International Journal of Educational Development 60 (2018) 60–79

Contents lists available at ScienceDirect

International Journal of Educational Development

journal homepage: www.elsevier.com/locate/ijedudev

How international tests fail to inform policy: The unsolved mystery of Australia's steady decline in PISA scores[☆]

Leila Morsy[a], Tatiana Khavenson[b], Martin Carnoy[b,c,*]

[a] University of New South Wales, Australia
[b] National Research University Higher School of Economics, Russian Federation
[c] Stanford University, United States

ARTICLE INFO

Keywords:
International tests
Educational policies
Quality of education
Social class differences
Private education

1. Introduction

Australian students' performance on the OECD's Programme for International Student Assessment (PISA) mathematics, reading, and science tests declined significantly across all Australian states, social class groups, and types of schools between 2000 and 2015. This paper reviews the explanations that Australian education experts and other observers give for these declines and assesses these explanations' empirical validity using Australian PISA (and TIMSS) microdata for the period 2000–2015.

Sustained decreases in national PISA scores are not unusual (OECD, 2016). Students' PISA mathematics performance in several European countries, including the Netherlands, Finland, Slovak Republic, Hungary, and Iceland, as well as in others, such as New Zealand, Canada, and the United States has declined. However, such decreases and the possible reasons for them are rarely discussed. Since the OECD is primarily interested in extracting policy recommendations on how to *raise* performance, its reports draw inferences about why high scoring and "gaining" countries "do well," and how these countries' education policies can serve as examples for lower scoring countries (for example, OECD, 2016), leaving the handwringing to local policymakers in the countries where test scores are systematically worsening. Policy examples from countries that "do well" on PISA are unlikely to be helpful for countries whose scores were rather high but are now declining unless it can be shown that the absence of OECD recommended policies (or others) explain why students are performing worse.

Australian education policymakers, officials, and the media have expressed considerable concern about the downward trend in students' mathematics (and reading and science) test scores over the past fifteen years (Tovey and Patty, 2013; Hardy, 2016). The *Sydney Morning Herald*, a widely read daily newspaper, has suggested (without justification) serious economic consequences if achievement does not improve and score trends are not rectified: "These results should be of concern to politicians, parents, and teachers. We all know that Australia's future competitiveness relies on the skills of its future workforce. With the right reforms, our students should be able to catch up by the next time they have to sit the test" (Bagshaw and Fisher, 2016).[1]

The explanations for the worsening PISA results vary, although none is based on strong empirical evidence. Students' poor (and implicitly declining) understanding of mathematics is often invoked as an explanatory factor (Heath, 2013; Preiss and Butt, 2013). Some analysts claim that teacher quality is declining (Ferrari, 2013; Piccoli, 2014). One prominent conservative think tank has suggested that Australia's enthusiasm for problem-based learning in mathematics over teaching facts and concepts is to blame (Buckingham, 2016). Others have argued that the fault lies in the increased privatization of Australia's education

☆ The authors would like to thank the University of New South Wales and the Basic Research Program of the National Research University Higher School of Economics for their financial support of this research.

* Corresponding author at: Stanford University, United States.
E-mail address: carnoy@stanford.edu (M. Carnoy).

[1] Whereas the causal connections between better schooling significantly raising PISA scores and higher PISA scores increasing economic competitiveness are difficult to establish (see Carnoy et al., 2016 on the school inputs-PISA scores connection and Tienken, 2008 and Castex and Dechter, 2014 on the connection between test scores and economic growth), the *Sydney Morning Herald* authors imply that school-based reforms are a main factor in increasing economic growth.

https://doi.org/10.1016/j.ijedudev.2017.10.018
Received 28 April 2017; Received in revised form 6 October 2017; Accepted 22 October 2017

system (Martyn-Jones, 2016)—specifically, that the movement of "better" students from government to Catholic and independent non-government schools may have harmed the performance of remaining public school students (Davidson, 2013). Still others scapegoat socio-economic inequality and Australians' obsessive use of smartphones (Munro, 2016).

The opinions of policymakers in the country about why student performance is declining need to be taken seriously and assessed, since they are likely to influence how the government attempts to "turn the educational system around." At the same time, their opinions should be tested empirically. In this paper, we use a purposive stratified sampling strategy to select interviewees with expertise in federal educational policy, state education policy, Australian PISA scores, or state-level knowledge of the mathematics curriculum and teaching. Media coverage was selected using a ProQuest search for "PISA" and "Australia." We contacted and asked these educational experts and policy makers to give us their explanations for the steady decline in Australian student performance on international tests. We then used PISA and TIMSS individual student (and in the case of TIMSS, individual teacher) microdata to assess whether our informants' explanations were supported empirically. We focused on mathematics scores, because these have declined more than reading or science scores. In the final section of the paper we discuss the results and draw conclusions.

2. Why scores have declined, according to Australian experts

The experts we interviewed generally converged on several possible reasons for the decline in Australian students' PISA mathematics scores. Some argued that the shift of students from government to publically subsidized non-government independent and Catholic schools (Australian Bureau of Statistics, 2017) has had a negative impact on students remaining in government schools, perhaps because of resources transferred to the non-government school sector. This concern is not unfounded. Data from the OECD indicates that countries with more private schools do no better than those with fewer. The presence of private schools does not, on its own, appreciably raise the average achievement of students overall (Montt, 2011). One interviewee elaborated: "There has been a shift to non-government schools. This could lead to a drop in the lower end [of the distribution of students] because the best students are shifting out of public and into non-government schools." Officials explained that children who leave government schools and enroll in non-government schools have, on average, a higher socio-economic background than those remaining in government schools. This concentrates lower SES children in government schools, and past research suggests that when the SES of Australian school declines, the achievement of individual children within that school, regardless of SES, falls with it, and vice-versa (Perry and McConney, 2010).

Second, some experts thought the influx of students who have newly immigrated to Australia might have affected scores. Even though there was little agreement on the direction of the effect, existing evidence suggests that, on average, foreign-born students have demonstrated better mathematical literacy than their Australian-born peers (Thomson and De Bortoli, 2008).

Some of our interviewees claimed that an increase in teachers teaching out-of-field could be an important factor explaining the decline in scores. Nearly all the experts we spoke with cited the decreasing number of math-trained teachers in Australia over the past 15 years. Staff in Australian Schools Survey data show that in 2013, 20% of teachers teaching mathematics had no formal qualifications or expertise in math (Weldon, 2015). According to one federal government report, forty percent of mathematics classes in grades 7–10 are taught by non-mathematics teachers (Office of the Chief Scientist, 2014). One official told us: "Growth in employment prospects for people with maths background has affected how many maths teachers we have. We have had a reduction in people with a strong maths background." Another interviewee explained: "There is a concern around capacity and confidence in primary mathematics teaching and to some extent in the mathematics teaching in the lower years of secondary [school]. There is a well-established discourse around the background of primary teachers not being particularly strong in mathematics" (Interview, December 2016). Research corroborates this: when students are taught math by teachers who have little mathematical content and pedagogical content knowledge, learning suffers (Baumert et al., 2010; Hill et al., 2005).

Finally, several key informants cited less time spent teaching mathematics. "A big factor was the implementation of the Australian curriculum in 2008–09. The notion that all eight areas of the curriculum were equal was taken up in some schools, and that led to teachers spending less time on math. In schools, time for teaching is the currency. That is what gets bargained when timetabling is planned. You are more important if you have more time. It's a very big issue in the structure of schools, and they are pushed on all sides to include things that are in general educational interest of students but to do it take time away from some core area, like math" (Interview, February 2017). One policymaker suggested that teachers with less background in mathematics might spend less time teaching math than a mathematics-trained teacher: "…if a school is struggling to get math teachers, the way to get around it is to reduce time spent on math" (Interview, December 2016).

3. Methodological approach and data

We assessed these experts' hypotheses using publicly available Australian individual student microdata from the 2000–2015 PISA tests and 1999–2015 TIMSS tests. We were aided in our analysis by the federal nature of Australia's education system (the jurisdiction of education is in the hands of the states, although the federal government has considerable influence over educational policy). The PISA survey/test randomizes its sampling of 15 year olds within each state as well as nationally. State data allow us to examine student performance in different states and of different sub-groups of students within each state over time. This can potentially differentiate education policies among states and their impact on student performance (Carnoy et al., 2015a).

We asked several of our interviewees about the possibility that state policy differences (in this case, between the most populous states New South Wales and Victoria), may have influenced PISA score declines; specifically, as we show, the smaller decline in recent years in Victoria than in New South Wales. Our informants agreed that there were differences—especially in philosophies of teacher regulation.

> Anecdotally, I think that from experience Victoria is teaching math differently. There is a much greater regulation of teachers and what they teach in New South Wales than in Victoria. In Victoria, there has been a heritage of emphasis on school-based curriculum development and emphasis on teaching the kids they have got. There is a difference in quality of mathematics teaching in schools in Victoria than in New South Wales. The sorts of practices and pedagogies used in Victoria show that the Victorians seem better at getting contemporary advice into practice. More decision-making, more applied. The [policymakers in] Victoria have listened to that research (Interview, February 23, 2017).

TIMSS data are available by state only for 2011 and 2015, but national TIMSS data over a twenty-year period do provide some detailed data on changes in teacher characteristics. These teacher data help us assess the validity of claims that Australia's mathematics teacher quality may be declining, and that this may be an important variable explaining decreasing student math performance in this period. The 2011 TIMSS data on teachers in different states also allows to compare teacher descriptions of their teaching in New South Wales and Victoria to check if they bear out our informants' opinions.

One factor complicating any analysis of international test results in Australia is that average Australian TIMSS mathematics scores have

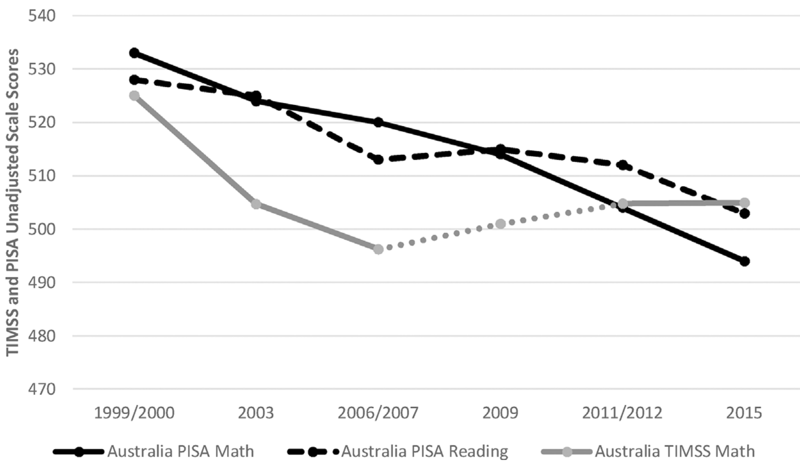

Fig. 1. Australia: PISA Mathematics and Reading Scale Scores and TIMSS Mathematics Scale Scores, as Reported by PISA and TIMSS, 1999/2000–2015.
Source: OECD PISA, Australia microdata, 2000–2015, and IEA, TIMSS, Australia Microdata, 1999–2015.

behaved somewhat differently over time than PISA mathematics scores. Australia shares this "anomaly" with the United States and Russia (Carnoy et al., 2015b). In Australia, PISA math scores declined steadily over time in the period 2000–2015, both as reported and adjusted for changes from year to year in the composition of students in the sample with various levels of family academic resources (as measured by books in the home). TIMSS math scores have also declined, but only between 1999 and 2007, followed by an increase in math performance in 2007–2015. PISA tests students in higher grades than TIMSS (mainly 8th, 9th, and 10th grades in PISA versus 8th grade in TIMSS), and the two tests themselves purportedly test different skills—TIMSS is a more curriculum based test than PISA. TIMSS assesses mathematics skills while PISA tests the real-world application of those skills. These differences could explain the different pattern of student performance over time.

To assess our interviewees' conjectures about the origins of the decline in scores, we developed a four-stage comparative approach. In the first stage, we describe the decline in average national PISA scores (mathematics and reading) and compare it with the decline and subsequent recovery of average national TIMSS scores. We also compare the declines in PISA scores for groups of students with different levels of family academic resources, and compare the PISA scores for students attending public and private schools,[2] adjusting those scores for students' and school socio-economic differences.

In the second stage, we describe how students from different states perform on PISA over time, adjusting test scores for individual student socio-economic background and other characteristics, as well as average school data, including type of school—government, Catholic, and independent.

In the third stage, we contrast the performance trends of students in different states and in different types of schools (government, Catholic, independent) by state. Did students in government schools exhibit greater declines in those states with greater shifts from government to non-government schools? Further, we address our interviewee's speculation that immigrant students' PISA performance over this period has differed from overall student performance.

In the fourth stage, we examine the claim that less time spent on math and a lack of math-trained teachers has depressed PISA scores. We use TIMSS microdata to assess whether 8th grade mathematics teacher characteristics and teaching methods have changed significantly in Australian schools, and whether there appears to be any relationship between math teacher characteristics and TIMSS 8th grade test scores. Since the PISA data show a considerable decline in the minutes per week students report that they learn mathematics in school (2003–2015, and especially in 2003–2009), we estimate the possible effect of that decline in math time on the decline in student math performance in each state. Students report a much smaller decline in time learning reading/language literacy.

