth of high-quality studies on infrastructure in Latin America and in other developing regions. Research funds are scarce, however, so agencies that fund research need to carefully consider which types of infrastructure investments should receive the highest priority for future research funding. Some types of infrastructure, such as electricity and running water, may be considered necessary for virtually all schools, so there is little reason to conduct research on them. Very expensive improvements in infrastructure may also be a low priority because they would have to have very large effects to be cost-effective investments. Any types of investment that are being heavily funded, such as the use of computers and other information technology devices, should be a high priority given the large investments being made in those types of infrastructure improvements. Such a priority-setting exercise would seem to be necessary to ensure that future research provides valuable information for education policy decisions in Latin America and, more generally, in all developing countries.

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