CESifo WORKING PAPERS
10831
2023
December 2023

Autonomous Schools, Achievement, and Segregation

Natalie Irmert, Jan Bietenbeck, Linn Mattisson, Felix Weinhardt

CESifo

Impressum:

CESifo Working Papers
ISSN 2364-1428 (electronic version)
Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH
The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute
Poschingerstr. 5, 81679 Munich, Germany
Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de
Editor: Clemens Fuest
https://www.cesifo.org/en/wp
An electronic version of the paper may be downloaded
· from the SSRN website: www.SSRN.com
· from the RePEc website: www.RePEc.org
· from the CESifo website: https://www.cesifo.org/en/wp

CESifo *Working Paper No. 10831*

Autonomous Schools, Achievement, and Segregation

Abstract

We study whether autonomous schools, which are publicly funded but can operate more independently than government-run schools, affect student achievement and school segregation across 15 countries over 16 years. Our triple-differences regressions exploit between-grade variation in the share of students attending autonomous schools within a given country and year. While autonomous schools do not affect overall achievement, effects are positive for high-socioeconomic status students and negative for immigrants. Impacts on segregation mirror these findings, with evidence of increased segregation by socioeconomic and immigrant status. Rather than creating "a rising tide that lifts all boats," autonomous schools increase inequality.

JEL-Codes: I210, I240, J150.

Keywords: autonomous schools, student achievement, school segregation.

Natalie Irmert
Lund University / Sweden
natalie.irmert@nek.lu.se

Jan Bietenbeck
Lund University / Sweden
jan.bietenbeck@nek.lu.se

Linn Mattisson
Socialstyrelsen
linn.mattisson@nek.lu.se

Felix Weinhardt
European University Viadrina
Frankfurt (Oder) / Germany
fweinhardt@diw.de

December 6, 2023
We thank Olmo Silva, Ludger Woessmann, and audiences at the spring 2023 Copenhagen Education Network Workshop and AEDE 2023 for helpful comments. We are grateful for funding from the Jan Wallanders och Tom Hedelius stiftelse samt Tore Browaldhs stiftelse. Jan Bietenbeck gratefully acknowledges the hospitality of the University of Duisburg-Essen while working on this paper.

1 Introduction

In the past few decades, many countries have enacted education reforms that have led to the establishment of autonomous schools, which are publicly funded but can operate more independently than government-run schools. Examples of such schools include academies in England, church schools in Hungary, free schools in Sweden, and charter schools in the United States. The central theoretical motivation for establishing these schools is the notion that there are competition-related welfare gains in the school sector: autonomous schools increase choice and thus competition for students who can vote with their feet (Tiebout 1956, Hoxby 2000). This creates an incentive for all schools to boost their productivity, which could lead to "a rising tide that lifts all boats" (Hoxby 2003). In practice, the rise of autonomous schools has sparked an intense academic and public debate, which primarily centers on their impacts on student achievement and school segregation.[1]

In this paper, we provide a comprehensive assessment of the effects of autonomous schools on these outcomes. Leveraging data from 15 countries over 16 years, we offer the broadest scope of analysis to date. Our findings paint a rather sobering picture: while autonomous schools do not raise overall achievement, they amplify inequality. Specifically, there are positive effects on the achievement of high-socioeconomic status and native students, contrasted with negative effects on low-socioeconomic status and immigrant students. Moreover, autonomous schools increase school segregation along these same two dimensions of student background. We conclude that competition-induced system-wide positive effects remain elusive at the international level.

To reach this conclusion, we assemble data on the prevalence of autonomous schools from the OECD's annual *Education At a Glance* reports. The data capture the share of students in a country who attend autonomous schools, separately for primary and lower secondary education. To measure achievement and segregation, we use data from five waves of the Trends in International Mathematics and Science Study (TIMSS), an international assessment of students' math and science knowledge. The assessment covers both fourth grade, which we link to the prevalence of autonomous schools in primary education, and eighth grade, which we link to the prevalence in lower secondary education. The linked data span the years 2003 to 2019 and contain individual-level information on achievement for 484,526 students. We add to this four measures of segregation by socioeconomic status (SES) and immigrant status at the country-year-grade level, which we compute using information gathered via the TIMSS student questionnaire and which we describe in more detail below.

Identifying the causal effects of autonomous schools in an international setting is difficult because countries and their school systems differ in many unobserved ways. We overcome this challenge using a novel (in the international setting) triple-differences re-

[1] We review the related literature on the impacts of autonomous schools below.

search design that leverages between-grade variation in the share of students attending autonomous schools within a given country and year. Our regressions account for all country-year-specific shocks, grade-year-specific shocks, and time-invariant country-grade differences that could potentially confound the effects of interest. Importantly, this means that we non-parametrically control for any grade-unspecific changes to a country's education system happening during our study period. The resulting estimates capture the causal country-wide impacts of autonomous schools.

The results reveal that autonomous schools do not affect overall math achievement and have at most a small negative effect on overall science achievement. However, these estimates mask important differences by student background, with consistently more positive impacts for high-SES students and native students in both subjects. For example, we estimate that a 10 percentage point (p.p.) increase in the share of students attending autonomous schools raises math achievement by 0.02 standard deviations (SD) among high-SES students but lowers it by 0.04 SD among immigrant students. An implication of this heterogeneity is that existing achievement gaps by SES and immigrant status increase. Specifically, a 10 p.p. increase in the share of students attending autonomous schools widens the SES achievement gap by five percent and the gap between natives and immigrants by 14 percent.

Motivated by this heterogeneity in the effects on achievement, we construct four measures of class-level segregation for high-SES and immigrant students. First, we compute the variance ratio index, which captures the relative probability that a randomly chosen classmate of a minority student belongs to this same minority group. Second, we compute the dissimilarity index, which corresponds to the share of minority students that would have to change classes in order to ensure an equal representation across classes. We construct these measures separately by country, year, and grade, which allows us to use the same triple-differences design as in the analysis of achievement effects. We find that autonomous schools have a positive effect on segregation for high-SES and immigrant students. For example, we estimate that a 10 p.p. increase in the share of students attending autonomous schools causes segregation for high-SES students as captured by the variance ratio index to increase by 0.14 SD.

Taken together, our results show that autonomous schools increase inequality in a broad sense. Achievement gaps by SES and immigrant status rise substantially, and the physical separation of these groups increases due to more segregation. We conclude that so far, autonomous schools have not yet created a "rising tide that lifts all boats."

Our paper relates to the growing literature on the effect of autonomous schools on student achievement. This effect can materialize via two main channels: first, students who attend autonomous schools may benefit. Second, autonomous schools may put competitive pressure on government-run schools, affecting achievement there. One large strand of the literature focuses exclusively on the first channel, with mixed findings (e.g. Abdulkadiroğlu et al. 2011, Angrist et al. 2013, Dobbie & Fryer 2015, Eyles et al. 2017, Eyles & Machin 2019, Bertoni et al. 2023). Another, smaller strand examines the second, competitive-pressure channel, also with mixed results (e.g. Winters 2012, Figlio et al. 2021).[2] The different settings and results in this literature make it difficult to draw conclusions about the aggregate effect of autonomous schools on achievement.

A handful of studies address this problem by exploiting regional-level variation in the prevalence of autonomous schools to study aggregate effects. Gilraine et al. (2021) show that charter school entry in North Carolina improves math achievement at the market level. Using nationwide data, Chen & Harris (2023) find that charter schools improve overall market-level English Language Arts achievement, with no significant effect on math achievement. Using variation across municipalities, Böhlmark & Lindahl (2015) find that free schools boost aggregate student achievement in Sweden, whereas Hsieh & Urquiola (2006) find zero to negative effects of voucher schools in Chile. Finally, Hanushek et al. (2013) use cross-country variation in decision-making autonomy as reported by school principals and student achievement in the Programme for International Student Assessment. They find that autonomy boosts achievement in richer countries, but that it is detrimental in poorer countries.[3] We add to this literature by providing international evidence using an estimation strategy that controls for unobserved country-by-year shocks.

Our paper also adds to the much smaller literature on the effect of autonomous schools on segregation. It is most closely related to recent work by Monarrez et al. (2022), who show that charter schools modestly increase school segregation by race and ethnicity in the United States. The authors base their conclusions on credible estimates from a triple-differences model, which leverages variation in the share of students attending charter schools between locations, grades, and years. This is similar to the empirical strategy that this paper uses to study effects at the international level. In earlier research, Hsieh & Urquiola (2006) show that the rise of voucher schools in Chile during the 1980s increased student sorting, and Böhlmark et al. (2016) show that free school penetration is associated with segregation by SES and immigrant status in Sweden. In comparison to this existing literature on segregation, this study is the first to examine causal effect of autonomous schools at the international level.

Last but not least, our study is the first to implement a triple-difference design as employed at the regional level by Monarrez et al. (2022) to study education outcomes at the international level. With grade-specific data on education policies widely available, we anticipate that this identification strategy might be used in future cross-country studies of determinants of education.

[2] Cohodes & Parham (2021) provide an excellent overview of both strands of literature in the context of charter schools in the United States.

[3] In a related study, West & Woessmann (2010) find that private schools boost student achievement in an international setting.

2 Data and descriptive analysis

2.1 Data sources and variable definitions

We collect data on the prevalence of autonomous schools from the OECD's annual *Education at a Glance* reports for the years from 1999 to 2019. The reports provide internationally comparable indicators on education systems, including enrollment in different types of schools. The relevant indicator for our purposes is the share of students enrolled in government-dependent private schools, which are defined as schools that receive at least half of their funding from the government but are privately managed (OECD 2018). In practice, most of the government-dependent private schools in the countries we consider receive all or nearly all of their funding from the government (see Online Appendix B for details). Importantly for our identification strategy, the share of students attending these schools is reported separately for primary and lower secondary education.