4. The trajectory of Australia's PISA and TIMSS scores

Australian students' PISA average mathematics and reading scores and TIMSS average mathematics scores as reported by PISA and TIMSS declined in the first decade and a half of the 21st century (Fig. 1). PISA performance declined rather steadily in both mathematics and reading in 2000–2015, and the mathematics scores declined more than the reading scores. The TIMSS mathematics scores had a more rapid decline in 1999–2007, but recovered substantially in 1999–2015 (Fig. 1).

We adjusted mathematics scores for the changing family academic resource (FAR) composition of students sampled in each year (Carnoy and Rothstein, 2013). Family academic resources are defined here as student reported books in the home.[3] To adjust scores for the FAR composition, we used the 2012 sample distribution among FAR groups to weight the scores in other years. This is equivalent to asking what the average test scores before and after 2012 would have been had the percentage of youth in each FAR group been the same as in 2012.[4] By adjusting scores in this way, we reduce the estimated decline in average test scores over time, although the overall pattern of student performance in math on PISA and TIMSS remains approximately the same as the unadjusted scores (Fig. 2). The scores adjusted for students' FAR composition in each year give us a better picture of how students' test scores are more likely to be associated with conditions in schools rather than the conditions of families that have changed over time.

Figs. 1 and 2 suggest that mathematics and reading scores of Australian students, no matter the international test, went down in the seven-year period, 2000–2007, that the decline continued for students taking the PISA test, but reversed for students taking the TIMSS mathematics test.

5. Analyzing the data by family academic resources

Table 1a shows that Australia's PISA mathematics scores have declined across all family academic resource (books in the home) groups

[2] In Australia, government schools are public. Non-government Catholic schools and independent schools are private. Independent schools include parochial non-Catholic schools as well as non-denominational schools.

[3] Books in the home (BIH) and other measures of family academic resources, such as mother's education (ME), are highly correlated, and BIH has the advantage that it has few missing values, unlike ME. Below, to estimate adjusted scores for different types of schools using regression analysis, we employ both BIH and ME as a FAR adjustment.

[4] We could have used any year as a base, but chose 2012 because it was the recent "math year" in the PISA, where the most extensively tested domain was mathematics, and our main focus in this paper is mathematics.

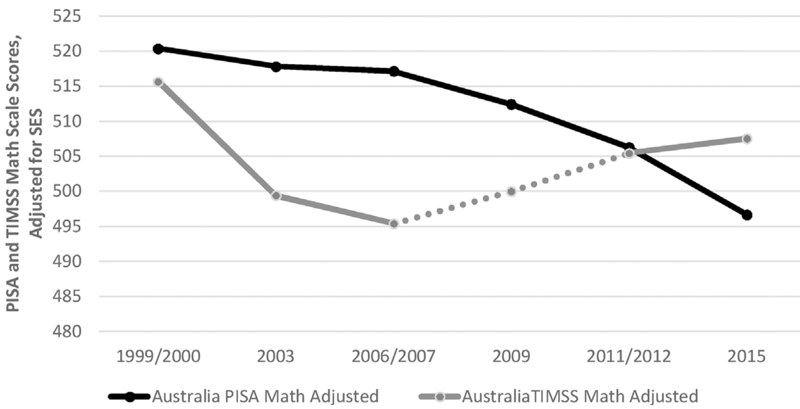

Fig. 2. Australia: PISA and TIMSS Mathematics Scale Scores, Adjusted to 2011 (TIMSS) or 2012 (PISA) Distribution of Students' Family Academic Resources (Books in the Home), 1999/2000–2015.
Source: OECD PISA, Australia microdata, 2000–2015, and IEA, TIMSS, Australia Microdata, 1999–2015.

of students in the past 15 years, but the decline has been the smallest in the 30% of middle FAR students and largest for the 14–24% of low and low-middle FAR students (Tables 1a). Indeed, until 2012, the decline for middle FAR students was negligible. The decline for the upper groups (201–500 books in the home) was also small during that period. In 2000–2012, the largest decline was in the lowest two groups, but in 2012–2015, the highest two FAR groups dropped the most. Table 1b shows that reading scores declined the most in the lowest FAR group and the upper two FAR groups, and that the middle FAR groups declined little, if at all.

We estimate that the pattern in TIMSS scores is similar when we analyze them by FAR groups during this same time frame. Lower FAR students' math performance fell in 1999–2015, but middle and higher FAR students' math performance fluctuated, yet ended up averaging about the same in 2015 as in 1999 (Table 2).

Thus, students from the lowest FAR groups had the largest declines in scores. In earlier PISA years, these two groups represented less than 15% of Australia's PISA sample; by 2015, they represented 24%. Whatever is happening in Australian society and its educational system, it seems to be having the largest negative academic effect on lower social class youth. We explore this issue further in terms of the inequality across and within government and non-government schools and across Australian states.

Table 1a
Australia. Reported PISA Mathematics Scale Scores, by Family Academic Resources, 2000–2015.
Source: OECD PISA, Australia microdata, 2000–2015.

	Test Year					
Family Academic Resources	2000	2003	2006	2009	2012	2015
0–10 books	480	472	462	445	440	432
11–25 books	491	481	479	475	464	462
26–100 books	505	505	509	503	500	493
101–200 books	536	531	529	526	519	509
201–500 books	553	558	557	558	549	535
More than 500 books	561	559	556	555	548	530
Average Total	533	524	520	514	504	494

Table 1b
Australia. Reported PISA Reading Scale Scores, by Family Academic Resources, 2000–2015.
Source: OECD PISA, Australia microdata, 2003–2015.

	Test Year					
Family Academic Resources	2000	2003	2006	2009	2012	2015
0–10 books	451	473	446	443	442	431
11–25 books	469	485	474	472	475	470
26–100 books	498	508	501	504	509	501
101–200 books	533	533	525	529	528	525
201–500 books	553	561	552	561	558	544
More than 500 books	562	552	547	552	554	540
Average Total	528	525	513	515	512	503

Table 2
Australia. Reported TIMSS Mathematics Scale Scores, by Family Academic Resources, 1995–2015.
Source: IEA, TIMSS Australia microdata, 1995–2015.

	Test Year					
Family Academic Resources	1995	1999	2003	2007	2011	2015
0–10 books	418	479	448	438	447	450
11–25 books	454	498	477	464	466	479
26–100 books	489	511	501	492	503	507
101–200 books	510	526	514	516	524	524
More than 200 books	529	544	526	532	549	541
Average Total	517	525	505	496	505	505

6. Analyzing the data by type of school

Did these changes over time occur equally for students in government and non-government schools? We have data on the type of school students attended for all test years in PISA in 2003–2015 and students' achievement in those schools. Since the socio-economic background (SES) of students, as measured by books in the home and mother's education, in these different types of schools is not the same, with independent schools catering to higher SES students, on average, and government schools to lower SES students, we estimate average scores by type of school in each year in two ways: (1) for the average distribution of student and school SES in the national PISA sample in each year; and (2) for the average distribution of student and school SES in 2012.

We estimate student PISA score in mathematics and reading (the average of the five plausible values),[5] A_{ij}, for each type of school (government, Catholic, independent) in each test year using standard OLS, as follows:

$$A_{ij} = C + \Sigma b_1 X_{ij} + b_2 AvgX_{ij} + e_{ij} \quad (1)$$

Where X_{ij} is a vector of student characteristics, including the student's grade level, BIH, mother's education, gender, and language spoken at home, $AvgX_{ij}$ is the average student socio-economic background in the

[5] In large-scale international and national assessments, tested students are typically given a booklet of only a subset of a pool of test items. These test booklets are linked by blocks of items that appear in multiple test booklets. To reduce measurement error and to obtain unbiased group level estimates, test results are presented as multiple values representing the likely distribution of a student's proficiency, called "plausible values," which should be averaged to obtain estimates of students' proficiency (von Davier et al., 2009).

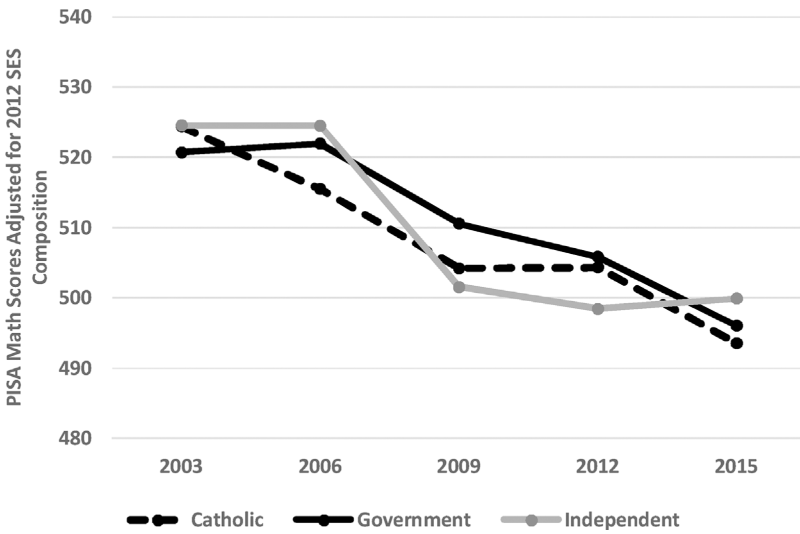

Fig. 3. Australia: PISA Mathematics Scale Scores by Type of School, Adjusted to 2012 Distribution of Student and School Socio-economic Background, 2003–2015.
Source: OECD PISA, Australia microdata, 2003–2015.

school *j* the student *i* attends, as measured, as measured by the PISA SES index, and e_{ij} is the error term.[6] We use the three estimated equations to calculate the average PISA score in each year for each type of school adjusted to the Australia average for student and school characteristics, first in each year (estimate 1) and then to the Australia average in 2012 (estimate 2).[7]

The trends in average scores by type of school differ slightly in the two estimates, but both show that, on average, students' math and reading performance in Catholic schools declined somewhat more than in government and independent schools in 2003–2015, and performance in independent schools declined significantly less after 2009. Fig. 3 presents the results of the second estimate for mathematics. The other important point to note from Figs. 3 is that once adjusted for differences in the SES composition of students in non-government and government schools, students in government schools score as high or higher than students in non-government schools, including independent schools.

The pattern of enrollment change over time among these types of schools varies from state to state, although not substantially. Enrollment during this period shifted from government schools to Catholic and independent schools, but the changes are gradual and not large. In the Australia PISA sample, Catholic school enrollment rose slightly, from 22 to 23% in 2003–2015. Government school enrollment fell from 61 to 58%. Independent school enrollment rose from 17 to 19%. In the two most populous states, New South Wales and Victoria, the percentage of the PISA sample attending government schools declined from 66 to 58% in 2003–2015 in New South Wales and stayed constant at 56% in Victoria. Catholic school enrollment increased by about 3 percentage points in NSW from 23% to 26% and fell in VIC from 27% to 23%. Independent school enrollment rose from 12 to 16% in New South Wales and from 18 to 21% in Victoria. Trends in other states varied considerably (see Appendix A Table A1).

If students shifting out of government schools into Catholic schools have lower average scores than the average Catholic school student but higher than the average government school student, it could explain the somewhat more rapid decline in Catholic school scores, and the declining scores in government schools as well. But it could be that both categories of school are doing a worse job over time with the students they have, especially the Catholic schools. One reason that independent schools in recent years may have had a significantly slower decline in PISA scores is that they are attracting higher scoring students from each SES group from Catholic and government schools. Alternatively, after the initial steep decline in adjusted scores in 2003–2009, they may have recruited better teachers or took organizational steps to halt the decline.

7. Australian state differences in PISA score trajectories

PISA and TIMSS are applied at the state level in Australia in order that both tests can be integrated in Australia's overall evaluation system. The data are publicly available with state identifiers in PISA for all years. The TIMSS data with state identifiers is only available for 2011 and 2015. This allows us to analyze the data to estimate state differences adjusted for student and school socio-economic background, as well as the student's gender, language spoken in the home, grade attended at the time of the PISA test, and type of school attended for the entire period 2000–2011. Since, in addition, TIMSS data are not available for type of school attended, we can only make estimates of family academic resource-adjusted scores by state for the two years, 2011 and 2015.

We estimate student performance on the PISA test in each state in each year by estimating the individual student test scores as a function of student characteristics (X_{ij}), the average student socio-economic background in the school *j* the student *i* attends ($AvgX_{ij}$), whether the student attends a government, Catholic, or independent private school ($Type_i$), and state where the student attends school ($State_i$). We use a standard OLS model of the relationship between a student's PISA score and these individual and school level variables, where e_{ij} is the error term. The model has the following specification for each PISA test year:

$$A_{ij} = C + \Sigma b_1 X_{ij} + b_2 AvgX_{ij} + c_1 Type_i + \Sigma d_1 State_i + e_{ij} \quad (2)$$

In a second set of estimates testing for the effect of math time (M_{ij}) on test scores in each year, we add minutes of math learning time as reported by students and the interaction of math learning time and average student SES in the school:

$$A_{ij} = C + \Sigma b_1 X_{ij} + b_2 AvgX_{ij} + c_1 Type_i + \Sigma d_1 State_i + f_1 M_{ij} + g_1 AvgX_{ij} {*} M_{ij} + e_{ij} \quad (3)$$

Table 3 shows the means and standard deviations for the student and school characteristics in the PISA samples in 2000–2015. The books in the home and mother's education variables are slightly different in 2000 than in the other years, and the school type is not available in the published data for that year, but otherwise, we can identify a rich set of variables for the entire period that allow us to adjust the reported scores for differences among states in the samples.