To measure achievement and segregation, we use individual-level data from TIMSS, an international student assessment conducted every four years since 1995 by the International Association for the Evaluation of Educational Achievement. TIMSS uses a two-stage clustered sampling approach to select nationally representative samples of fourth- and eighth-grade students. In the first stage, schools are selected, and in the second stage, classes within these schools are randomly chosen. In these selected classes, all students take standardized tests in math and science and provide comprehensive background information through questionnaires. We link fourth-grade students to the prevalence of autonomous schools in primary education and eighth-grade students to the prevalence of autonomous schools in lower secondary education.

Our first main outcome is student achievement, measured using TIMSS math and science scores. These scores are comparable across TIMSS waves and are reported as five plausible values, which are random draws from a posterior distribution.[4] To obtain unbiased coefficient estimates, we use the average of these five plausible values for each subject. For ease of interpretation, we standardize these averages to have a mean of zero and a standard deviation of one.

Our second main outcome is segregation by SES and immigrant status. We focus on these two dimensions because of our own findings indicating differences in the impact of autonomous schools on achievement by SES and immigrant status and because of the distinct school choices along these dimensions documented in prior research (e.g. Böhlmark et al. 2016, Bertoni et al. 2020). We define SES based on the number of books in a student's home, with more than 100 books indicating high SES.[5] We determine immigrant status

[4]Plausible values are used in most international student assessments, see Jerrim et al. (2017).

[5]Books at home have been widely used as a proxy for SES in previous research, see for example Wößmann (2003). We would like to use parental education as an additional measure of SES, but unfortunately this information is only available for eighth-grade students. Since our regressions rely on between-grade variation, we need to use a measure that is available for both fourth- and eighth-grade students.

using information on a student's country of birth provided in the student questionnaire.

We exploit TIMSS' sampling of entire classes within schools to measure segregation at the class level. This is especially advantageous in systems in which students are tracked within schools, as it allows us to capture both between- and within-school segregation. We calculate two measures of segregation of high-SES students and immigrant students: the variance ratio index and the dissimilarity index. The variance ratio index captures the relative probability that a randomly selected classmate of a minority student belongs to the same minority group, while the dissimilarity index corresponds to the share of minority students that would have to change classes in order to ensure equal representation. Both indices account for the overall student composition in a country, which makes them comparable across countries and time.[6] They range from 0 to 100, with higher values indicating greater segregation levels. We calculate the indices separately for each country, grade, and year.

2.2 Sample selection, summary statistics, and trends in autonomous school attendance

Our identification strategy exploits within-country between-grade variation in the share of students attending autonomous schools over time. Therefore, we select all countries that participated in at least two waves of TIMSS with both fourth- and eighth-grade students, and for which data on the share of students attending autonomous schools are available for these waves. 15 countries fulfill these requirements: Australia, Chile, Finland, Hungary, Ireland, Italy, Japan, South Korea, Lithuania, Norway, Russia, Slovenia, Sweden, Turkey, and the United Kingdom. The sample spans the years 2003 to 2019 and includes a total of 484,526 students distributed across 106 country-grade-year cells.

Table 1 shows summary statistics for this sample. When computing these statistics, we use weights that adjust for individual sampling probabilities and that give equal weight to all country-grade-year cells. In our sample, six percent of students are classified as immigrants, while roughly one third have more than 100 books at home, indicating high SES. Across all years, about ten percent of students attend autonomous schools. The bottom of the table shows means and standard deviations for the segregation indices, which are measured at the country-grade-year level.[7] The means of these indices are broadly similar to the corresponding indices measuring school segregation of minority students at the level of metropolitan areas in the United States (Monarrez et al. 2022).

Figure 1 visualizes the evolution of autonomous school attendance from 1999 to 2019, separately by country and grade level. Several countries experienced significant increases, most notably the United Kingdom, where lower-secondary autonomous school enrollment surged from zero to over 60 percent. Chile, Hungary, and Sweden also saw substantial

[6] Online Appendix B provides additional details on the calculation of the segregation indices.

[7] There are only 80, rather than 106, observations for the indices measuring segregation of immigrants because no information on country of birth was collected in fourth grade in TIMSS 2011.

growth, with smaller but noteworthy increases in Australia, Finland, Norway, and Slovenia. Importantly, these trends varied between grade levels: with the exception of Chile and Slovenia, the increase of autonomous school enrollment in lower secondary school outpaced the rise in primary school in all countries. Finally, six countries in our sample had no autonomous schools at either grade level during the entire sample period.

Online Appendix Figures A.1 to A.6 depict the corresponding trends in our outcome variables. Regarding achievement, there is no clear overall trend among the 15 countries, with some showing increasing trends and others displaying decreasing trends. Similarly, trends in segregation remain relatively stable during this time period for most countries, with a few exceptions. In the analysis below, we explore whether these trends can be attributed to changes in autonomous school enrollment.

3 Empirical strategy

We estimate triple-differences specifications that leverage between-grade variation in the share of students attending autonomous schools within a given country and year. Intuitively, we ask whether an increase in autonomous-school enrollment at the secondary level, relative to the primary level, results in corresponding changes in the outcome variable between the two levels. When estimating effects on achievement, we use student-level data and the following specification:

$$A_{icgt} = \alpha^a + \beta^a ATS_{cgt} + X'_{icgt}\gamma^a + \delta^a_{cg} + \lambda^a_{ct} + \theta^a_{gt} + \varepsilon^a_{icgt}, \tag{1}$$

where i denotes students, c denotes countries, g denotes grades, and t denotes years. A_{icgt} is achievement in math or science and ATS_{cgt} is the share of students enrolled in autonomous schools. X_{icgt} is a vector containing the student characteristics listed in Table 1, which we interact with country dummies. δ_{cg} is a vector of country-grade fixed effects, λ_{ct} is a vector of country-year fixed effects, and θ_{gt} is a vector of grade-year fixed effects. When estimating this specification, we use weights that adjust for individual sampling probabilities and that give equal weight to all country-grade-year cells. We cluster standard errors at the country-grade level.

In contrast to achievement, segregation is a system-level outcome. Therefore, when estimating effects on segregation, we use data at the country-grade-year level and the following specification:

$$S_{cgt} = \alpha^s + \beta^s ATS_{cgt} + \delta^s_{cg} + \lambda^s_{ct} + \theta^s_{gt} + \varepsilon^s_{icgt}, \tag{2}$$

where S_{cgt} is the variance ratio index or the dissimilarity index measuring segregation of either high-SES students or immigrant students and the other variables and parameters are defined in a manner equivalent to those in Equation 1.

The identification of the effect of autonomous schools in Equations 1 and 2 relies on a comprehensive set of fixed effects. Most importantly, by using between-grade variation, we are able to include country-year fixed effects that account for all grade-unspecific changes to the education system over time. This is an improvement over previous studies on international differences in education outcomes, which have included country and year fixed effects but which have not been able to account for country-specific changes that could be correlated with the outcome and the treatment (e.g. Brunello & Rocco 2013, Hanushek et al. 2013, Bergbauer et al. 2021).

4 Results

4.1 Effect on achievement: overall effect

Table 2 presents estimates of the aggregate effect of autonomous schools on math and science achievement. Columns 1 and 3 show results from regressions that omit student controls and reveal at most small impacts: a 10 p.p. increase in the share of students attending autonomous schools is estimated to raise math achievement by 0.007 SD and decrease science achievement by 0.009 SD. Neither of these estimates is statistically significant at conventional levels. Columns 2 and 4 add student controls to these regressions, which makes the coefficients slightly more negative: a 10 p.p. increase in the share of students attending autonomous schools is now estimated to decrease math achievement by an insignificant 0.003 SD and science achievement by a marginally significant 0.017 SD. Overall, the takeaway from these results is that the aggregate effect of autonomous schools on achievement appears to be small and, if anything, negative.

We test the robustness of this finding with respect to sample selection choices. In Online Appendix Table A.1, we initially exclude the six countries that never had autonomous schools from our sample. As would be expected, this leaves the estimates largely unchanged. We then proceed to further exclude each of the remaining nine countries from the sample one by one. This again does not change the estimates much, with one exception: when we exclude England, the coefficients become more positive and much larger, but also less precisely estimated. This is not entirely surprising. Figure 1 shows that England contributes substantially to the between-grade variation in the share of students attending autonomous schools over time. This is what the triple-differences specification uses to estimate the effect. Moreover, the fact that the estimates become more positive when England is excluded is in line with the finding in Eyles et al. (2017) that attending a primary school academy has a small negative effect on test scores in this country. We therefore conclude that the main findings stand.

How do these estimates compare to those in the previous literature? Chen & Harris (2023) use nationwide data from the United States and find that a 10 p.p. increase in the charter market share raises English Language Arts achievement by 0.01 SD, with less robust results for math achievement. Gilraine et al. (2021) find that students exposed to charter school entry in North Carolina experience an average improvement in math achievement of 0.02 SD relative to untreated students. In the context of Chile, Hsieh & Urquiola (2006) find that if anything, voucher school enrollment has a small negative effect on aggregate math achievement. Böhlmark & Lindahl (2015) find that a 10 p.p. increase in the share of students attending free schools in Sweden is associated with 1.7 percentile rank higher math and English achievement. In sum, the previous literature has found small effects of autonomous schools on achievement, which range from negative to positive. Our results are fully consistent with these findings but provide a more general assessment of this impact using data from 15 countries.

4.2 Effect on achievement: heterogeneity

In Table 3, we examine whether the effect of autonomous schools on achievement differs by student background. Columns 1 and 2 split the sample by SES. In these specifications, a 10 p.p. increase in the share of autonomous schools is estimated to raise high-SES students' achievement by a statistically significant 0.022 SD in math, with a smaller and insignificant 0.008 SD increase in science. In contrast, the effect for low-SES students is negative in both subjects, with a notable 0.027 SD decline in science scores. Columns 3 and 4 reveal similar differences by immigrant status, with consistently more positive estimates for natives than for immigrants in both subjects.

The bottom rows of Panels A and B show estimates of the implied change in the achievement gap between high- and low-SES students and native and immigrant students. In three out of four cases, these changes are economically meaningful and highly statistically significant. For example, a 10 p.p. increase in the share of students attending autonomous schools raises the gap in math achievement between high- and low-SES students by 0.033 SD, which corresponds to five percent of the sample mean. Similarly, the gap in math achievement between native and immigrant students increases by 0.050 SD, which corresponds to 14 percent of the sample mean. In the conclusion, we use these estimates to predict future earnings differences between groups based on estimates of the relation between test scores and earnings in the previous literature.

We move on to test the robustness of these findings. First, note that the samples in columns 3 and 4 of Table 3 exclude observations from TIMSS 2011 because information on immigrant status is not available for both grades in that wave. Online Appendix Table A.2 confirms that the overall effects in the sample excluding TIMSS 2011 are very similar to those shown in Table 2. Second, we test whether our results are sensitive to the exact definition of the SES variable, since our definition of high SES as having more than 100 books at home is somewhat arbitrary. We examine heterogeneity using two different definitions of high SES based on the books-at-home variable: having more than

200 books at home, and having more books at home than the country median value. Online Appendix Table A.3 shows that our results are robust to these changes, and that the heterogeneity by SES is often even more pronounced in these regressions.

4.3 Effects on segregation

Table 4 shows estimates of the effect of autonomous schools on segregation. Columns 1 and 2 focus on segregation by SES and reveal positive effects: a 10 p.p. increase in the share of students attending autonomous schools is estimated to raise the variance ratio index by 0.62 (about 0.14 SD) and the dissimilarity index by 0.89 (about 0.15 SD). Column 3 similarly shows a positive effect on segregation by immigrant status, with a coefficient of 0.043 (about 0.12 SD for a 10 p.p. rise in the share) for the variance ratio index. In contrast, the estimated effect on the dissimilarity index in column 4 is close to zero and insignificant. Overall, these results show that there is a non-negligible effect of autonomous schools on segregation.

We again test the robustness of these findings. Specifically, in Online Appendix Table A.4, we first drop all countries which never had autonomous schools in our sample period, and then drop the remaining countries from the sample one by one. Overall, the results stand. When excluding England, the variance radio index for immigrant students shows a larger positive effect but at lower precision. In contrast, when removing Hungary, the estimates for the variance-ration index and the dissimilarity index for high-SES students are larger and highly statistically significant. Across all specifications in the table, all estimates are positive, confirming our main findings.

These results align well with those from the small existing literature that studies how autonomous schools affect segregation. Monarrez et al. (2022) find that charter schools in the United States modestly increase school segregation for Black, Hispanic, Asian, and White students. Their headline finding is that a 10 p.p. increase in the share of students attending charters leads to about a 0.9 increase in the variance ratio index for minority students. This corresponds to about 0.07 SD, which is slightly more than half the size (in terms of SD) of our estimates. Notice that both Monarrez et al. (2022) and we leverage variation across grades and regions in a triple-differences setting. In a more descriptive study, Böhlmark et al. (2016) show that free school penetration is associated with segregation by SES and immigrant status in Sweden. Overall, our results add to this small literature by estimating effects on segregation at the international level.

5 Conclusions

We study whether autonomous schools, which are publicly funded but can operate more independently than government-run schools, affect student achievement and school segregation at the international level. Our empirical analysis uses individual-level data on student achievement in math and science from TIMSS 2003 to 2019, which we merge to data on the share of students attending autonomous schools by country and grade. Based on detailed information on students' background and class composition, we compute four measures of segregation by SES and immigrant status. To identify the causal effects of autonomous schools, we estimate novel (in the international context) triple-differences specifications, which exploit variation in the share of students attending autonomous schools between grades within a given country and year.

Our results show little evidence of any overall effect of autonomous schools on achievement. However, this null result masks important heterogeneity: high-SES students consistently benefit from autonomous schools, while immigrant students see their achievement decrease. This implies that rather than leading to "a rising tide that lifts all boats," autonomous schools increase existing achievement gaps by SES and immigrant status. Finally, in line with this finding, we document that autonomous schools lead to increased segregation by SES and immigrant status.

How important are these effects in economic terms? To gauge this, we now use the estimates from Chetty et al. (2014*a*,*b*) to provide a quantification in terms of later wages. Chetty et al. (2014*a*) show that a one SD better teacher (in terms of value added) increases single-grade test scores by 0.14 SD and Chetty et al. (2014*b*) show that this relates to US$ 39,000 higher cumulative individual lifetime earnings. Using our estimated effect on the native-immigrant gap in math, this would imply that a 10 p.p. increase in the share of students attending autonomous schools increases the corresponding earnings gap by $(0.05/0.14) * \$39,000 = \$13,929$. The equivalent effect on the SES earnings gap would be $(0.033/0.14) * \$39,000 = \$9,193$. This quantification exercise necessarily relies on a number of strong assumptions, but it suggests that autonomous schools lead to non-negligible increases in future earnings inequality.

References

Abdulkadiroğlu, A., Angrist, J. D., Dynarski, S. M., Kane, T. J. & Pathak, P. A. (2011), 'Accountability and Flexibility in Public Schools: Evidence from Boston's Charters and Pilots', *The Quarterly Journal of Economics* **126**(2), 699–748.

Angrist, J. D., Pathak, P. A. & Walters, C. R. (2013), 'Explaining Charter School Effectiveness', *American Economic Journal: Applied Economics* **5**(4), 1–27.

Bergbauer, A. B., Hanushek, E. A. & Woessmann, L. (2021), 'Testing', *Journal of Human Resources* (forthcoming).

Bertoni, M., Gibbons, S. & Silva, O. (2020), 'School Choice During a Period of Radical School Reform. Evidence from Academy Conversion in England', *Economic Policy* **35**(104), 739–795.

Bertoni, M., Heller-Sahlgren, G. & Silva, O. (2023), 'Free to improve? The Impact of Free School Attendance in England', CEP Discussion Paper 1946, Centre for Economic Performance, LSE.

Böhlmark, A., Holmlund, H. & Lindahl, M. (2016), 'Parental Choice, Neighbourhood Segregation or Cream Skimming? An Analysis of School Segregation after a Generalized Choice Reform', *Journal of Population Economics* **29**(4), 1155–1190.

Böhlmark, A. & Lindahl, M. (2015), 'Independent Schools and Long-Run Educational Outcomes: Evidence from Sweden's Large-Scale Voucher Reform', *Economica* **82**(327), 508–551.

Brunello, G. & Rocco, L. (2013), 'The Effect of Immigration on the School Performance of Natives: Cross Country Evidence Using PISA Test Scores', *Economics of Education Review* **32**, 234–246.

Chen, F. & Harris, D. N. (2023), 'The Market-Level Effects of Charter Schools on Student Outcomes: A National Analysis of School Districts', *Journal of Public Economics* **228**, 105015.

Chetty, R., Friedman, J. N. & Rockoff, J. E. (2014*a*), 'Measuring the Impacts of Teachers I: Evaluating Bias in Teacher Value-Added Estimates', *American Economic Review* **104**(9), 2593–2632.

Chetty, R., Friedman, J. N. & Rockoff, J. E. (2014*b*), 'Measuring the Impacts of Teachers II: Teacher Value-Added and Student Outcomes in Adulthood', *American Economic Review* **104**(9), 2633–2679.

Cohodes, S. R. & Parham, K. S. (2021), Charter Schools' Effectiveness, Mechanisms, and Competitive Influence, *in* 'Oxford Research Encyclopedia of Economics and Finance', Oxford University Press.

Dobbie, W. & Fryer, R. G. (2015), 'The Medium-Term Impacts of High-Achieving Charter Schools', *Journal of Political Economy* **123**(5), 985–1037.

Duncan, O. D. & Duncan, B. (1955), 'A Methodological Analysis of Segregation Indexes', *American Sociological Review* **20**(2), 210–217.

Eyles, A. & Machin, S. (2019), 'The Introduction of Academy Schools to England's Education', *Journal of the European Economic Association* **17**(4), 1107–1146.

Eyles, A., Machin, S. & McNally, S. (2017), 'Unexpected School Reform: Academisation of Primary Schools in England', *Journal of Public Economics* **155**, 108–121.

Figlio, D. N., Hart, C. M. & Karbownik, K. (2021), Competitive Effects of Charter Schools, mimeo.

Gilraine, M., Petronijevic, U. & Singleton, J. D. (2021), 'Horizontal Differentiation and the Policy Effect of Charter Schools', *American Economic Journal: Economic Policy* **13**(3), 239–276.

Graham, B. S. (2018), 'Identifying and Estimating Neighborhood Effects', *Journal of Economic Literature* **56**(2), 450–500.

Hanushek, E. A., Link, S. & Woessmann, L. (2013), 'Does School Autonomy Make Sense Everywhere? Panel Estimates from PISA', *Journal of Development Economics* **104**, 212–232.

Hoxby, C. M. (2000), 'Does Competition among Public Schools Benefit Students and Taxpayers?', *American Economic Review* **90**(5), 1209–1238.

Hoxby, C. M. (2003), School Choice and school Productivity. Could School Choice be a Tide that Lifts all Boats?, *in* 'The economics of school choice', University of Chicago Press, pp. 287–342.

Hsieh, C.-T. & Urquiola, M. (2006), 'The Effects of Generalized School Choice on Achievement and Stratification: Evidence from Chile's Voucher Program', *Journal of Public Economics* **90**(8-9), 1477–1503.

Jerrim, J., Lopez-Agudo, L. A., Marcenaro-Gutierrez, O. D. & Shure, N. (2017), 'What Happens When Econometrics and Psychometrics Collide? An Example Using the PISA Data', *Economics of Education Review* **61**, 51–58.