[6] Because students are clustered at the classroom level, we estimate cluster-corrected Huber-White estimators for Eq. (1).

[7] To conserve space, we do not show our regression results for Eq. (1), but they are available from the authors on request.

Table 3
Australia PISA Survey: Means and Standard Deviations of Individual Student SES variables, Grade Attended at Time of Test, Language Spoken at Home, School Type Attended, and State, 2000–2015.
Source: OECD PISA Australia Microdata.

	2000	2003		2006		2009		2012		2015	
Variable	Mean	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Female	0.47	0.49	0.50	0.49	0.50	0.51	0.50	0.49	0.50	0.50	0.50
7th, 8th or 9th grade	0.07	0.09		0.09		0.11		0.11	0.31	0.11	0.32
10th grade	0.76	0.72		0.71		0.71		0.70	0.46	0.75	0.44
11th or 12th grade	0.17	0.19		0.20		0.19		0.19	0.39	0.14	0.35
0–10 books in home	0.05	0.05	0.21	0.07	0.26	0.08	0.27	0.10	0.30	0.11	0.31
11–25 books in home	0.15	0.09	0.28	0.11	0.31	0.11	0.31	0.12	0.33	0.13	0.33
26–10 books in home	0.19	0.28	0.45	0.30	0.46	0.29	0.45	0.30	0.46	0.30	0.46
10–20 books in home	0.22	0.22	0.42	0.21	0.41	0.21	0.41	0.20	0.40	0.21	0.40
20–50 books in home	0.20	0.21	0.40	0.19	0.39	0.19	0.39	0.17	0.38	0.17	0.38
More than 500 books	0.17	0.13	0.34	0.11	0.32	0.10	0.30	0.09	0.28	0.09	0.28
BiH Missing Values	0.02	0.02	0.14	0.01	0.11	0.02	0.13	0.02	0.15	0.03	0.17
ME: None or ISCED 1	0.03	0.04	0.20	0.02	0.15	0.01	0.10	0.04	0.19	0.04	0.19
ME: ISCED 2	0.25	0.20	0.40	0.19	0.39	0.04	0.20	0.15	0.36	0.11	0.32
ME: ISCED 3A, 3B, 3C, 4	0.38	0.33	0.47	0.35	0.48	0.49	0.50	0.34	0.47	0.31	0.46
ME: ISCED 5B	0.29*	0.12	0.32	0.13	0.33	0.12	0.32	0.12	0.33	0.13	0.34
ME: ISCED 5A		0.27	0.44	0.27	0.44	0.29	0.45	0.30	0.46	0.36	0.48
ME_ Missing Values	0.04	0.04	0.20	0.04	0.19	0.05	0.22	0.05	0.22	0.05	0.22
Australian Indig Lang	0.00	0.001	0.02	0.002	0.04	0.002	0.04	0.002	0.05	0.00	0.06
English	0.82	0.90	0.30	0.90	0.30	0.89	0.32	0.88	0.33	0.88	0.32
Asian languages	0.06	0.04	0.20	0.02	0.14	0.03	0.17	0.06	0.24	0.03	0.18
European languages	0.07	0.03	0.16	0.01	0.11	0.01	0.07	0.02	0.13	0.01	0.09
Arabic language	0.02	0.01	0.12	0.002	0.04	0.01	0.08	0.01	0.12	0.01	0.08
Other language	0.02	0.004	0.06	0.004	0.06	0.03	0.16	0.01	0.09	0.06	0.24
language Missing	0.02	0.01	0.11	0.02	0.13	0.04	0.20	0.02	0.14	0.02	0.15
Indigenous Status	0.01	0.022	0.15	0.029	0.17	0.032	0.18	0.035	0.18		
ESCS school mean	0.41**	0.22	0.44	0.20	0.40	0.33	0.39	0.24	0.42	0.24	0.44
Sch type Catholic		0.22	0.42	0.22	0.41	0.22	0.41	0.23	0.42	0.23	0.42
Sch type Government		0.61	0.49	0.62	0.49	0.60	0.49	0.59	0.49	0.58	0.49
Sch type Independent		0.17	0.37	0.16	0.37	0.18	0.39	0.18	0.39	0.19	0.39
ACT	0.02	0.02	0.14	0.02	0.14	0.02	0.14	0.02	0.14	0.02	0.13
NSW	0.34	0.32	0.47	0.33	0.47	0.32	0.46	0.32	0.47	0.31	0.46
VIC	0.25	0.24	0.43	0.24	0.43	0.24	0.43	0.25	0.43	0.25	0.43
QLD	0.18	0.19	0.39	0.20	0.40	0.21	0.41	0.20	0.40	0.21	0.40
SA	0.08	0.09	0.29	0.08	0.27	0.07	0.26	0.07	0.26	0.07	0.26
WA	0.10	0.11	0.31	0.10	0.30	0.10	0.31	0.11	0.31	0.11	0.31
TAS	0.03	0.02	0.15	0.03	0.16	0.02	0.16	0.02	0.15	0.02	0.15
NT	0.01	0.01	0.09	0.01	0.09	0.01	0.09	0.01	0.09	0.01	0.09
Rural school	0.01	0.01	0.08	0.02	0.14	0.01	0.11	0.01	0.11	0.04	0.20

Notes: * in year 2000, represents mean of ISCED 5A, 5B, and 6 combined; ** in year 2000, represents mean of "wealth" variable (articles in the home).

Table 4 presents the estimates of students' individual PISA mathematics scores as a function of the variables in Table 3.[8] In the regression estimates we present here, we do not include the rural school variable. When we do include it, it is not statistically significant. The estimated coefficients shown in Table 4 are the average of the estimates for five plausible values of PISA mathematics scores in the student level microdata. Standard errors of the coefficients are also calculated based on the estimates of the five plausible values (see footnote 5). As in Eq. (1), we estimate cluster-corrected Huber-White estimators for Eqs. (2) and (3). The reported significance levels of our estimated coefficients in Table 4 (and Table 12) are based on adjusted standard errors.

The coefficients for each state represent the difference between that state's average score adjusting for student and school characteristics and the average score in New South Wales, the reference state. To estimate the mean adjusted score in New South Wales, we used the standard procedure of multiplying the estimated coefficients times the Australian mean for each of the variables other than the state dummy variables and added the sum these products to the intercept term.

There are many interesting results in Table 4, but the one of most interest for our analysis in that attending a Catholic or independent school rather than a government school had no significant relationship to a student's performance on either the PISA math or reading test when student and school SES are controlled for. This suggests, again, that the modest shift from government to non-government schools in Australia during this period 2003–2015, had minimal impact on PISA scores.

When we compare reported scores by state and those state scores are adjusted for student and school socio-economic differences from our regression analysis shown in Table 4 (for math), we find that there are some notable differences in the pattern of PISA test score declines in the various Australian states, but student performance in both math and reading did decline in every state in 2000–2015. In addition, adjusted mathematics and reading scores in most states also tended to converge in the 15 years covered by the PISA tests. These comparisons are shown in Tables 5a and 5b, Figs. 4 and 5, and Appendix A Figs. A1–A4. To conserve space, the Appendix figures do not show all possible comparisons. Figs. 4 and 5 compare math and reading scores in the two most populous states, New South Wales and Victoria. For most of the other comparisons, we use New South Wales as the reference state, since one-third of the Australian PISA sample attends schools in New South Wales.

[8] We made similar estimates for PISA reading scores. They are available from the authors on request.

Table 4
Australia: Estimates of PISA Mathematics Score, by Year, Including State Fixed Effects, 2000–2015.
Source: OECD PISA, Australia Microdata, 2003, 2006, 2009, 2012, 2015. Notes: Reference dummy variables: grade = 10th; BiH = 0–10; books; ME = ISCED 3A, B, C or ISCED 4; language = English; school type = government; state = NSW.

Variable	2000	Variable	2003	2006	2009	2012	2015
Female	−16.49***	Female	−11.43***	−19.25***	−15.58***	−18.79***	−14.01***
	(4.35)		(2.41)	(2.15)	(1.67)	(1.88)	(2.60)
Grade 9th and less	−53.11***	Grade 9th and less	−48.80***	−40.05***	−44.71***	−38.91***	−29.93***
	(8.03)		(3.18)	(3.48)	(3.22)	(3.07)	(1.35)
Grade 11th and higher	52.10***	Grade 11th and higher	42.13***	36.23***	34.83***	34.99***	23.95***
	(4.79)		(3.21)	(2.65)	(3.27)	(2.52)	(0.73)
11–50 books in home	22.09**	11–25 books in home	2.84	11.67***	23.49***	15.40***	−19.36***
	(10.06)		(5.50)	(3.45)	(3.36)	(3.44)	(2.63)
51–100 books in home	26.45***	26–100 books in home	18.29***	32.34***	43.59***	41.46***	22.03***
	(9.35)		(5.27)	(3.37)	(3.82)	(3.07)	(3.07)
101–250 books in home	46.48***	101–200 books in home	34.80***	47.21***	59.48***	53.00***	33.06***
	(9.22)		(5.35)	(3.62)	(3.99)	(3.24)	(2.48)
251–500 books in home	50.48***	201–500 books in home	53.29***	67.60***	82.60***	74.85***	50.91***
	(9.49)		(5.42)	(3.56)	(3.92)	(3.63)	(2.38)
More than 500 books	54.36***	More than 500 books	54.71***	63.33***	79.67***	74.31***	47.85***
	(9.48)		(5.88)	(4.14)	(4.84)	(4.34)	(3.00)
BH missing	−9.53	BH missing	4.00	3.55	11.87	−3.63	0.00
	(20.38)		(7.85)	(7.51)	(7.30)	(8.04)	(0.00)
ME: None or ISCED 1	−30.56***	ME: None or ISCED 1	−0.51	−12.31**	−18.33**	−7.17	−7.16**
	(10.91)		(5.53)	(4.91)	(7.30)	(5.02)	(2.87)
ME: ISCED 2	−12.44**	ME: ISCED 2	1.50	0.15	−14.81***	−5.31**	−1.08
	(5.60)		(2.59)	(2.00)	(4.56)	(2.17)	(3.49)
ME: ISCED 5A, 5B, 6	20.60***	ME: ISCED 5B	−6.70**	−10.19***	−0.02	−5.41**	1.46
	(4.75)		(3.14)	(2.65)	(3.10)	(2.22)	(2.62)
		ME: ISCED 5A	12.57***	13.01***	14.57***	17.46***	17.48***
			(2.65)	(1.72)	(2.55)	(2.15)	(1.68)
ME: missing	−23.93**	ME: missing	−25.72***	−31.31***	−35.77***	−24.96***	−35.56***
	(10.65)		(5.26)	(6.06)	(5.05)	(4.30)	(3.62)
Australian Indigenous Lang.	−34.48	Australian Indigenous Language	−71.27***	−98.92***	−54.19***	−69.78***	−83.73***
	(23.61)		(16.89)	(17.65)	(15.55)	(12.32)	(5.58)
Asian languages	18.18*	Asian languages	23.03***	18.70	53.82***	41.62***	35.11***
	(9.70)		(7.46)	(11.75)	(7.29)	(4.76)	(2.74)
European languages	−20.33**	European languages	−14.85**	0.50	−42.65***	−10.56*	−43.21***
	(8.19)		(6.70)	(9.79)	(12.08)	(6.40)	(5.27)
Arabic language	−47.09**	Arabic language	−17.79**	−3.85	−0.15	−19.91**	−17.41**
	(18.51)		(8.40)	(21.67)	(13.79)	(9.56)	(8.54)
Other language	−35.43**	Other language	−30.96*	−31.17***	22.50***	−20.97***	−1.69
	(15.83)		(17.66)	(10.69)	(7.09)	(7.36)	(2.21)
Language missing	−9.70	Language missing	−55.28***	−44.07***	−25.30***	−30.82***	0.00
	(19.29)		(8.98)	(7.97)	(4.71)	(8.01)	(0.00)
Indigenous	−60.45***	Indigenous	−54.21***	−42.70***	−30.91***	−42.62***	
	(10.49)		(5.42)	(4.67)	(3.76)	(2.94)	
Wealth (school average)	39.55***	ESCS school mean	62.66***	55.70***	74.60***	64.07***	53.62***
	(5.57)		(6.66)	(6.56)	(7.57)	(4.27)	(1.77)
School type Catholic		School type Catholic	4.65	−3.46	−5.81	−2.38	−3.81
			(4.60)	(4.42)	(4.97)	(3.66)	(2.51)
School type Independent		School type Independent	−1.05	0.64	−18.29**	−4.28	4.61*
			(7.75)	(6.42)	(7.11)	(4.23)	(2.38)
ACT	−6.07	ACT	−6.88	−8.11	−14.59**	−23.88***	−10.46***
	(7.61)		(5.00)	(6.17)	(6.22)	(4.47)	(1.86)
VIC	−15.74*	VIC	−8.02*	−2.90	5.67	−8.66**	3.67***
	(8.68)		(4.29)	(4.61)	(4.33)	(4.05)	(1.21)
QLD	−26.35***	QLD	−12.49***	−8.08	−5.81	−14.56***	−9.81***
	(8.21)		(4.49)	(5.40)	(6.13)	(3.58)	(2.06)
SA	−17.42**	SA	8.77	−2.29	3.98	−16.17***	−4.55*
	(8.43)		(6.40)	(4.48)	(4.72)	(4.06)	(2.72)
WA	−18.03**	WA	−3.75	−5.55	2.55	−12.82***	7.91***
	(8.06)		(4.26)	(6.23)	(5.75)	(3.73)	(1.43)
TAS	−11.53	TAS	4.91	8.77**	6.49	−2.59	−0.67
	(7.37)		(4.97)	(4.29)	(5.24)	(3.96)	(2.13)
NT	−10.71	NT	−13.33**	−13.91***	−2.38	−38.88***	0.67
	(8.79)		(5.56)	(5.24)	(3.71)	(8.19)	(5.80)
Constant	496.28***	Constant	483.49***	479.24***	446.77***	458.97***	461.12***
R2	0.26	R2	0.28	0.28	0.32	0.32	0.24
Observations	3022	Observations	12,551	14,170	14,251	14,455	13,918

*** statistically significant at 0.01 level.
** statistically significant at 0.05 level.
* statistically significant at 0.10 level.

Table 5a
Australia: PISA Mathematics Scores, Reported and Adjusted for Average Australian Sample Student and School SES in Each Year, 2000–2015.
Source: OECD PISA, Australia microdata, 2000–2015.

Variable	2000	2003	2006	2009	2012	2015
NSW Reported	540	526	523	512	509	494
VIC Reported	529	511	513	512	501	499
QLD Reported	525	520	519	518	503	486
SA Reported	526	535	520	509	489	489
WA reported	547	548	531	529	516	504
ACT Reported	548	548	539	527	518	505
TAS Reported	517	507	502	487	478	469
NT Reported	502	496	481	487	452	478
NSW Adjusted	546	528	522	514	513	496
VIC Adjusted	530	520	519	520	504	499
QLD Adjusted	520	516	514	508	498	487
SA Adjusted	529	537	520	518	496	491
WA Adjusted	528	525	517	516	499	504
ACT Adjusted	540	521	514	499	489	485
TAS Adjusted	535	533	531	520	510	495
NT Adjusted	535	515	508	512	474	496

The test score trends in Tables 5a and 5b, Figs. 4 and 5, and Appendix A Figs. A1–A4 are based on the average composition of students in the Australia PISA sample in *each year* the test was given. Thus, the test score we show in each state in each year is "corrected" for differences in the social class composition of the samples among states. The trend is not corrected for changes in the social class composition of the national sample from one year to the next. However, for our purposes in this section, we are interested in verifying whether the PISA test scores in math and reading declined at different rates, and therefore the year by year comparability of state scores tells us whether the decline in one state is equal to or not equal to a decline in another state.

Fig. 4 shows the results of our estimates of reported (unadjusted) and student/school socio-economic background adjusted PISA math scores for New South Wales and Victoria. Together, the two states serve more than 50% of Australian students. The graph suggests that overall the decline in PISA math scores was greater in New South Wales than in Victoria, and that both the reported and adjusted math results in recent years have not been significantly different in the two states—the scores have "converged." Fig. 5 compares the trend of reading scores for the same two states, and here the decline in student performance in Victoria is much smaller than in New South Wales. Victoria reading scores did not decline until 2015, and then about the same as in New South Wales. The Appendix A figures show reported and adjusted math and reading scores in New South Wales and Queensland, where students scored generally lower than in New South Wales when scores were adjusted for SES, especially in mathematics (Appendix A Figs. A1 and A2); adjusted math scores in New South Wales compared with South Australia and West Australia (Appendix A Fig. A3); and adjusted math scores comparing New South Wales with the smaller jurisdictions (Appendix A Fig. A4). An additional policy puzzle is why, when adjusted for SES, students in the Australian Capital Territory and Northern Territory scored considerably lower than in other states. One conclusion we can draw from Tables 5a and 5b and the figures is that students in Victoria and Western Australia declined less in math and reading than most other states, and students in Australian Capital Territory and South Australia declined the most. However, the differences are not great.

Table 5b
Australia: PISA Reading Scores, Reported and Adjusted for Average Australian Sample Student and School SES in Each Year, 2000–2015.
Source: OECD PISA, Australia microdata, 2000–2015.

Variable	2000	2003	2006	2009	2012	2015
NSW Reported	539	530	519	516	513	502
VIC Reported	516	514	504	513	517	507
QLD Reported	521	517	509	519	508	500
SA Reported	537	532	514	506	500	503
WA reported	538	546	524	522	519	507
ACT Reported	552	549	535	532	525	516
TAS Reported	514	508	496	479	485	476
NT Reported	489	496	460	478	466	474
NSW Adjusted	544	530	520	517	516	503
VIC Adjusted	520	523	515	519	521	507
QLD Adjusted	514	516	505	510	503	501
SA Adjusted	537	537	513	516	506	505
WA Adjusted	520	523	511	511	503	507
ACT Adjusted	540	521	512	503	497	495
TAS Adjusted	531	533	527	514	515	502
NT Adjusted	525	514	494	506	485	494

Fig. 6 shows TIMSS mathematics scores by state in 2011 and 2015, adjusted for changes in the family academic resource distribution (as measured by books in the home) in each state between 2011 and 2015. Thus, the average scores shown for 2011 are adjusted to the 2015 distribution of the sample by books in the home. The changes in TIMSS scores by state confirm our PISA findings (Fig. 4) that adjusted mathematics scores in Victoria fell considerably less than in New South Wales in 2011/2012 to 2015 (also true of reported scores). They also confirm that math scores in Western Australia declined less (or rose, in TIMSS) in that period. Not all the relative changes in TIMSS and PISA by state behave similarly, but most do.

8. The shift from government to non-government schools

Our earlier discussion showing the similar trajectories of PISA mathematics sc`ores in government, Catholic, and independent schools suggest that if shifts had any effect on test scores, they were small at the national level. However, we can try to glean insights about the decline by comparing how students in the three different types of schools performed across states. Did scores of students attending public schools decline more in some states than in others, and were these declines associated with greater movements out of government to non-government schools?

We estimated the mathematics scores in each type of school in each state, adjusting the scores for the changes in the individual and school socio-economic background of the samples across states and across test years *within each type of school*. To do this, we estimated the test scores for each type of school (government, Catholic, and independent) as a function of student characteristics attending that type of school and the average socioeconomic background of students in the sample of that type of school and dummy variables for each state (reference state was New South Wales). We then estimated the average score for each type of school in each year in each state, assuming that the individual characteristics of students attending that type of school in each year were those of the sample of students in Australia as a whole in that type of school in 2012. By doing this, we adjusted for differences in the SES of students in different schools within the sample of Catholic or government or independent schools in each year and possible changes in the socio-economic composition over the years, 2003–2015. This gets us closer to an estimate of changes in the "quality" of, say, Catholic education in a given state compared to Catholic education in another state, since we "adjust" for the differences in individual student and school social class characteristics across states and time *within that category of school*. Just to be clear, in this set of estimates, we do not adjust for social class differences between types of schools, so we only compare differences across states *within a category of school*.

Table 6 show the results of our estimated average mathematics scores for each type of school across states and time and Table 7 summarizes the absolute and percentage declines in mathematics test scores for each state within school category in 2003–2015. The results show that in every state but New South Wales, students in Catholic

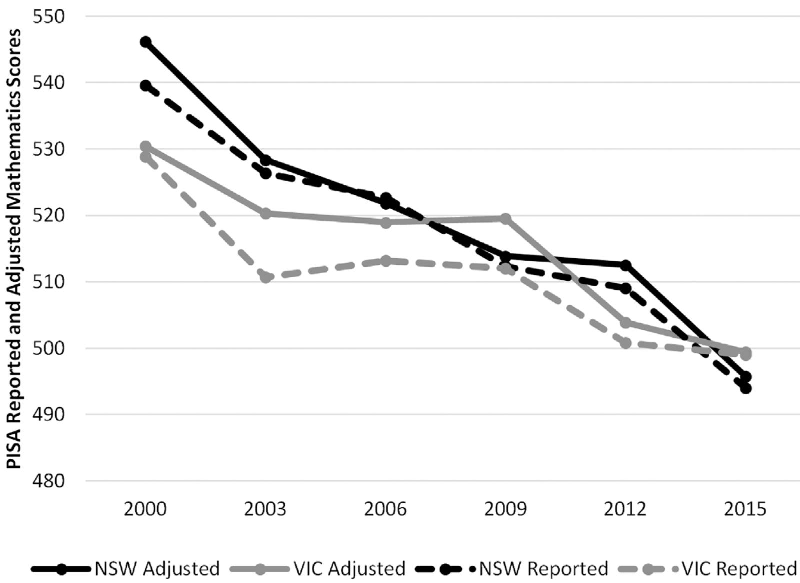

Fig. 4. PISA Mathematics Scores, New South Wales and Victoria States, Reported and Adjusted for Individual and School Socio-Economic Differences in Each Test Year, 2000–2015.
Source: OECD PISA, Australia microdata, 2000–2015.

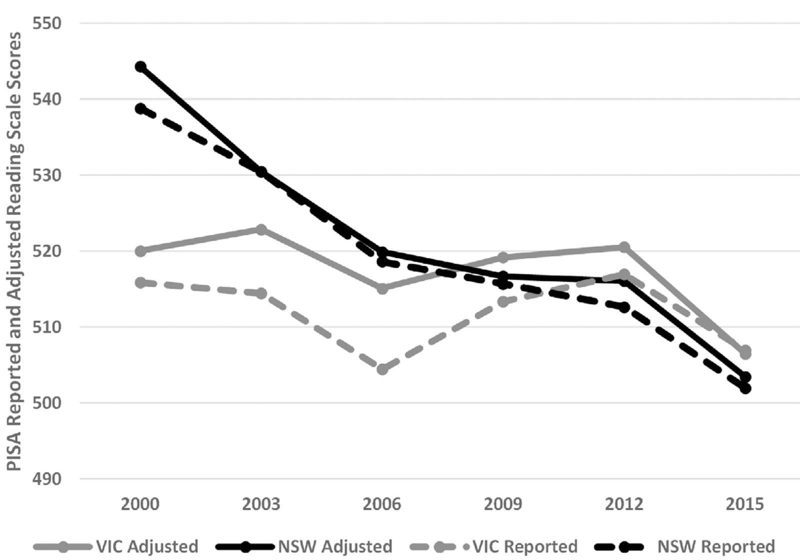

Fig. 5. PISA Reading Scores, New South Wales and Victoria States, Reported and Adjusted for Individual and School Socio-Economic Differences in Each Test Year, 2000–2015.
Source: OECD PISA, Australia microdata, 2000–2015.

schools had greater declines in scores than did students in government schools, and that in every state but South Australia and the Australian Capital Territory, the two jurisdictions with the greatest overall declines, students in Catholic schools had larger decreases in test scores than students in independent schools.

The fact that students in government schools were not the ones with the largest test score declines, except in the most populous state, New South Wales, suggests that if declining PISA scores are an indicator of declining educational quality, the problem does not lie solely or even mainly in government schools. It is also notable that in the states with the largest decreases in math scores, students in non-government schools suffered large declines in test scores, and that in the two states that had the smallest declines in test scores during these twelve years—Victoria and Western Australia—students in government and independent schools had very small decreases in test scores. This pattern of declines also characterizes the Northern Territory.

Could any of this be related to shifts of students from government to non-government schools? We have controlled for changes in the social class composition of students in each type of school among states and over time. Since these are not longitudinal surveys, we do not know whether students of lower or higher academic ability moving, on average, into non-government schools from government schools, or from Catholic schools to independent schools, were one reason for different changes in non-government school and government school scores in this period.

In the two states with the smallest decline in scores, we note that the shifts of students from government to non-government schools (Victoria and Western Australia) were relatively small (Appendix A Table A1), and in the Australian Capital Territory, the state with the largest decline in math scores, the shifts from government to independent schools were relatively great. The bottom line, however, is that states that had smallest or largest declines in math test scores did so because students in all three types of schools in the state declined less than or more than in other states (Table 7).

9. Can the decline in PISA scores be traced to increases in non-native English speakers?

We tested the proposition that an influx of non-native English speakers contributed to the decline in the scores. We used social class adjusted test scores for math and reading by state and type of school for only those in the sample who indicated that they spoke English at home and compared them with social class adjusted scores for the whole sample.