Massey, D. S. & Denton, N. A. (1988), 'The Dimensions of Residential Segregation', *Social Forces* **67**(2), 281–315.

Monarrez, T., Kisida, B. & Chingos, M. (2022), 'The Effect of Charter Schools on School Segregation', *American Economic Journal: Economic Policy* **14**(1), 301–40.

OECD (2018), 'OECD Handbook for Internationally Comparative Education Statistics 2018 - Concepts, Standards, Definitions and Classifications', *OECD Publishing* .

Schneeweis, N. (2011), 'Educational Institutions and the Integration of Migrants', *Journal of Population Economics* **24**(4), 1281–1308.

Tiebout, C. M. (1956), 'A Pure Theory of Local Expenditures', *Journal of Political Economy* **64**, 416–416.

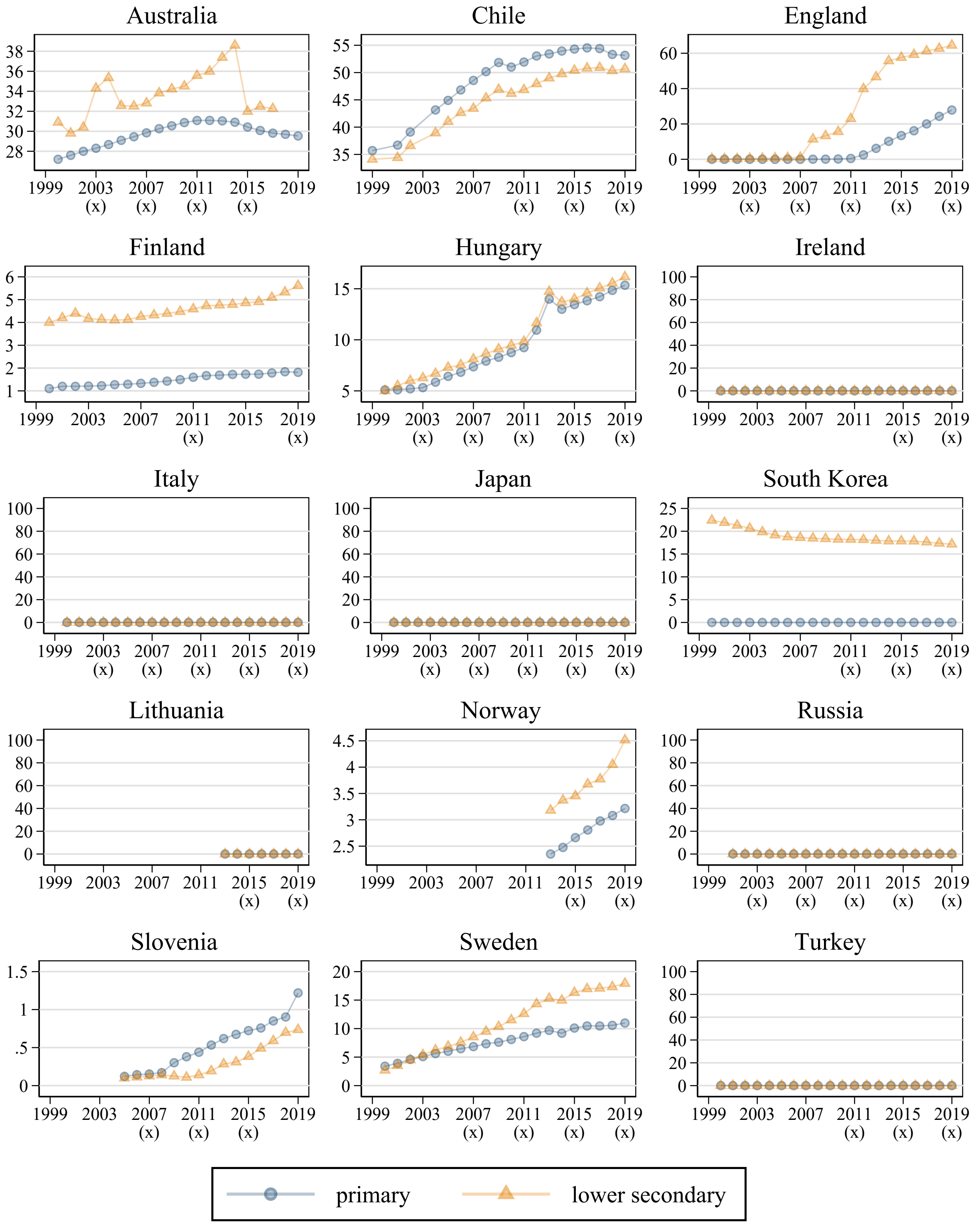
West, M. R. & Woessmann, L. (2010), 'Every Catholic Child in a Catholic School: Historical Resistance to State Schooling, Contemporary Private Competition and Student Achievement Across Countries', *The Economic Journal* **120**(546), F229–F255.

Winters, M. A. (2012), 'Measuring the Effect of Charter Schools on Public School Student Achievement in an Urban Environment: Evidence from New York City', *Economics of Education Review* **31**(2), 293–301.

Wößmann, L. (2003), 'Schooling Resources, Educational Institutions and Student Performance: the International Evidence', *Oxford Bulletin of Economics and Statistics* **65**(2), 117–170.

Figures and Tables

Figure 1: Trends in the share of students attending autonomous schools, by country and grade level



Notes: The figure shows trends in the share of students attending autonomous schools, separately by country and for primary and lower secondary education. Data for England are imputed from data for the United Kingdom, see Online Appendix B for details. (x) indicates years in which the country participated in TIMSS with both fourth and eighth grade; these are the years included in the analysis sample.

Table 1: Summary statistics

	Mean	SD	N
Student characteristics			
Female	0.49	0.50	484,423
Age	12.35	2.06	483,424
Immigrant	0.06	0.24	418,694
Books at home:			
11–25	0.24	0.43	476,495
26–100	0.31	0.46	476,495
101–200	0.17	0.37	476,495
more than 200	0.16	0.36	476,495
Autonomous schools			
Share autonomous	9.70	15.75	484,526
Student achievement			
Math score	0.00	1.00	484,526
Science score	0.00	1.00	484,526
Segregation (country-grade-year level)			
High SES: variance ratio index	14.49	4.46	106
High SES: dissimilarity index	33.92	5.93	106
Immigrant status: variance ratio index	9.48	3.71	80
Immigrant status: dissimilarity index	56.68	14.89	80

Notes: The table shows means and standard deviations and the number of students observed with each variable for the 484,526 students included in the analysis sample. Statistics are computed using weights that adjust for individual sampling probabilities and that give equal weight to all country-grade-year cells. Information on country of birth was not collected in fourth grade in TIMSS 2011, which explains the larger number of missing values for the immigrant variable. The omitted category for books at home is 0–10 books. The bottom four rows show statistics for segregation indices, which are measured at the level of 106 country-grade-year cells; the number of observations for the indices related to immigrant status is reduced because of the missing information on country of birth in 2011.

Table 2: Effect of autonomous schools on student achievement

	Math		Science	
	(1)	(2)	(3)	(4)
Share autonomous	0.0007	–0.0003	–0.0009	–0.0017*
	(0.0008)	(0.0007)	(0.0011)	(0.0009)
Observations	484,526	484,526	484,526	484,526
Student controls	No	Yes	No	Yes
Country-grade fixed effects	Yes	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes	Yes
Grade-year fixed effects	Yes	Yes	Yes	Yes

Notes: The table shows estimates of the effect of autonomous schools on student achievement in math and science. Student controls include age and dummies for female, books at home, and immigrant, all of which are interacted with country dummies. Regressions use weights that adjust for individual sampling probabilities and that give equal weight to all country-grade-year cells. Standard errors in parentheses are clustered at the country-grade level. * p<0.10, ** p<0.05, *** p<0.01.

Table 3: Effect of autonomous schools on student achievement, heterogeneity

	By SES		By immigrant status	
	High (1)	Low (2)	Native (3)	Immigrant (4)
Panel A: math achievement				
Share autonomous	0.0022***	–0.0010	0.0011*	–0.0039*
	(0.0006)	(0.0009)	(0.0006)	(0.0019)
Observations	159,262	317,233	325,955	21,705
Change in gap	0.0033***		0.0050***	
	(0.0007)		(0.0018)	
Panel B: science achievement				
Share autonomous	0.0008	–0.0027***	–0.0012	–0.0020
	(0.0010)	(0.0009)	(0.0009)	(0.0016)
Observations	159,262	317,233	325,955	21,705
Change in gap	0.0034***		0.0008	
	(0.0005)		(0.0012)	
Student controls	Yes	Yes	Yes	Yes
Country-grade fixed effects	Yes	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes	Yes
Grade-year fixed effects	Yes	Yes	Yes	Yes

Notes: The table shows estimates of the effect of autonomous schools on student achievement in math and science, separately by socioeconomic status and immigrant status. High (low) SES is defined as having more than 100 (at most 100) books at home. The combined sample sizes in columns 1-2 and columns 3-4 differ from those in Table 2 because of missing values on the SES and immigrant variables. Student controls include age and dummies for female, books at home (not in columns 1-2), and immigrant (not in columns 3-4), all of which are interacted with country dummies. The bottom rows in Panels A and B show the change in the achievement gap between groups, which is estimated using seemingly unrelated regression. Sample means of these gaps are: high-SES-low-SES math (science) gap: 0.5954 (0.6363); native-immigrant math (science) gap: 0.3590 (0.4526). Regressions use weights that adjust for individual sampling probabilities and that give equal weight to all country-grade-year cells. Standard errors in parentheses are clustered at the country-grade level. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table 4: Effect of autonomous schools on segregation