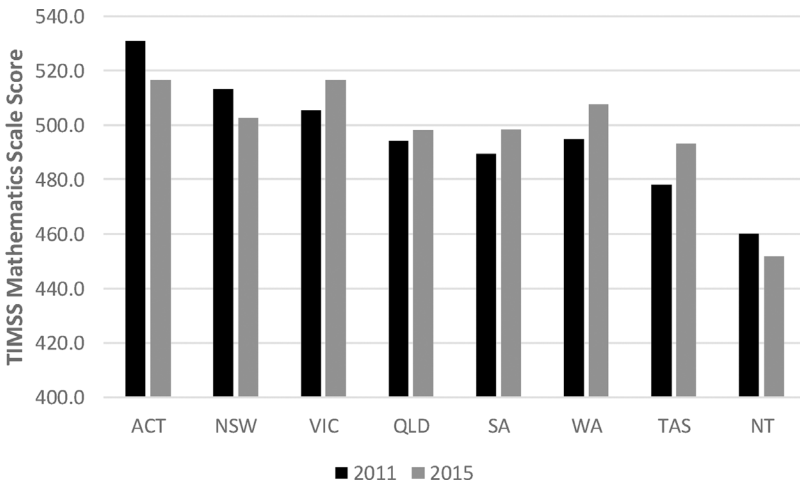

Fig. 6. TIMSS Mathematics Scores, by State, Reported and Adjusted for Family Academic Resources Across Years Within Each State, 2011–2015. Source: IEA, TIMSS, Australia microdata, 2011 and 2015.

Table 6
Australia: PISA Mathematics Scores, by Type of School, Adjusted for 2012 Average Sample Student and School SES in Each Type of School, 2003–2015.
Source: OECD PISA, Australia microdata, 2003–2015.

	Year of PISA Test				
	2003	2006	2009	2012	2015
State	Government Schools				
NSW	512.0	508.5	492.3	499.6	482.2
VIC	498.9	504.8	494.9	497.6	485.7
QLD	497.9	505.2	484.6	482.2	475.4
WA	507.1	501.8	487.6	481.1	492.2
SA	507.2	501.5	494.7	487.6	475.4
NT	496.1	492.7	491.0	456.8	490.0
ACT	488.0	487.4	467.7	463.1	468.8
TAS	516.0	517.9	493.6	496.0	483.6
State	Catholic Schools				
NSW	531.6	526.1	509.4	521.9	508.5
VIC	530.7	531.8	525.5	512.0	509.5
QLD	526.1	514.6	499.2	508.0	489.3
WA	540.2	522.8	524.1	514.9	513.7
SA	540.7	533.5	520.2	505.2	505.2
NT	523.7	515.9	496.2	462.0	488.4
ACT	535.2	535.3	498.6	499.0	495.9
TAS	539.1	541.5	518.9	519.9	499.5
State	Independent Schools				
NSW	551.6	541.7	534.4	540.4	531.3
VIC	548.5	528.2	539.9	544.3	541.1
QLD	548.5	523.0	538.4	538.8	525.4
WA	549.5	536.2	544.4	539.1	537.5
SA	579.6	538.5	540.7	537.7	532.8
NT	540.6	517.3	528.7	519.5	525.6
ACT	585.9	536.3	547.0	551.8	531.9
TAS	559.7	547.3	564.7	542.3	534.7

We found no difference between the adjusted scores in the two largest states–New South Wales and Victoria–for the English only students and the total samples of students, except for independent schools in 2003. In that year, the scores for students who spoke only English at home attending independent schools were somewhat higher than in the total sample of students attending independent schools. Nevertheless, the difference disappeared by 2006 and adjusted scores for both student language samples have remained virtually the same in both states since.[9]

10. Have different family academic resource groups fared equally well in different states?

In Table 1a, we showed that students with fewer family academic resources had the largest declines in PISA mathematics scores (disadvantaged FAR students (0–25 BIH) were also the only ones to show significant declines in TIMSS scores in 1999–2015—see Table 2). However, in one state, Victoria, the PISA mathematics scores of disadvantaged students had a very different trajectory than in other states. The scores of those students in Victoria were among the lowest in Australia in 2003, along with Tasmania and Northern Territory, but by 2015, they were the highest, along with those in Western Australia (Table 8). The math scores of the disadvantaged group of students in Victoria did not decline in this period, unlike scores in other states, all showing declines of 30–50 points in 2003–2015.

Furthermore, we observe that in three jurisdictions—New South Wales, the Northern Territory, and Tasmania—the gap between advantaged and disadvantaged students increased considerably, which means that the scores of advantaged students declined, but declined much less than the scores of the disadvantaged. In four jurisdictions—Queensland, South Australia, Western Australia, and the Australian Capital Territory—advantaged and disadvantaged student scores behaved similarly in that they declined about the same amount in 2003–2015. This was also true of advantaged and disadvantaged student scores in Victoria, with the important difference that neither the scores of advantaged nor disadvantaged students declined.

Thus, in some states, such as New South Wales, test score inequality between advantaged and disadvantaged students increased even as scores declined; in other states, such as neighboring Queensland, test score inequality remained approximately the same, even as scores declined; and in Victoria, scores overall may have declined (but less than in New South Wales or Queensland), but the scores of disadvantaged student scores did not decline, and the gap between advantaged and disadvantaged students' performance grew smaller (Fig. 7).

The comparison between the two most populous states in Australia, New South Wales and Victoria, provides an interesting contrast of greater math score decline and increasing test score inequality in New South Wales and lower test score decline and decreasing test score inequality in Victoria. The result of these contrasting patterns was that, whereas both disadvantaged and advantaged students in New South Wales scored about 20 points higher in 2003 than their counterparts in Victoria, by 2015, advantaged students in Victoria scored about the same as those in New South Wales, but disadvantaged students in Victoria score 15 points higher than their counterparts in New South Wales. The "Victoria difference" may provide clues as to the overall decline of PISA scores in Australia.

[9] The results comparing the estimates of native English-speaking students to the entire sample for various state score trajectories are available from the authors on request.

Table 7
Australia: PISA Math Scores, by Type of School, Adjusted for 2012 Average Australia Sample Student and School SES in Each Type of School, Absolute and Relative Declines, 2003–2015. Source: OECD, PISA microdata, 2003–2015.

	Government Schools		Catholic Schools		Independent Schools	
State	Points Decline, 2003–2015	Percent Decline, 2003–2015	Points Decline, 2003–2015	Percent Decline, 2003–2015	Points Decline, 2003–2015	Percent Decline, 2003–2015
NSW	−29.8	−5.8	−23.1	−4.3	−20.3	−3.7
VIC	−13.2	−2.6	−21.2	−4.0	−7.4	−1.3
QLD	−22.5	−4.5	−36.8	−7.0	−23.1	−4.2
WA	−14.9	−2.9	−26.5	−4.9	−12.0	−2.2
SA	−31.8	−6.3	−35.4	−6.6	−46.8	−8.1
NT	−6.1	−1.2	−35.3	−6.7	−15.0	−2.8
ACT	−19.2	−3.9	−39.3	−7.3	−54.0	−9.2
TAS	−32.4	−6.3	−39.6	−7.3	−25.0	−4.5
National Average	−24.7	−4.7	−30.8	−5.9	−24.7	−4.7

Table 8
PISA Mathematics Scale Score Difference Between Disadvantaged and Advantaged Students, by State, 2003–2015.
Source: OECD, PISA Australia microdata, 2003–2015.

	PISA Test Year					
State	2003	2006	2009	2012	2015	Net Change, 2003–15
NSW Disadvantaged	481.3	474.5	462.4	455.0	443.5	−37.8
VIC Disadvantaged	459.8	462.8	454.9	455.0	459.3	−0.6
QLD Disadvantaged	477.0	481.0	466.3	455.3	442.7	−34.4
SA Disadvantaged	492.1	480.0	470.4	440.1	443.7	−48.4
WA Disadvantaged	499.0	475.4	475.2	463.7	462.5	−36.5
NT Disadvantaged	460.0	423.7	394.0	385.0	430.3	−29.6
ACT Disadvantaged	493.3	474.4	459.9	444.7	447.3	−46.0
TAS Disadvantaged	459.8	440.4	430.2	420.9	419.9	−39.9
NSW Advantaged minus Disadvantaged score	78.7	85.2	91.1	102.5	92.3	13.6
VIC Advantaged minus Disadvantaged score	81.2	85.1	97.7	84.0	72.8	−8.4
QLD Advantaged minus Disadvantaged score	77.1	76.0	100.1	96.0	85.7	8.5
SA Advantaged minus Disadvantaged score	77.3	73.5	79.8	89.4	80.2	2.9
WA Advantaged minus Disadvantaged score	84.9	96.5	95.5	94.7	80.5	−4.4
NT Advantaged minus Disadvantaged score	76.7	112.2	147.9	121.4	101.6	24.9
ACT Advantaged minus Disadvantaged score	85.9	100.2	100.2	113.9	91.2	5.3
TAS Advantaged minus Disadvantaged score	80.3	98.0	98.1	105.5	99.3	19.0

Note: “Disadvantaged” students defined as those reporting 0–25 books in the home; “advantaged” students defined as those reporting 200+ books in the home.

11. Have different family academic resource groups fared equally well in different types of schools?

To understand how different FAR groups have performed in different types of schools, we chart the regression coefficients of two measures of FAR differences over the 2003–2015 period. The first of these is the coefficient for students reporting 201–500 books in the home—the next to the highest level of books in the home. Since the coefficient represents the estimated difference in test score between students reporting this high level of books in the home and the reference variable—students reporting 11–25 books in the home—we argue that the behavior of this coefficient is a measure of the achievement gap (other variables included in the regressions estimates) between higher and lower FAR students.

Fig. 8 shows the trajectory of the 201–500 books in the home coefficient from the separate regression of PISA scores for each type of school in each test year. The graph lines suggest that Catholic schools have generally had a larger gap in math score between lower and higher FAR students than either government or independent schools during this period, although the gap increased in all three types of schools in 2003–2009 and then fell subsequently to 2003 levels. Neither were the gaps very different in the three school types except in 2009.

The second measure of SES test score differences among different types of schools is the coefficient of the average PISA SES index for the school. The higher this coefficient, the larger the test score difference between higher and lower SES schools in each school type. Fig. 9 shows the trajectory of this coefficient for each type of school in 2003–2015.

In this case, it appears that government schools are characterized by the largest math test score differences among schools of different average student socio-economic background, and independent schools, the lowest. This finding makes sense, because we would expect that government schools have the widest average SES range of schools in the system, whereas independent schools probably have the lowest. As in the case of the trajectory of the individual student FAR SES gap, the school inequality measure increased between 2003 and 2009 and then declined. It also converged among types of schools. One reason for the

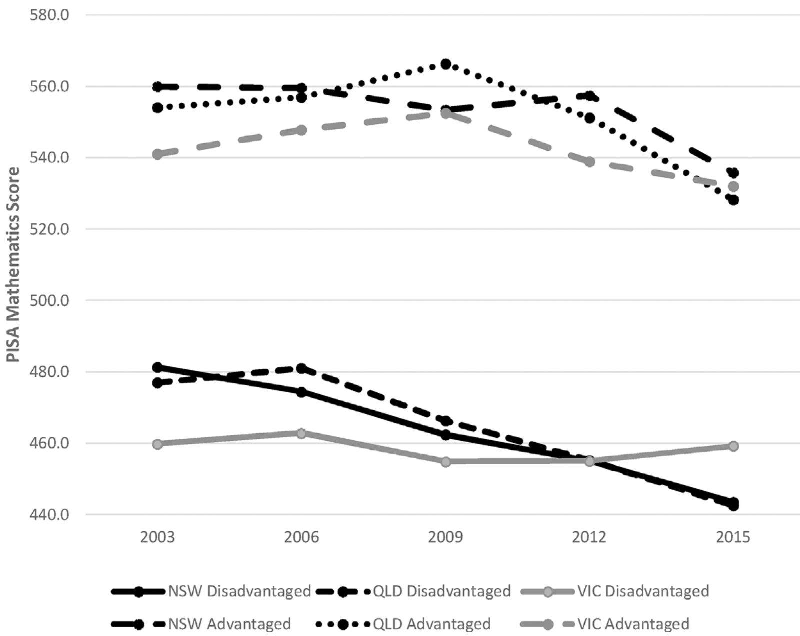

Fig. 7. PISA Mathematics Score, by State, Disadvantaged and Advantaged Students, 2003–2015.
Source: OECD PISA, Australia microdata, 2003–2015.

convergence may have been the shift of students from government to Catholic and particularly independent schools, which may have driven down the difference in test scores between higher and lower SES government schools if higher scoring students in higher SES government schools shifted to non-government schools or it lower scoring students in lower SES government schools made the shift. The explanation is consistent with the trajectory of the SES coefficient for independent schools if the test scores of shifted higher SES students from government to independent schools were higher than the average scores of higher SES students in the independent schools or if the scores of students shifting from low SES government schools were lower than the average scores in low SES independent schools. Both these hypotheses fall in the realm of possibility.

Yet, these increases and decreases in inequality do not seem to be a particularly good explanation for decreases in test scores during this period. PISA test scores declined whether test score inequality increased or decreased and, as we have shown, they declined in all three types of schools, although somewhat less so in government schools. The pattern of rise and fall in test score inequality is also inconsistent with any systematic shifts of particularly high or low-scoring students out of government schools to non-government schools.

12. Can we identify any decline in the quality of mathematics teachers in Australia (from TIMSS data)?

Another reason experts have floated to explain the decline in Australia's PISA mathematics scores is the deterioration in the quality of Australia's math teachers. Since average mathematics scores have decreased across all types of schools (more so in Catholic schools), and since mathematics scores have declined more than reading scores, it is possible that some generic decline in school inputs have especially influenced math scores. Math teachers have typically been in short supply, and this shortage may have been exacerbated in the past 15 years because of the growth of information services industries and the concomitant increase in the relative wages for math skills.

We have limited data to measure the quality of Australia's mathematics teaching in 2000–2015. Using the data we do have, the case for a decline in the quality of mathematics teaching is not strong. In terms of teacher salaries, the ratio of pay after 15 years of experience relative to starting pay is lower in Australia than in many OECD countries, and the ratio of secondary teachers' salary to primary teachers' salary is much lower in Australia than in most OECD countries, but average teacher salary is relatively higher in Australia than in most OECD countries (OECD, 2005–2014), teacher salaries have increased more than the

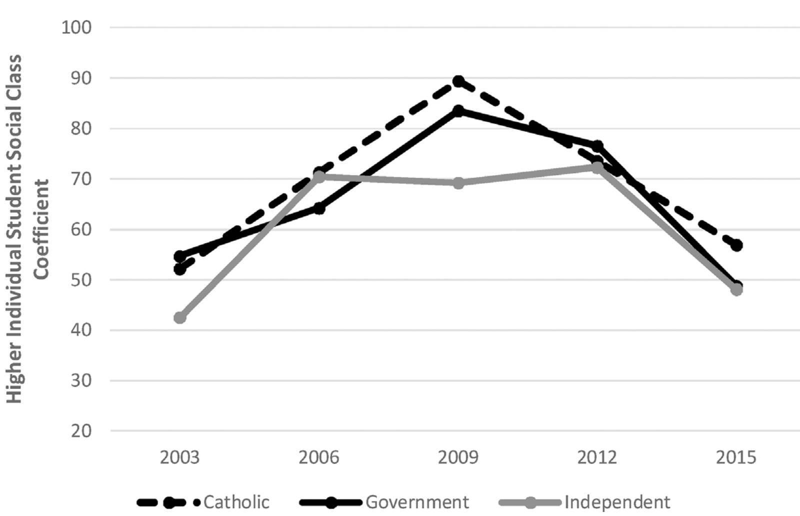

Fig. 8. Australia: Estimated Coefficient of Advantaged Student SES Relative to Disadvantaged Student SES, by Type of School, 2003–2015 (difference in PISA mathematics score).
Source: OECD PISA, Australia microdata, 2003–2015.

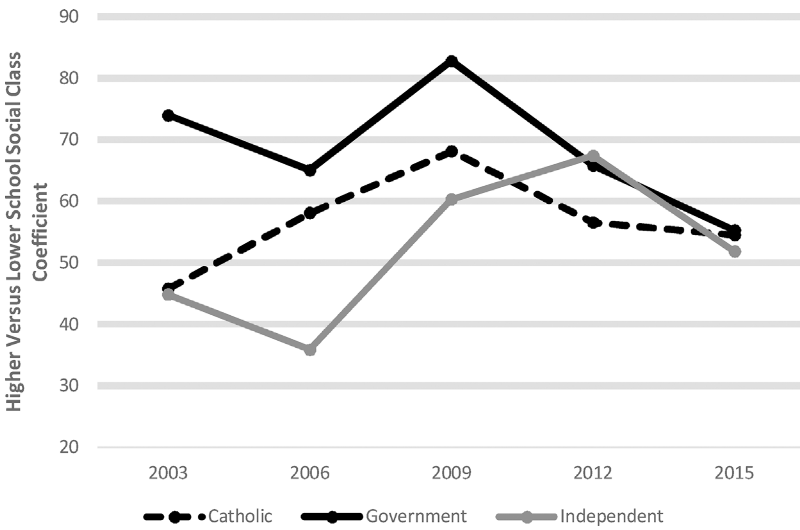

Fig. 9. Australia: Estimated Coefficient of Higher Versus Lower School SES, by Type of School, 2003–2015 (difference in PISA mathematics score).
Source: OECD PISA, Australia microdata, 2003–2015.

average for the OECD in 2000–2013 (OECD, 2005–2014), and teachers' salaries in Australia compared to salaries for similarly educated workers in prime working age are about the same as the average for the OECD—25–64 years old teachers in Australia earned about 83% of workers with similar education in 2013 (OECD, 2015, Table D3.2.a). Teachers' salaries compared to salaries in math-related occupations are probably lower, and this could have resulted in a decline in the attractiveness of math teaching in this period, but we have no evidence that this relative salary declined in the past fifteen years.

Another indicator of quality is class size. The number of students in primary and lower secondary schools in Australia changed little in the period covered by the PISA tests, staying at about 23–25 students per class, about the OECD average—higher than some countries and lower than others (OECD, 2015, see Table D.2.1).

The TIMSS survey collects data on the type of education mathematics teachers report having taken, teachers' assessments of coverage of the curriculum and of parent and student attitudes toward schooling, and on the kind of math practices they use in their math teaching. We could trace reported education and these teacher assessments in some cases, from 1999 to 2015, and in others, from 2003 to 2015. In general, the changes over time suggest that mathematics teaching may have even improved over time, with the caveat that these are teacher reports.

The way TIMSS asked the question, mathematics teachers can indicate more than one type of training, so estimated percentages for each category of pre-service training depend on how many boxes respondents chose to mark. The results of the TIMSS survey show that except in 2007, about 60% of mathematics teachers marked that they had preparation in mathematics as pre-service training. However, it could be that in the earliest year, 1999, most teachers had been trained in mathematics departments of universities (as indicated), whereas in the latest year, 2015, they were mostly trained in schools of education. The survey results are much clearer in showing that teachers teaching mathematics increasingly have had training mainly in a science subject or have been trained in science as well as mathematics (see Appendix A Table A2).

However, mathematics teachers' pre-service training probably varies from state to state, and the difference is large in the pattern reported in the two most populous states, New South Wales and Victoria. We only have state data for one year in the TIMSS, 2011, but math teacher-reported differences are consistent with claims by our policy informants that mathematics teachers in Victoria are now much more likely to have taken their pre-service training in science subjects rather than mathematics (Appendix A Table A3). It is the case that students' adjusted PISA math performance in Victoria declined somewhat more in 2006–2012 than in New South Wales, but not in 2012–2015 (see Table 5a). It is therefore unclear whether the science pre-service training of math teachers in Victoria has had a major influence on student performance in that state.

TIMSS also asked mathematics teachers how they assessed certain aspects of teaching quality, and teachers', parents', and students' attitudes toward academic achievement in their schools. The results of these questions suggest a strong upward trend in how teachers assessed teachers' understanding and implementation of curricular standards in their schools. Teachers' assessment of teachers' expectations for student achievement also shows a considerable increase in 2003–2015. Teachers' views of parents' involvement in school and support for student achievement did not change significantly (although teachers judge more than 40% of parents as having very high or high support for student achievement and less than 20% as having low or very low support). On the other hand, teachers reported view of students' desire to do well in school showed a great increase in students who had a very high or high desire to do well and a sharp decline in students who had a low or very low desire to do well (Table 9).

The data in Table 9 suggest that mathematics teachers have an increasingly favorable view of what is happening in their schools regarding curriculum coverage, expectations of students, and of students' desire to achieve. This may be a "naïve" view, in the sense that things are getting worse, but teachers don't know it. Or students might be learning more mathematics taught in school (as suggested by the TIMSS test) but it does not show up in PISA scores.

Table 10 gives support to the notion that teachers are not being naïve and that the teaching of mathematics in Australia might be improving rather than declining. Although the questions are not constant across years, there are five questions that traverse three or more years. Three of those questions suggest that math teaching methods associated with teaching higher levels of understanding are being used more frequently: "work on problems for which there is no immediately obvious method of solution;" "decide on their own procedures for solving complex problems;" and "explain their answers." Teachers reported that "memorize formulas and procedures" also increased in frequency, perhaps in respond to increased testing.

We can also compare the results for New South Wales and Victoria in the one year for which we have teacher response data for individual states, 2011. Teachers in New South Wales are more "positive" in how

Table 9
Australia: Teachers' Opinions About Teaching Practices, Parent Involvement, and Student Commitment in the Teachers' Schools, 2003–2015.
Source: IEA, TIMSS Australia microdata, 2003, 2007, 2011, 2015.

	2003		2007		2011		2015	
How would you characterize each of the following within your school?	Very high + high	Very low + low	Very high + high	Very low + low	Very high + high	Very low + low	Very high + high	Very low + low
Teachers' understanding of the school's curricular goals	70.7	4.1	64.0	9.3	75.6	2.7	86.9	0.9
Teachers' degree of success in implementing the school's curriculum	59.3	4.7	62.4	3.8	68.9	1.2	75.1	1.1
Teachers' expectations for student achievement	59.3	7.4	64.4	7.4	73.4	5.0	77.4	3.7
Parental involvement in school activities	27.3	38.6	23.1	38.0	28.3	39.1	29.2	33.2
Parental support for student achievement	41.9	22.6	42.9	15.8	46.2	18.8	41.4	18.2
Students' desire to do well in school	30.4	19.2	30.5	21.3	42.9	15.7	48.5	9.5

they characterize teachers' and students' attitudes than teachers in Victoria. But teachers in Victoria are more likely to teach math in a way that allows students to decide on their own procedures and that relates the problems to students' daily lives. It would be a stretch, given the sample sizes in these data, to do a proper analysis of which of these variables is more important in student math achievement (Appendix A Table A4).

Overall, then, none of these indicators support the notion that dramatic negative changes in teaching are occurring in Australian classrooms or in the capacity of Australian teachers to teach mathematics. Unless math teachers in Australia are misrepresenting how they teach mathematics, the TIMSS results would not explain the steady decline in PISA mathematics scores in 2000–2015, or the smaller, but still significant, decline in scores in 2003–2015, or the even smaller but still significant decline in math scores between the two "PISA mathematics test years," 2003 and 2012.

13. Does decreasing exposure to mathematics lessons in Australian classrooms explain mathematics test score declines?

Although the data don't show that Australian teachers are teaching mathematics less effectively than in the past, they may be exposing students to fewer minutes per week of mathematics, as claimed by several of our interviewees. This could be negatively impacting student achievement. Table 11 presents the average number of class minutes per week, by state, that students in the PISA survey reported learning mathematics in the years 2003–2015. The number of reported math minutes declines on average, especially between 2003 and 2006. The 2003 data are somewhat suspect, however, because of the very high standard deviation of reported minutes in that year (181 min) compared to later years (98, 79, 60, and 77 in 2006, 2009, 2012, and 2015). Another source of data about minutes of math exposure in school are the 8th grade teacher reports in the TIMSS survey of how many minutes they spend teaching mathematics. As shown in Table 12, 8th grade teachers report teaching 200–220 min per week during these same years, and there is no significant decline. The difference in minutes reported in the PISA and TIMSS surveys could be due to the higher grades attended by students in the PISA sample (9th–11th); math teaching in upper grades of secondary school might have declined while math teaching in the lower grades of secondary school remained the same.

Recent studies with a strong identification strategy use PISA student learning time data to show that more time exposure to the subject matter produces significant gains in achievement in that subject, although the effect is small (Lavy, 2015; Rivkin and Schiman, 2015). We add variables for standardized minutes of math time and the interaction between standardized minutes and the average SES of students in a school to our basic model (Eq. (1) and results in Table 4)—this is the model shown in Eq. (2).

Table 12 shows the results for the relevant estimated coefficients. These are correlational, not causal. They suggest that in some years (2006, 2012, 2015), there is a positive relation between student

Table 10
Australia: Proportion of Mathematics Teachers Reporting That They Used Certain Mathematics Teaching Methods in More than One-Half their Lessons, 2003–2015.
Source: IEA, TIMSS Australia microdata, 2003, 2007, 2011, 2015.

	Every or Almost Every Lesson + Half the Lessons			
In teaching mathematics to this class, how often do you ask students to do the following?	2003	2007	2011	2015
Listen to me explain how to solve problems			95.9	89.9
Memorize formulas and procedures		31.2	66.0	63.5
Work on problems for which there is no immediately obvious method of solution	8.2	10.4	24.7	26.9
Relate what they are learning in mathematics to their daily lives	39.3	46.9	54.8	
Decide on their own procedures for solving complex problems	23.3	27.7	46.9	
Explain their answers	63.6	62.4	85.1	
Practice adding, subtracting, multiplying, and dividing without using a calculator	38.5	45.1		
Work on fractions and decimals	25.6	18.4		
Write equations and functions to represent relationships	16.7	14.5		
Work together in small groups	18.3	24.9		
Interpret data in tables, charts or graphs	8.2	7.0		
Apply facts, concepts and procedures to solve routine problems		54.9	87.1	
Work problems (individually or with peers) with my guidance			90.7	92.0
Work problems together in the whole class with direct guidance from me			70.3	78.7
Work problems (individually or with peers) while I am occupied by other tasks			40.2	46.4
Take a written test or quiz			14.3	16.2

Table 11
Australia: PISA Student Report Class Time Spent Learning Mathematics, by State, 2003–2015, and TIMSS Teacher Reported Teaching Time on Mathematics, 1999–2015 (minutes/week).
Source: OECD PISA Australia microdata, 2003–2015; IEA TIMSS Australia microdata, 1999–2015.