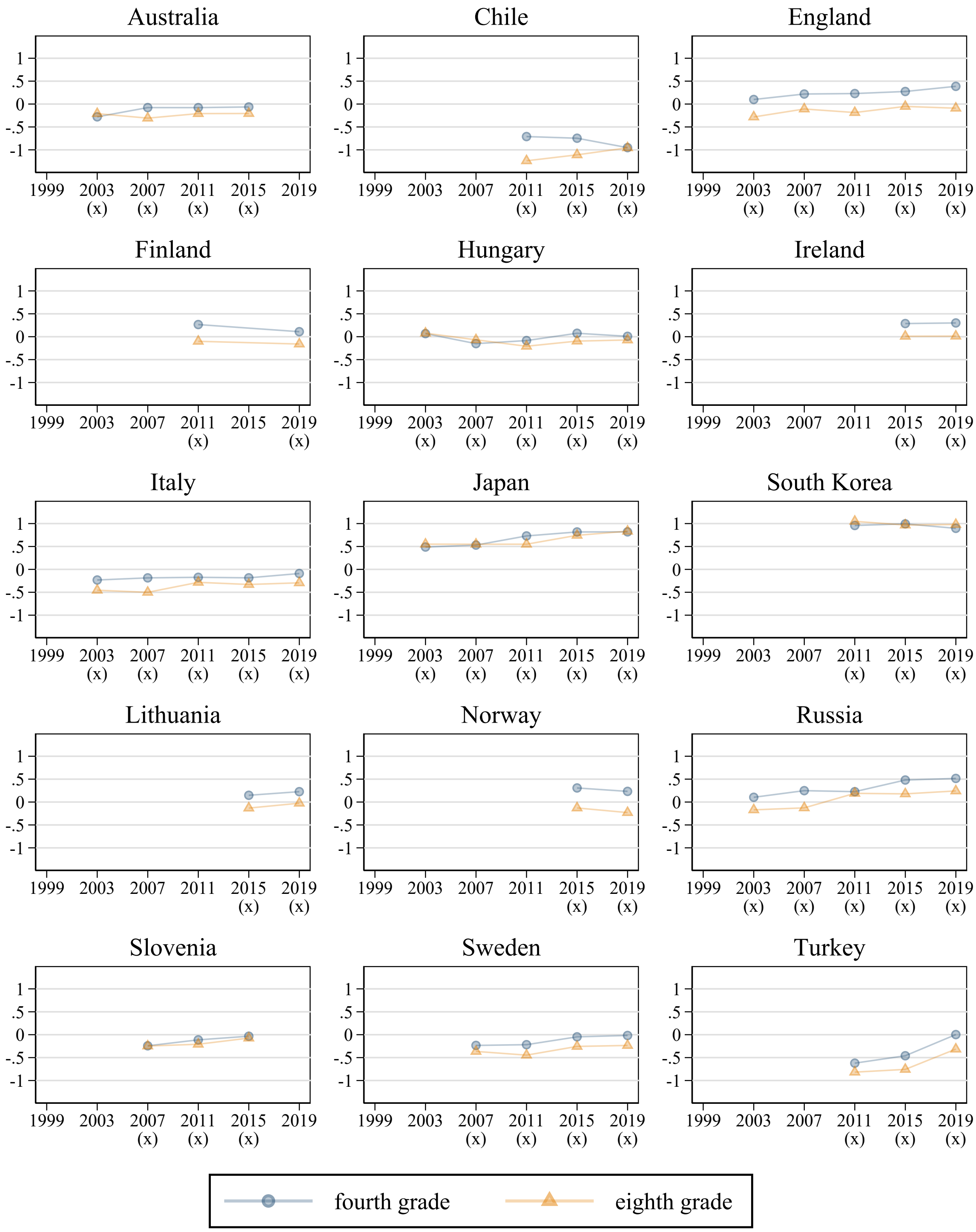
	By SES		By immigrant status	
	Variance ratio index	Dissimilarity index	Variance ratio index	Dissimilarity index
	(1)	(2)	(3)	(4)
Share autonomous	0.062**	0.089*	0.043*	0.004
	(0.030)	(0.046)	(0.025)	(0.062)
Observations	106	106	80	80
Country-grade fixed effects	Yes	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes	Yes
Grade-year fixed effects	Yes	Yes	Yes	Yes

Notes: The table shows estimates of the effect of autonomous schools on segregation. For this analysis, the data are collapsed at the country-grade-year level. The sample size is smaller in columns 3-4 because information on country of birth was not collected in fourth grade in TIMSS 2011. See text for details on how the four outcome measures of segregation are computed. Standard errors in parentheses are clustered at the country-grade level. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

– ONLINE APPENDIX –

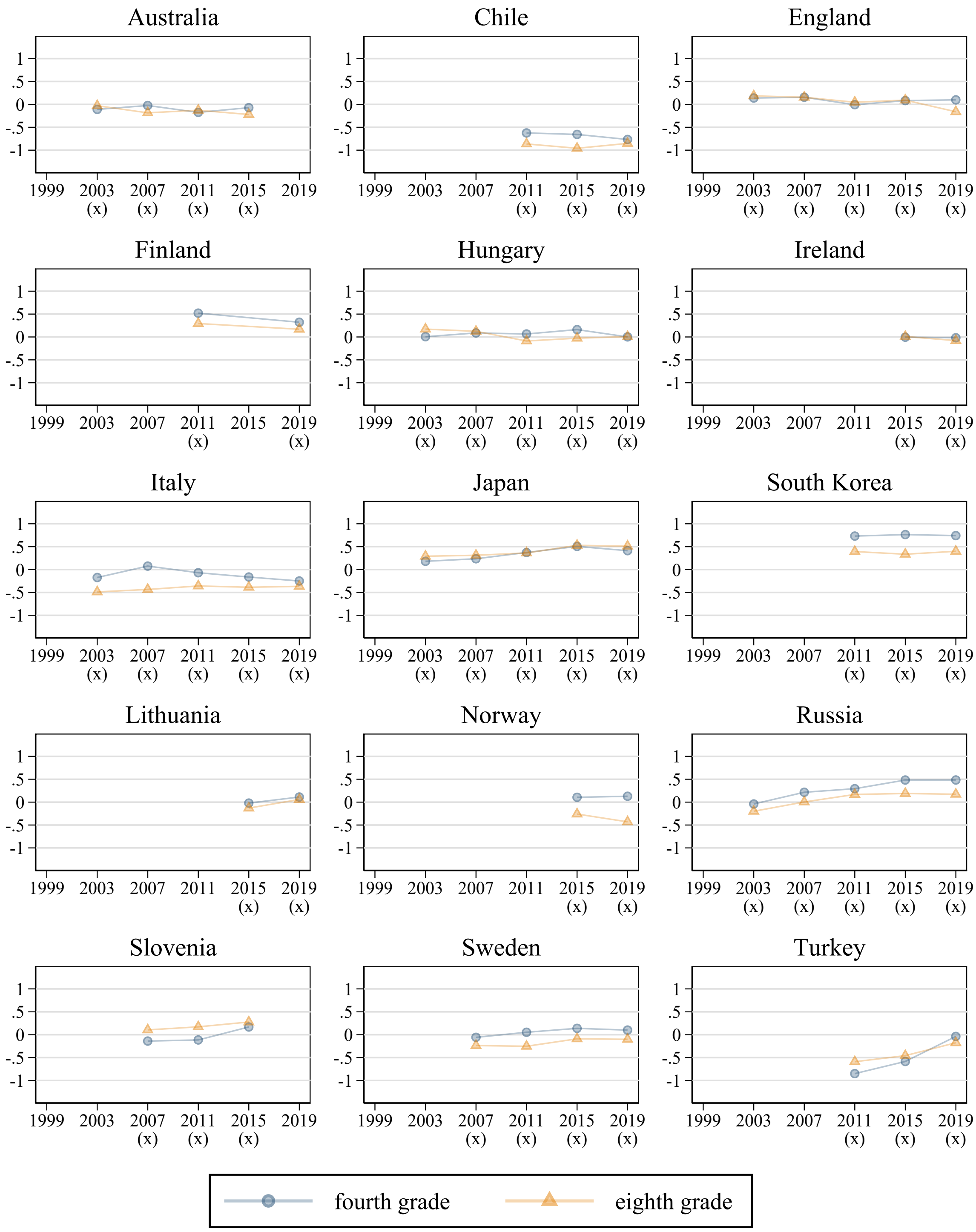
A Additional figures and tables

Online Appendix Figure A.1: Trends in math achievement, by country and grade level