PISA Student Reported Class Time Spent on Mathematics (minutes/week)					
	2003	2006	2009	2012	2015
Australia	266	246	240	236	238
NSW	254	262	240	234	240
VIC	274	251	251	242	244
QLD	268	216	227	227	228
SA	263	240	240	233	239
WA	276	254	243	249	239
ACT	239	232	226	219	220
TAS	291	230	242	245	252
TIMSS Teacher Reported Teaching Time on Mathematics (minutes/week)					
	1999	2003	2007	2011	2015
Australia	210	212	201	221	215

Table 12
Australia: Estimated Mathematics Achievement Related to Average School SES, Student Reported Minutes of Mathematics per Week in Class, and School SES*Math Minutes Interaction, 2003–2015.
Source: OECD PISA Australia microdata, 2003–2015.

	PISA Test Year				
Variable	2003	2006	2009	2012	2015
ESCS mean (school SES)	62.54***	54.18***	71.14***	64.76***	53.12***
	(6.34)	(6.26)	(7.76)	(4.98)	(4.26)
Minutes learning math per week (z-scores)	−11.91***	13.68***	0.87	5.94***	2.07*
	(1.17)	(0.88)	(1.29)	(1.01)	(1.20)
Interaction school SES*minutes for math	5.71**	−4.85*	3.39	−3.12	5.67**
	(2.33)	(2.51)	(2.30)	(2.75)	(2.66)
Grade attended	Yes	Yes	Yes	Yes	Yes
Student characteristics	Yes	Yes	Yes	Yes	Yes
School Type	Yes	Yes	Yes	Yes	Yes
State Fixed effects	Yes	Yes	Yes	Yes	Yes

*** statistically significant at 0.01 level.
** statistically significant at 0.05 level.
* statistically significant at 0.10 level.

reported time on math in the class and student math achievement. In recent years (2009–2015), the effect is not significant or significant but small, between two and six points (about 0.02 and 0.06 standard deviation of math PISA test score increase for a one standard deviation increase in teaching time- 60–80 min per week, depending on the year). This small size effect is consistent with Lavy's and Rivkin and Schiman's estimates of the time effect on student achievement.

The other interesting result in this table is the possible interaction between minutes per week of math exposure and school SES. In 2003 and 2015, this is positive, suggesting that the higher the SES of the school, the greater is the effect on student achievement of more minutes of mathematics. But in 2006, the interaction effect is negative, and in 2009 and 2012, it is not statistically significant. Therefore, we cannot conclude that higher SES students are consistently more benefitted by more math exposure.

We use the regression results from the model that includes math minutes to test whether adjusting for minutes of math in class in each year of the test significantly affects the decline in mathematics score across time in different states. Table 13 shows the results of re-estimating the adjusted average PISA mathematics scores in each state in each year, in this case including the minutes per week of math reported by students. There is some difference between these and our previously estimated adjusted scores, but it is not great. The trajectories of the two most populous states, New South Wales and Victoria, change little in relative terms when we adjust for minutes taught. The largest effect appears to be on the ACT achievement level in 2015, which changes the adjusted score by 7 points.

Thus, minutes of math students report learning in class do have some effect on adjusted achievement scores, but explain little of the decline in PISA mathematics scores. For example, if the 2003 average minutes reported are correct (266 min), raising math taught per week in 2015 by 30 min (about 0.4 standard deviations of teaching time) to increase them to the 2003 level, would, according to our estimate, increase math achievement by about one point on the PISA test. Even in 2012, when the estimated coefficient of math minutes is three times as large, the impact of a thirty-minute increase in minutes would only be about 2 points.

14. Discussion and conclusions

Australian students' PISA scores in mathematics have fallen steadily since their relatively high performance the first time the test was applied, in 2000. The decline persists when students' performance is adjusted for changes in the family academic resources of students sampled, and we observe it for students in all Australia's eight states, for both socially advantaged and disadvantaged students, and in both government and private schools, although the trends vary somewhat from state to state and in different types of schools. The declines in scores are large enough that they should be quite easy to explain, and there is no shortage of reasons given by Australian experts for why Australian mathematics education (and Australian education more generally) is getting worse.

We found that these reasons largely failed to stand up to empirical scrutiny. Indeed, there were some surprises. For example, many experts in Australia assume that student performance in government schools has worsened more than in private schools, and that government school test score decline is pulling down the national average. Our estimates showed that, adjusting for students' family academic resource differences, students in Catholic schools had the largest decline in

Table 13
Australia: PISA Mathematics Scores, Adjusted for Average Australian Sample Student SES, School SES, and Student Reported Minutes Spent Learning Mathematics in Class, in Each Year, 2003–2015.
Source: OECD PISA microdata, 2003–2015.

Variable	2003	2006	2009	2012	2015
NSW w/adjustment for minutes	528	522	517	517	498
VIC w/adjustment for minutes	521	520	522	508	500
QLD w/adjustment for minutes	516	520	512	503	490
SA w/adjustment for minutes	537	523	520	500	493
WA w/adjustment for minutes	525	517	520	502	505
ACT w/adjustment for minutes	521	519	504	493	492
TAS w/adjustment for minutes	535	534	521	515	495
NT w/adjustment for minutes	517	513	516	479	498
NSW w/o adjustment for minutes	528	522	514	513	496
VIC w/o adjustment for minutes	520	519	520	504	499
QLD w/o adjustment for minutes	516	514	508	498	487
SA w/o adjustment for minutes	537	520	518	496	491
WA w/o adjustment for minutes	525	517	516	499	504
ACT w/o adjustment for minutes	521	514	499	489	485
TAS w/o adjustment for minutes	533	531	520	510	495
NT w/o adjustment for minutes	515	508	512	474	496

mathematics scores in 2003–2015. This was true in every state except New South Wales. Although in some states, government school students had larger declines than students in independent schools, in three states, students in government schools had the lowest decline, and in two others, student performance in government and independent schools declined about the same.

A priori, the most persuasive explanations for the lower PISA score we heard from experts was that the quality of mathematics teachers had significantly deteriorated in this period and that the amount of time spent on math decreased significantly. We found only modest support for the quality of math teacher explanation, but considerable support for the time on math explanation. Compared to fifteen years ago, in today's Australia a much higher proportion of math teachers is trained in science or science as well as mathematics. Yet, if this were an important cause of student PISA math decline, the decrease should have been larger in Victoria than in New South Wales, since a much higher percentage of math teachers in Victoria indicate science training than in New South Wales. The opposite is the case—New South Wales students' scores fell more than in Victoria, and that was especially true for student performance in government schools.

Further, according to responses on the TIMSS questionnaire, teachers appear to better understand the curriculum and are more successful at implementing it in 2015 than in 2003. Their expectations for students are higher, and, according to teacher responses, students are more motivated to do well. It is possible that teachers' self-reports of their school's functioning and of their own approach to teaching lack reliability. However, given that several measures we examined indicated the same trend, it is just as likely that math teaching is not deteriorating as claimed.

The decrease in time spent on mathematics appears to be real, at least according to PISA students' reports. However, according to our estimates, the smaller reported exposure to mathematics has only a small effect on average PISA mathematics scores. Taken together, our assessment of the teacher quality and math time explanations suggests that the "quality" of mathematics teaching in Australia may have, in fact, declined somewhat (less time on math), but the estimated effects are small. And at least in some states, teaching quality may have even improved because of state policies.

All this shows that despite the considerable insight that Australia's educational experts have into what is occurring in Australian schools, many of their views are off the mark, especially in explaining the reasons for the decline in Australia's PISA scores. Misidentifying these reasons is not benign. For example, based on the notion that government schools are leading the drive downward, some politicians are suggesting funding cuts for government schools, when, given our results, precisely the opposite policy—to increase their funding—may be appropriate.

That does not mean we can claim to have the answer for why students in Australia are performing worse on the PISA mathematics test. For one, the fact that Australian students' TIMSS performance turned the corner in 2007 and began rising (adjusted for changes in the socioeconomic background of students in the TIMSS samples) may indicate that the PISA test items are not picking up improvements in mathematics teaching and learning in Australia. Second, the exercise we have gone through in this paper suggests how difficult it is to derive educational policies from international test results, which, after all, are just snapshots of different cohorts of students' performance on a particular test of students' ability at one level of schooling (or age) at different points in time.

Nevertheless, our study does point to several clues to explaining student math performance declines if, indeed, "math performance" is truly declining. One clue is the difference in score declines between New South Wales and Victoria. Because they are demographically and geographically similar, New South Wales and Victoria are comparable examples among the Australian states and territories. Victoria has experienced more modest declines in math (and reading) scores (no declines for disadvantaged students), at the same time showing a modest closing of the gap between advantaged and disadvantaged students. In addition, TIMSS math scores in Victoria increased in 2011–2015, whereas they fell in New South Wales. Victoria teachers' approach to teaching mathematics could have partly (though probably not entirely, or even mainly) contributed to these smaller declines. The Victoria approach appears to emphasize mathematics education as a system of understanding patterns in the world, and strategic and conceptual thinking in which students are actively engaged, rather than, as in New South Wales, where the data appear to show a teaching approach that more passively engages students to solve procedures (Boaler and Selling, 2017). If we are to find reasons for declines in Australia's PISA math scores, a deeper examination of the differences in educational policies and practices between these two most populous states could provide answers.

Another clue is that, of the three school sectors, Catholic schools have shown the greatest declines in mathematics performance. This decline could be larger than in other types of schools because Catholic schools may be enrolling more low-scoring students across social classes, or because the teaching in Catholic schools is less effective. In NSW, government schools must wait to hire teachers who have completed their accreditation, including having received a license number, which is the final step of any teachers' formal qualification process. However, independent and Catholic schools can hire conditionally accredited teachers—or those who have not yet completed their teaching degree—with the proviso that they work on their qualification while they are teaching. In practice, it is possible that Catholic schools hire more conditionally accredited teachers who take longer to complete their degree than independent schools. Independent schools may, on average, be more selective in their hiring process, and they may attract more promising teachers than Catholic schools. This is only a hypothesis and would require further research.

Finally, as one of our expert informants argued, Australia's strategy of relying on parental choice and competition between government and private schools to improve education (Morsy et al., 2014)—despite increasing evidence that choice plans are not effective (see Orfield and Frankenberg, 2013; Carnoy, 2017)—may have created the conditions for declining student performance. Emphasizing choice and competition has probably drawn attention away from public school improvement policies that work, such as state level teaching improvement strategies, strong school accountability, and adequate funding for low-income schools.

Appendix A

Table A1
Australia: Proportion of Students by Type of School and State, 2003 and 2015 (%).
Source: OECD, PISA, Australia microdata, 2003 and 2015.

	2003			2015		
State	Catholic	Government	Independent	Catholic	Government	Independent
NSW	22.6	65.5	11.9	25.7	58.2	16.1
VIC	26.6	56.3	17.2	23.1	56.3	20.6
QLD	18.1	65.4	16.5	20.4	59.0	20.6
SA*	17.4	49.9	32.7	22.2	56.4	21.4
WA	24.1	58.3	17.7	20.0	57.5	22.5
ACT	27.3	60.3	12.4	31.0	50.8	18.1
TAS	20.6	70.3	9.1	21.8	62.3	15.9
NT	11.6	68.4	20.0	12.3	65.3	22.4

Note: * the figures for South Australia in 2003 may be off, since in 2006 and later years, the figures remained rather stable—21–22% in Catholic schools, 56–58% in government schools, and 21–22% in independent schools.

Table A2
Australia: Proportion of Teachers Reporting Types of Pre-Service Education Received, 1999–2015 (percent indicating that they had received that type of training).
Source: IEA, TIMSS microdata, 1999, 2003, 2007, 2011, 2015. Note: *Science is the sum of teachers who ticked off that they received pre-service training in biology, physics, chemistry, or earth sciences.

Pre-Service Training	1999	2003	2007	2011	2015
Mathematics	67.4	61.1	49.2	57.3	64.1
Science*	47.2	37.3	33.9	77.0	72.4
Education–Mathematics	36.2	58.3	45.7	45.8	60.2
Education–Science	21.0	25.2	24.7	29.3	36.3
Education–General	44.6	38.1	31.9	26.2	42.8
Other	40.1	42.2	39.4	35.9	45.4

Table A3
Comparing the Proportion of Teachers Reporting Types of Pre-Service Education Received, Australia, New South Wales, and Victoria, 2011 (percent indicating that they had received that type of training).
Source: IEA, TIMSS Australia microdata, 2011. Note: * Science is the sum of teachers who ticked off pre-service training in biology, physics, chemistry, or earth sciences–since multiple ticks are possible, the proportion of teachers with pre-service training in science can exceed 100%.

Pre-Service Training	Australia	New South Wales	Victoria
Mathematics	57.3	67.4	47.7
Science*	77.0	69.9	110.6
Education–Mathematics	45.8	63.3	21.4
Education–Science	29.3	17.1	41.0
Education–General	26.2	21.7	23.7
Other	35.9	20.7	42.4

Table A4
Comparing Teachers' Opinions About Teaching Practices, Parent Involvement, and Student Commitment in the Teachers' Schools, and the Proportion of Mathematics Teachers Reporting That They Used Certain Mathematics Teaching Methods in More than One-Half their Lessons, Australia, New South Wales, and Victoria, 2011.
Source: IEA, TIMSS Australia microdata, 2011.