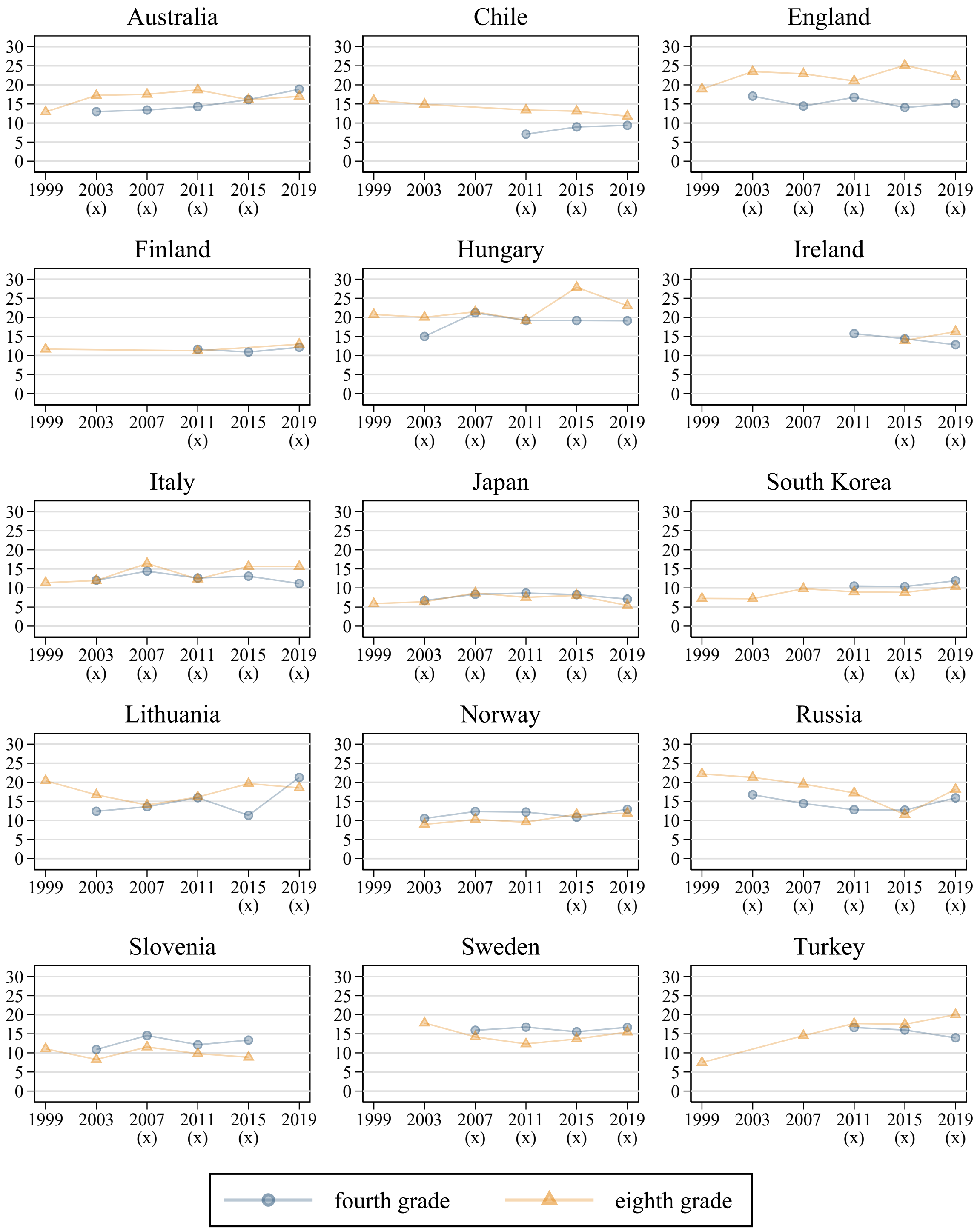
Notes: The figure shows trends in math achievement, separately by country and grade level. (x) indicates years included in the analysis sample.

Online Appendix Figure A.2: Trends in science achievement, by country and grade level



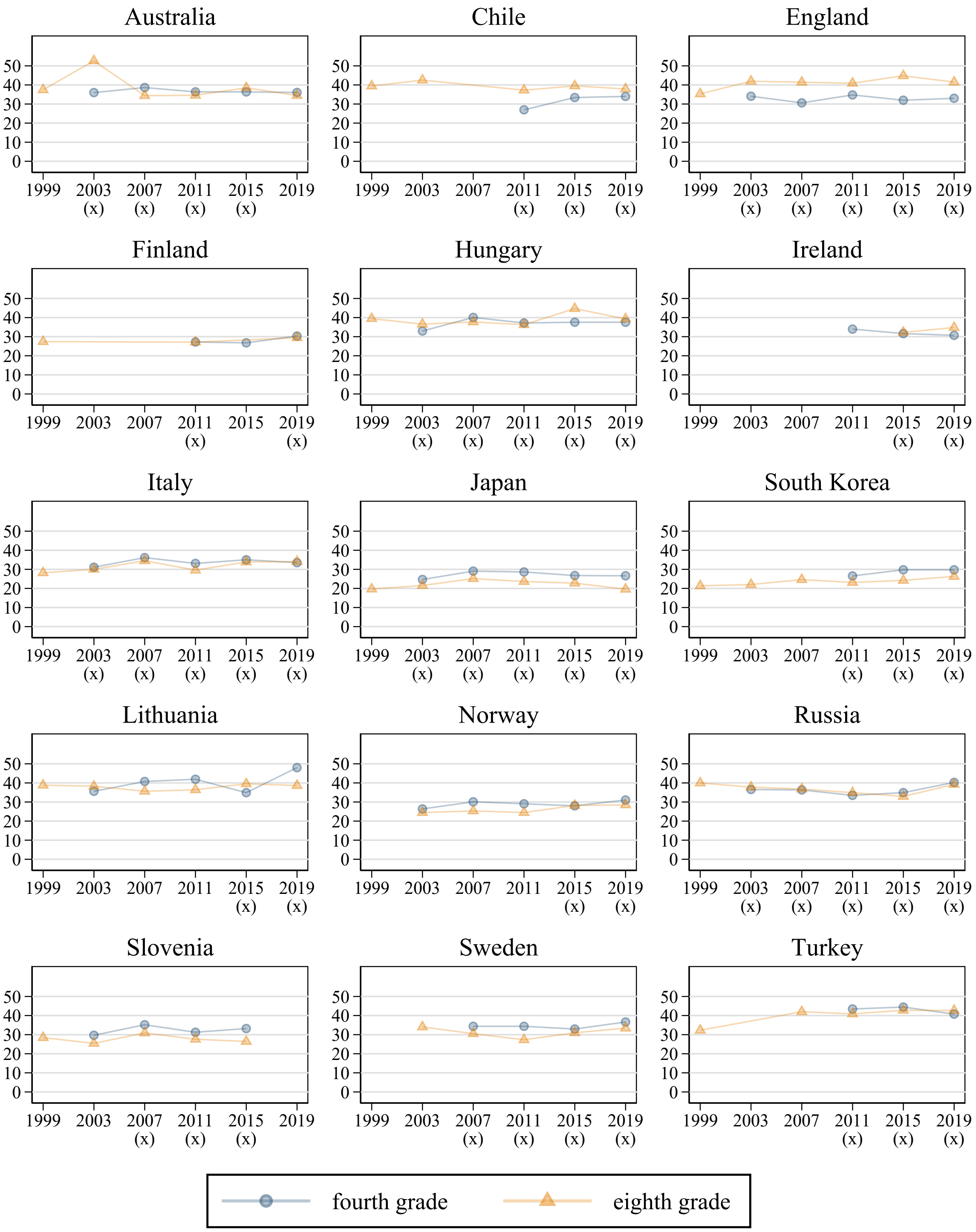
Notes: The figure shows trends in science achievement, separately by country and grade level. (x) indicates years included in the analysis sample.

Online Appendix Figure A.3: Trends in variance ratio index for high-SES students, by country and grade level



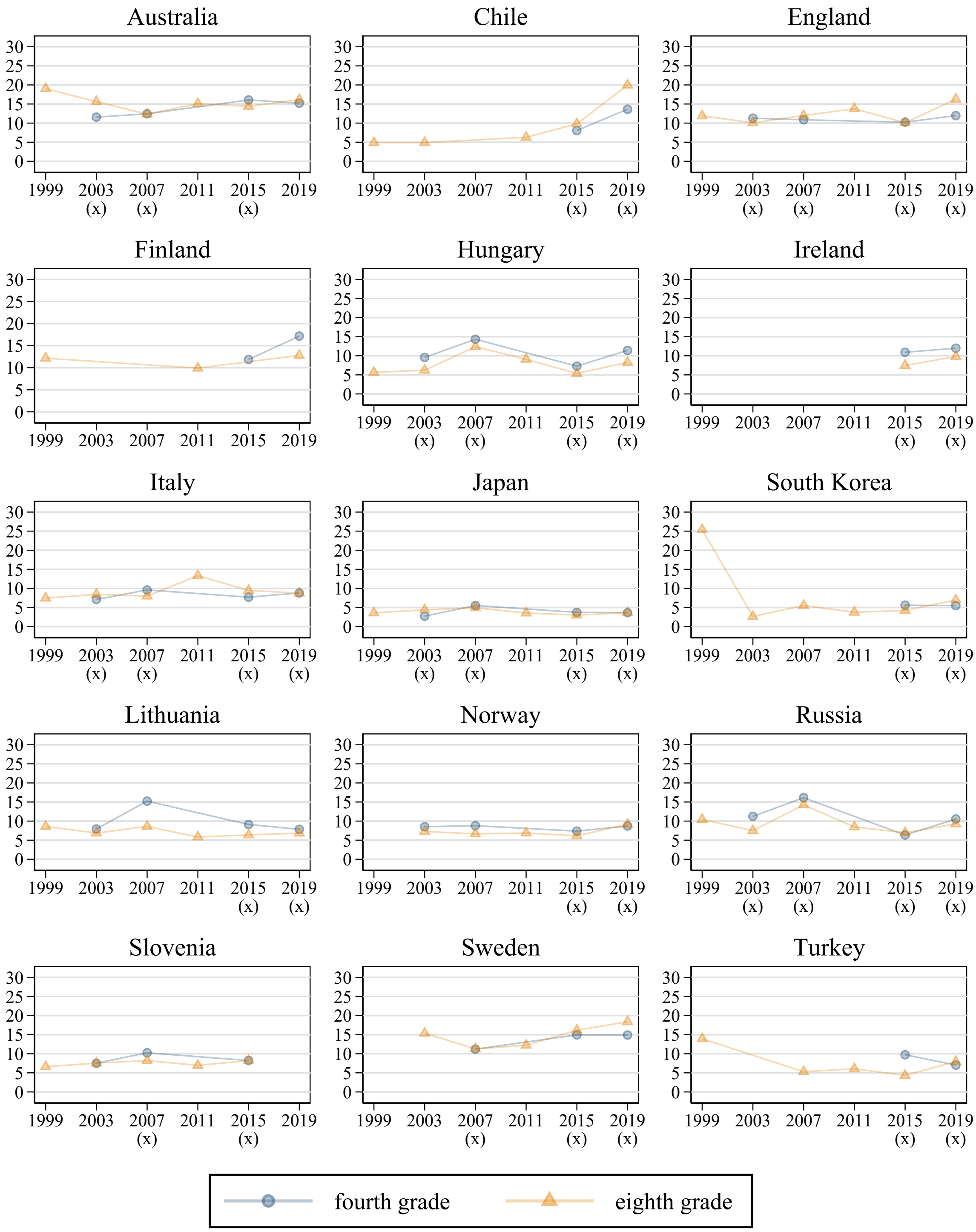
Notes: The figure shows trends in segregation of high-SES students, separately by country and grade level. Segregation is measured using the variance ratio index. (x) indicates years included in the analysis sample.

Online Appendix Figure A.4: Trends in dissimilarity index for high-SES students, by country and grade level



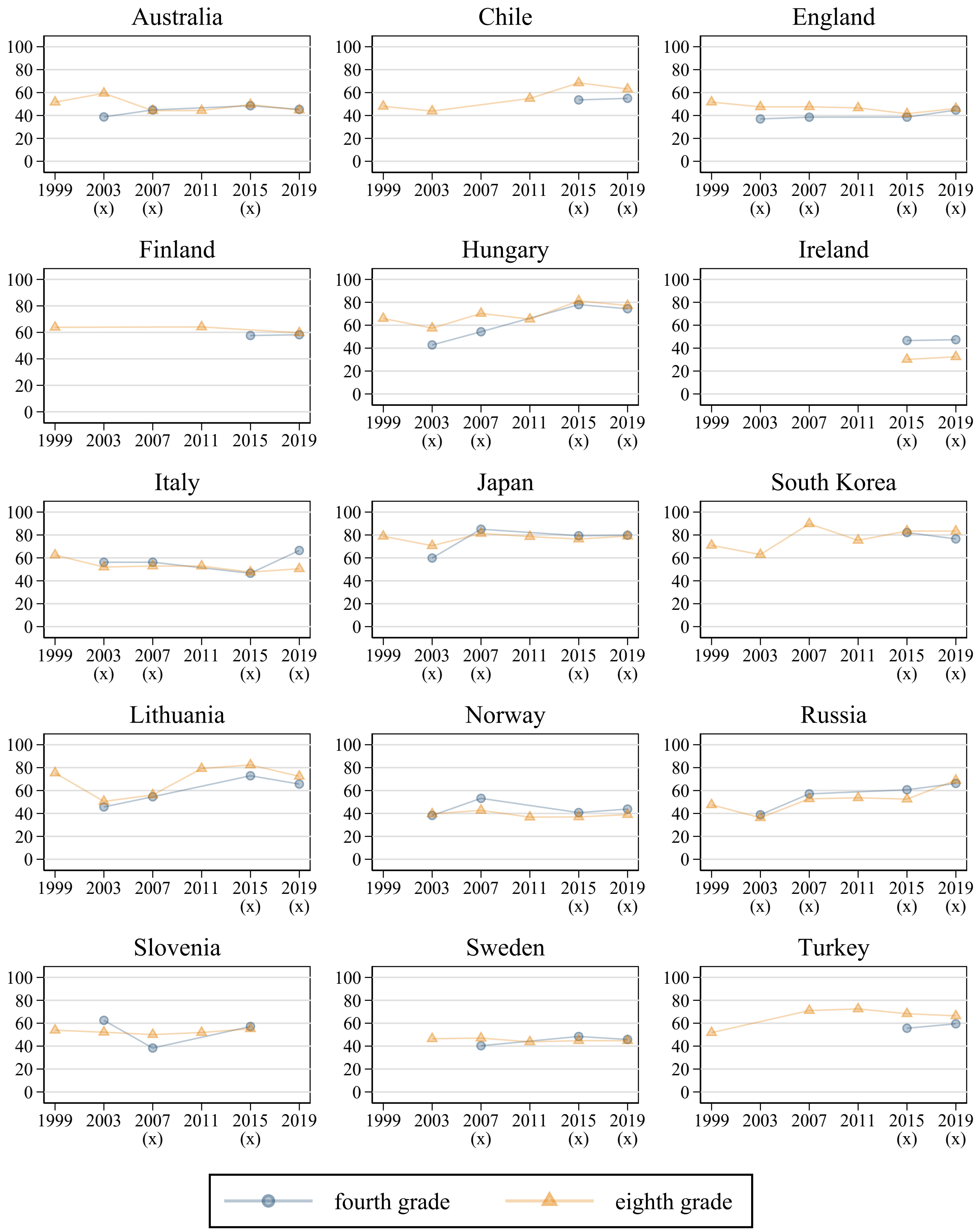
Notes: The figure shows trends in segregation of high-SES students, separately by country and grade level. Segregation is measured using the dissimilarity index. (x) indicates years included in the analysis sample.

Online Appendix Figure A.5: Trends in variance ratio index for immigrant students, by country and grade level



Notes: The figure shows trends in segregation of immigrant students, separately by country and grade level. Segregation is measured using the variance ratio index. (x) indicates years included in the analysis sample. The year 2011 is not included in the analysis sample for any country because information on country of birth was not collected in fourth grade in that wave. Finland is dropped from the sample because it only has one year of data.

Online Appendix Figure A.6: Trends in dissimilarity index for immigrant students, by country and grade level



Notes: The figure shows trends in segregation of immigrant students, separately by country and grade level. Segregation is measured using the dissimilarity index. (x) indicates years included in the analysis sample. The year 2011 is not included in the analysis sample for any country because information on country of birth was not collected in fourth grade in that wave. Finland is dropped from the sample because it only has one year of data.

Online Appendix Table A.1: Effect of autonomous schools on student achievement, samples excluding specific countries

	All with	Countries excluded from the sample: all without variation and additionally								
	variation	Australia	Chile	England	Finland	Hungary	S. Korea	Norway	Slovenia	Sweden
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A: math achievement										
Share autonomous	0.0003	–0.0005	0.0003	0.0073	0.0003	0.0008*	0.0003	0.0003	0.0006*	0.0002
	(0.0004)	(0.0004)	(0.0005)	(0.0103)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0003)	(0.0004)
Observations	284,122	236,736	254,808	246,546	265,614	239,891	256,890	266,570	258,119	247,802
Panel B: science achievement										
Share autonomous	–0.0005	–0.0008*	–0.0005	0.0086*	–0.0005	–0.0001	–0.0005	–0.0005*	–0.0007**	–0.0002
	(0.0003)	(0.0004)	(0.0004)	(0.0040)	(0.0003)	(0.0005)	(0.0004)	(0.0003)	(0.0003)	(0.0004)
Observations	284,122	236,736	254,808	246,546	265,614	239,891	256,890	266,570	258,119	247,802
Student controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-grade FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Grade-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table shows estimates of the effect of autonomous schools on student achievement in math and science for different subsamples of countries. Column 1 drops the following six countries with no variation in share autonomous from the sample: Ireland, Italy, Japan, Lithuania, Russia, and Turkey. Columns 2-10 additionally drop individual remaining countries as indicated in the column headers. Student controls include age and dummies for female, books at home, and immigrant, all of which are interacted with country dummies. Regressions use weights that adjust for individual sampling probabilities and that give equal weight to all country-grade-year cells. Standard errors in parentheses are clustered at the country-grade level. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Online Appendix Table A.2: Effect of autonomous schools on student achievement, sample restricted to cells and students with information on immigrant status

	Math (1)	Science (2)
Share autonomous	–0.0003	–0.0017*
	(0.0007)	(0.0009)
Observations	484,526	484,526
Student controls	Yes	Yes
Country-grade fixed effects	Yes	Yes
Country-year fixed effects	Yes	Yes
Grade-year fixed effects	Yes	Yes

Notes: The table shows estimates of the effect of autonomous schools on student achievement in math and science for the subset of students with information on immigrant status. Student controls include age and dummies for female, books at home, and immigrant, all of which are interacted with country dummies. Regressions use weights that adjust for individual sampling probabilities and that give equal weight to all country-grade-year cells. Standard errors in parentheses are clustered at the country-grade level. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Online Appendix Table A.3: Effect of autonomous schools on student achievement, heterogeneity using alternative definitions of SES

	Highest category		Above country median	
	High	Low	High	Low
	(1)	(2)	(3)	(4)
Panel A: math achievement				
Share autonomous	0.0044***	–0.0010	0.0021***	–0.0013
	(0.0006)	(0.0008)	(0.0006)	(0.0009)
Observations	77,908	398,587	169,451	307,044
Panel B: science achievement				
Share autonomous	0.0019	–0.0022**	0.0007	–0.0027***
	(0.0013)	(0.0008)	(0.0010)	(0.0009)
Observations	77,908	398,587	169,451	307,044
Student controls	Yes	Yes	Yes	Yes
Country-grade fixed effects	Yes	Yes	Yes	Yes
Country-year fixed effects	Yes	Yes	Yes	Yes
Grade-year fixed effects	Yes	Yes	Yes	Yes

Notes: The table shows estimates of the effect of autonomous schools on student achievement in math and science, separately by socioeconomic status. In columns 1-2, high (low) SES is defined as having more than 200 (at most 200) books at home. In columns 3-4, high (low) SES is defined as having more than (at most) the country-specific median number of books at home. Student controls include age and dummies for female and immigrant, all of which are interacted with country dummies. Regressions use weights that adjust for individual sampling probabilities and that give equal weight to all country-grade-year cells. Standard errors in parentheses are clustered at the country-grade level. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Online Appendix Table A.4: Effect of autonomous schools on segregation, samples excluding specific countries