How would you characterize each of the following within your school?	AUS	NSW	VIC	In teaching mathematics to this class, how often do you ask students to do the following?	AUS	NSW	VIC
	% Very High or High				% More than Half the Lessons		
Teachers' understanding of the school's curricular goals	75.6	78.9	75.4	Listen to me explain how to solve problems	95.9	96.2	98.7
Teachers' degree of success in implementing the school's curriculum	68.9	72.3	64.1	Memorize rules, procedures, and facts	66.0	79.9	53.7
Teachers' expectations for student achievement	73.4	78.3	68.0	Work on problems for which there is no immediately obvious method of solution	90.7	87.3	91.7
Parental involvement in school activities	28.3	30.3	27.4	Take a written test or quiz	70.3	67.2	66.7
Parental support for student achievement	46.2	48.2	45.8	Relate what they are learning in mathematics to their daily lives	40.2	30.4	40.0
Students' desire to do well in school	42.9	50.1	42.6	Decide on their own procedures for solving complex problems	24.7	15.9	26.1
				Explain their answers	14.3	10.6	11.0
				Work problems (individually or with peers) with my guidance	54.8	51.3	59.7
				Work problems together in the whole class with direct guidance from me	46.9	50.4	48.2
				Work problems (individually or with peers) while I am occupied by other tasks	85.1	86.8	83.3

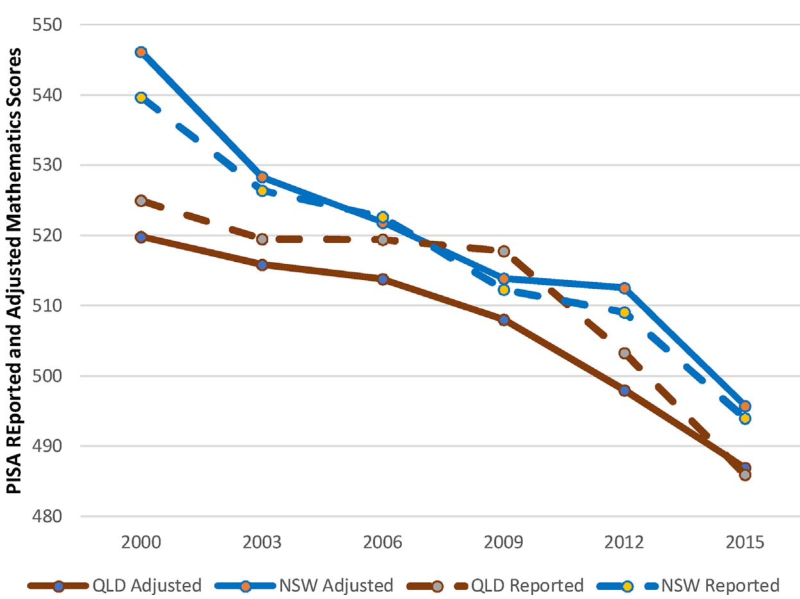

Fig. A1. PISA Mathematics Scores, New South Wales and Queensland, Reported and Adjusted for Individual and School Socio-Economic Differences in Each Test Year, 2000–2015.
Source: OECD, PISA, Australia microdata, 2000–2015.

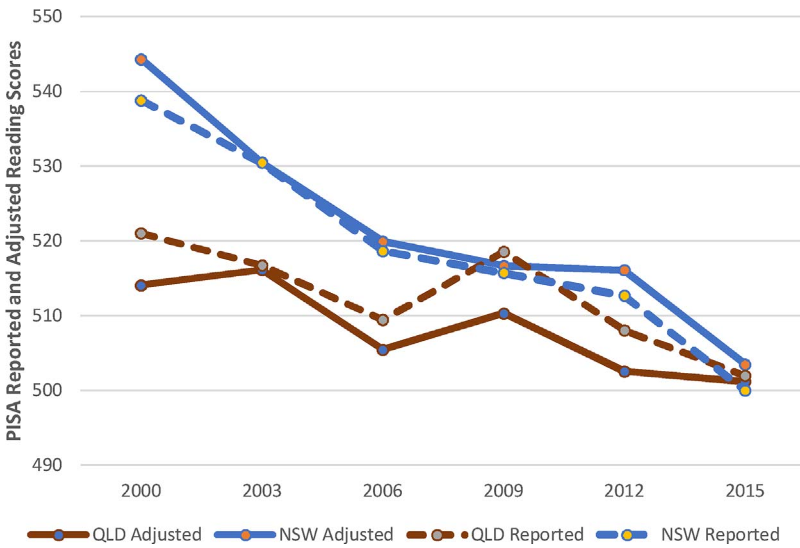

Fig. A2. PISA Reading Scores, New South Wales and Queensland, Reported and Adjusted for Individual and School Socio-Economic Differences in Each Test Year, 2000–2015.
Source: OECD, PISA, Australia microdata, 2000–2015.

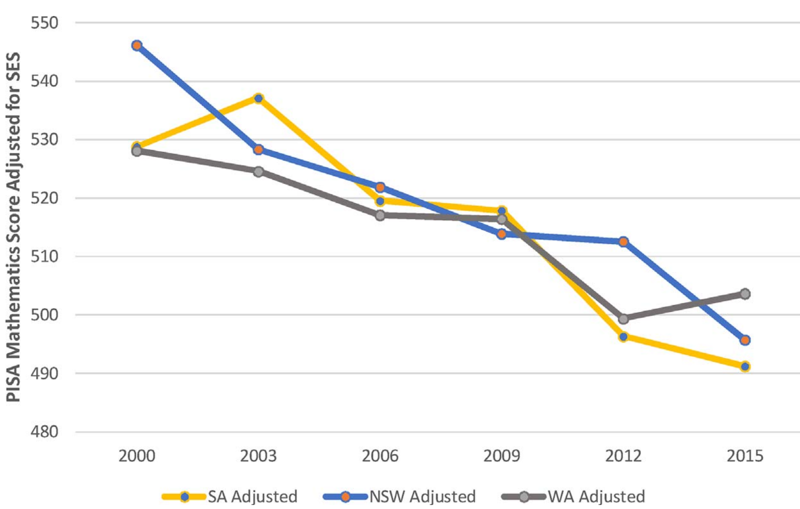

Fig. A3. PISA Mathematics Scores, New South Wales, South Australia, and Western Australia Adjusted for Individual and School Socio-Economic Differences in Each Test Year, 2000–2015.
Source: OECD, PISA, Australia microdata, 2000–2015.

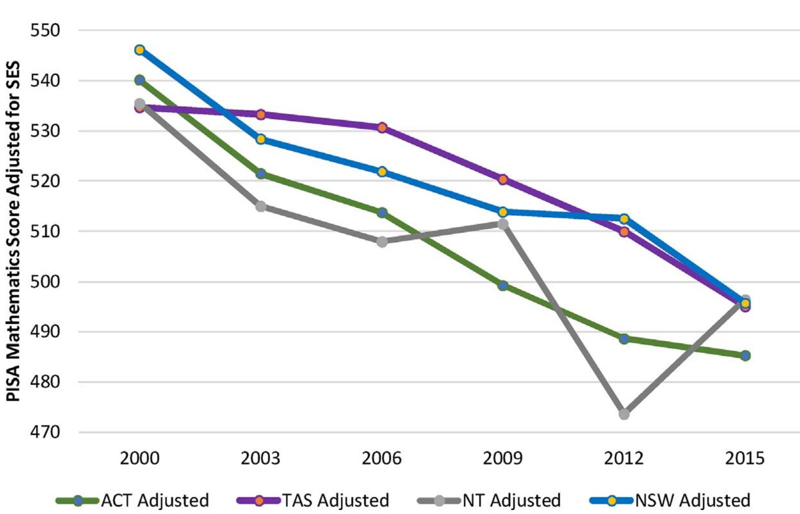

Fig. A4. PISA Math Scores, NSW, Northern Territory Tasmania, and Australian Capital Territory, Adjusted for Individual and School Socio-Economic Differences in Each Test Year, 2000–2015.
Source: OECD, PISA, Australia microdata, 2000–2015.

References

Australian Bureau of Statistics, 2017. Government School Enrolments on the Rise. Australian Bureau of Statistics, Canberra, Australia.
The Sydney Morning Herald (Producer), Bagshaw E., Fisher J. (Directors). 2016. What PISA says about Australian schools, [Video/DVD] Sydney, Australia.
Baumert, J., Kunter, M., Blum, W., Brunner, M., Voss, T., Jordan, A., et al., 2010. Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress. Am. Educ. Res. J. 47 (1), 133–180.
Boaler, J., Selling, S.K., 2017. Psychological imprisonment or intellectual freedom? A longitudinal study of contrasting school mathematics approaches and their impact on adults' lives. J. Res. Math. Educ. 48 (1), 78–105.
Buckingham, J., 2016. Why Australia's PISA Results are a Catastrophe. Australian Financial Review December 6.
Carnoy, M., Rothstein, R., 2013. What do international tests really show us about student performance? Economic Policy Institute, Washington, DC.
Carnoy, M., Garcia, E., Khavenson, T., 2015a. Bringing it back home. Economic Policy Institute, Washington, DC.
Carnoy, M., Khavenson, T., Ivanova, A., 2015b. Using TIMSS and PISA results to inform educational policy: A study of russia and its neighbours. Compare 45 (2), 248–271.
Carnoy, M., Khavenson, T., Loyalka, P., Schmidt, W., Zakharov, A., 2016. Revisiting the relationship between international assessment outcomes and educational production: Evidence from a longitudinal PISA-TIMSS sample. Am. Educ. Res. J. 53 (4), 1054–1085.
Carnoy, M., 2017. School vouchers are not a proven strategy for improving student achievement. Economic Policy Institute, Washington, D.C.
Castex, G., Dechter, E., 2014. The changing roles of education and ability in wage determination. J. Labor Econ. 32 (4), 685–710.
Davidson, K., 2013. How Privilege Rules over School Funding. The Age pp. 21, April 29.
Ferrari, J., 2013. Billions Fail to Stop Slide in Schools: Students Slump in World Rankings. The Australian December 4.
Hardy, K., 2016. PISA Results show Further Decline in Australia's Education Rankings. The Sydney Morning Herald December 6.
Heath, P., 2013. Sputnik Moment Looms in Australian Education. Sydney Morning Herald December 2.
Hill, H.C., Rowan, B., Ball, D.L., 2005. Effects of teachers' mathematical knowledge for teaching on student achievement. Am. Educ. Res. J. 42 (2), 371–406.
Lavy, V., 2015. Do differences in schools' instruction time explain international achievement gaps? Evidence from developed and developing countries. Econ. J. 125, F397–F424.
Martyn-Jones, L., 2016. Australia's Slide Down PISA Global Academic Rankings Reflects a Stratified Education System. The Courier Mail December 18.
Montt, G., 2011. PISA in Focus: Private Schools: Who Benefits? OECD, Paris, France (No. 7).
Morsy, L., Gulson, K., Clarke, M., 2014. Democracy,'sector-blindness' and the delegitimation of dissent in neoliberal education policy: a response to Discourse 34 (2), May 2013. Discourse: Stud. Cult. Polit. Educ. 35 (3), 444–461.
Munro, K., 2016. Why Is Australia's Education System Going Backwards? The Sydney Morning Herald December 9.
OECD, 2005–2014. Education at a Glance 2005–2014: OECD Indicators, OECD Publishing, Paris, France. doi:10.1787/eag-2005-2014-en.
OECD, 2015. Education at a Glance 2015: OECD Indicators. OECD Publishing, Paris, France. http://dx.doi.org/10.1787/eag-2015-en.
OECD, 2016. PISA 2015 Results: Excellence and Equity in Education, vol. I OECD Publishing, Paris, France.
Office of the Chief Scientist, 2014. Science, Technology, Engineering and Mathematics: Australia's Future. Australian Government, Canberra, Australia.
Orfield, G., Frankenberg, E., 2013. Educational Delusions?: Why Choice can Deepen Inequality and How to Make Schools Fair. University of California Press, Oakland, CA.
Perry, L.B., McConney, A., 2010. Does the SES of the school matter? An examination of socioeconomic status and student achievement using PISA 2003. Teach. Coll. Rec. 112 (4), 1137–1162.
Piccoli, A., 2014. Resting on Laurels is No Option as Poorer Nations Improve Education Systems. Sydney Morning Herald January 28.
Preiss, B., Butt, C., 2013. Maths Results a Concern in PISA Schools Study. Sydney Morning Herald December 3.
Rivkin, S.G., Schiman, J.C., 2015. Instruction time, classroom quality, and academic achievement. Econ. J. 215, F425–F448.
Thomson, S., De Bortoli, L., 2008. Exploring Scientific Literacy: How Australia Measures up. The PISA 2006 Survey of Students' Scientific, Reading and Mathematical Literacy Skills. ACER.
Tienken, C.H., 2008. Rankings of international achievement test performance and economic strength: correlation or conjecture? Int. J. Educ. Policy Leadersh. 3 (4), 1–15.
Tovey, J., Patty, A., 2013. OECD Report Finds Australian Students Falling Behind. Sydney Morning Herald December 4.
von Davier, M., Gonzalez, E., Mislevy, R., 2009. What ar plausible values and why are they useful? IERI Monograph Series: Issues and Methodologies in Large Scale Assessments 2. pp. 9–36.
Weldon, P.R., 2015. The Teacher Workforce in Australia: Supply, Demand, and Data Issues. Australian Council for Educational Research, Camberwell, VIC (No. Policy Insights Issue 2).