	All with	Countries excluded from the sample: all without variation and additionally								
	variation (1)	Australia (2)	Chile (3)	England (4)	Finland (5)	Hungary (6)	S. Korea (7)	Norway (8)	Slovenia (9)	Sweden (10)
Panel A: variance ratio index for high-SES students										
Share autonomous	0.063	0.034	0.060	0.125	0.065	0.103***	0.062	0.063	0.058	0.063
	(0.041)	(0.037)	(0.041)	(0.498)	(0.043)	(0.020)	(0.045)	(0.041)	(0.051)	(0.047)
Observations	62	54	56	52	58	52	56	58	56	54
Panel B: dissimilarity index for high-SES students										
Share autonomous	0.117	0.033	0.111	0.135	0.116	0.207***	0.115	0.117	0.101	0.115
	(0.085)	(0.042)	(0.086)	(0.428)	(0.086)	(0.045)	(0.090)	(0.085)	(0.090)	(0.089)
Observations	62	54	56	52	58	52	56	58	56	54
Panel C: variance ratio index for immigrant students										
Share autonomous	0.048	0.005	0.048	0.656*	0.048	0.046	0.048	0.048	0.062*	0.053
	(0.037)	(0.033)	(0.038)	(0.360)	(0.037)	(0.053)	(0.038)	(0.037)	(0.033)	(0.036)
Observations	44	38	40	36	44	36	40	40	40	38
Panel D: dissimilarity index for immigrant students										
Share autonomous	0.129***	0.110***	0.129***	0.232	0.129***	0.151***	0.135***	0.128***	0.105***	0.129***
	(0.026)	(0.020)	(0.024)	(0.893)	(0.026)	(0.049)	(0.031)	(0.026)	(0.011)	(0.031)
Observations	44	38	40	36	44	36	40	40	40	38
Student controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-grade FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Grade-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table shows estimates of the effect of autonomous schools on segregation for different subsamples of countries. Column 1 drops the following six countries with no variation in share autonomous from the sample: Ireland, Italy, Japan, Lithuania, Russia, and Turkey. Columns 2-10 additionally drop individual remaining countries as indicated in the column headers. The sample size is smaller in panels C and D because information on country of birth was not collected in fourth grade in TIMSS 2011. Standard errors in parentheses are clustered at the country-grade level. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

B Data Appendix

This appendix provides further description of data sources, variable definitions, and the construction of our estimation sample.

B.1 Data sources

B.1.1 Share of students in autonomous schools

We obtain data on the share of students enrolled in autonomous schools from the OECD Education at a Glance (EAG) database, which provides internationally comparable indicators related to education outcomes, investments, and policy contexts. Importantly for our analysis, one of these indicators reports the enrollment of students across different types of educational institutions. In particular, the data include the distribution of students across three types of institutions: public, government-dependent private, and independent-private, separately for three levels of education (primary, lower-secondary, upper-secondary). The relevant category for our analysis are government-dependent private institutions, which are defined as *educational institutions for which a private organization has ultimate control, but at least half of the funding is received from the government* (OECD, 2018). In practice, government-dependent private schools in our sample receive on average almost 90% of their funding from the government.[8]

For the years 1999-2013, the EAG data are published in the annual EAG reports. The data are reported with a two year lag, which means that data for the time period 1999-2013 are published in the EAG reports from the years 2001-2015. The relevant tables are: Table C1.4. in the EAG reports 2001, 2011, 2012, and 2013; Table C2.4. in 2002, 2003, 2004, 2008; Table D5.1. in 2005; Table C2.9. in 2007; Table C1.5. in 2009, 2010, 2014; and Table C1.4a. in 2015. Data for the year 2014 and onward are no longer included in the EAG reports, but are instead available online (on https://stats.oecd.org/; table 'Enrolment by gender, programme orientation, mode of study and type of institution' with code EAG_ENRL_SHARE_CATEGORY).

B.1.2 Student achievement and segregation

To measure achievement and segregation, we use individual-level data from TIMSS. TIMSS is an international student assessment administrated by the International Association for the Evaluation of Educational Achievement every four years since 1995. The study draws nationally representative samples of fourth- and eighth-grade students through a two-stage clustered sampling design, where schools are selected in the first stage and classes within these schools are randomly sampled in the second stage. All students in the selected classes participate in the assessment and provide detailed background information via questionnaires. Test scores from the assessments in both math and science are reported as five plausible values. This reflects the fact that TIMSS tests each student only on a subset of questions and uses these answers and Item Response Theory to compute a distribution of test scores for each student. The plausible values are random draws from this posterior distribution. We use the mean of the five plausible values in

[8] We obtain this figure from an analysis of the PISA 2018 data. PISA collects information on the type of school as well as the share of funding that is received from the government. Based on these variables, we find that government-dependent private schools in the countries in our sample receive on average 86% of their funding from the government.

math and science as measures of achievement and use the rich information on the social composition of the sampled classes to construct indices of segregation at the class level.

B.2 Measuring segregation

The variance ratio index is commonly used by economists to study school or neighborhood segregation (Graham 2018, Monarrez et al. 2022) and is defined as follows. Let the number of minority students in class $i = 1, ..., N$ be denoted by m_i and the total class size p_i. M is the total number of minority students in the country, and Q the overall share of minority students in the country. Then the index is calculated by:

$$VR = \frac{Isolation - Q}{1 - Q} \quad \text{with} \quad Isolation = \sum_{i=1}^{N} \frac{m_i}{p_i} \cdot \frac{m_i}{M} \tag{3}$$

As evident from the equation, the variance ratio index builds on an index of isolation, which describes the probability that a randomly selected classmate of a minority student is from this minority group, too. In a perfectly segregated school system, the isolation index will be equal to one, meaning that all classmates of a minority student are also members of this group. In contrast, in absence of segregation, the isolation index equals the overall share of minority students in the country. The variance ratio index is obtained by scaling the isolation index by the overall share of minority students in the country. Ultimately, the index measures the excess isolation of minority students compared to a perfectly integrated school system relative to the excess isolation of a perfectly segregated school system. The index is bounded between zero and one, with higher values indicating higher degrees of segregation. To facilitate interpretation of our results, in our analysis we scale the index to be between zero and 100.

The dissimilarity index is the most widely used measure of segregation in the sociology literature (Duncan & Duncan 1955, Massey & Denton 1988) but has also been applied by economists (Graham 2018, Monarrez et al. 2022). It is defined as follows:

$$DI = \frac{1}{2} \sum_{i=1}^{N} \left| \frac{m_i}{M} - \frac{r_i}{R} \right| \tag{4}$$

Here, m_i denotes again the number of minority students in class i and M denotes the total number of minority students in the country. r_i and R are the number of students who belong to the majority group in class i and the country as whole, respectively. Intuitively, the index measures the proportion of minority students who need to change classes to ensure an even distribution across classrooms, relative to the share of students that would need to change when there is perfect segregation (Graham 2018). If there is no segregation, the relative share of minority and other students will be the same in all classes (which means $\frac{m_i}{M} = \frac{r_i}{R}$ for all i), so the dissimilarity index will be equal to zero. If, on the other hand, there exists perfect segregation, minority students are in classes without any students from the majority group (which means in a given class either m_i or r_i is equal to zero), so that the index is equal to one. Like with the variance ratio index, in our analysis we scale the dissimilarity index to lie between zero and 100.

We compute our segregation measures at the class level for both fourth- and eighth-grade students. In doing so, we use the appropriate TIMSS sampling weights in order to ensure that our segregation measures are nationally representative.[9]

[9]TIMSS samples representative samples of students, not classes. We follow Schneeweis (2011) and

B.3 Sample construction

In our empirical analysis, we employ a triple-differences model to estimate the effects of autonomous schools on achievement and segregation. This identification strategy relies on within-country, between-grade variation over time. Therefore, we need to restrict our sample to countries for which we have data on both the primary and lower-secondary level for at least two time periods. This means that we restrict the sample to countries that participated in at least two waves of the TIMSS assessment with both fourth- and eighth grade students, and for which data on the share of students in autonomous schools is available for the years of their TIMSS participation.

In addition, we restrict the sample as follows:

- We exclude observations from Norway before 2013 because the share of students in autonomous schools cannot be clearly identified: before 2013, Norway did not separately report enrollment shares for independent-private and government-dependent private institutions but instead had these two types of institutions pooled in one category.
- We exclude the United States because the National Center for Education Statistics (NCES), the agency that reports education statistics to the OECD, does not consider charter schools as government-dependent private schools, but instead includes them in the category of public institutions. We received this information from the NCES after requesting information about charter school categorization in summer 2022.
- We exclude New Zealand because autonomous schools were first introduced, but shortly after disestablished within our study period. When they were disestablished, schools previously operating as autonomous schools were not closed but instead reorganized as public schools. This implies that while the share of students in autonomous schools in our data would be zero for the time period after the abolition, both the segregation of students and their achievement could still be influenced by the fact that some schools operated as autonomous schools before, which could bias our estimates.

Moreover, we apply the following imputations:

- We impute the share of students in autonomous schools to zero if data on autonomous schools in the EAG data set is coded as missing with either one of the following two flags: a. category does not apply or n. magnitude is negligible or zero; and if at the same time the share of students enrolled in the two other categories (public institutions and independent private institutions) sums up to 100 percent.
- We impute the share of students attending autonomous schools in the Russian Federation in the year 2003 for both primary and lower-secondary institutions. As the data are available for two preceding years and all subsequent years until 2019, we take the average of the enrollment share in 2004 and 2002 to impute the data for the year 2003. Since the share of students in autonomous schools in the Russian Federation is zero throughout our study period, we impute a share of zero for the year 2003.

weight a class with the sum of all student weights within this class.

- The EAG data base does not report statistics separately for countries within the United Kingdom. However, the reported share of students in autonomous schools across the United Kingdom mimics closely the share of students enrolled in academies in England.[10] We thus impute the share of students in autonomous schools in England as the corresponding share in the United Kingdom.

To obtain our final sample, we merge the TIMSS data with the EAG data on autonomous schools. We merge TIMSS fourth-grade data with the data on autonomous schools at the primary level, and TIMSS eighth-grade data with data on autonomous schools at the lower-secondary level. Our final analysis sample consists of 15 countries over the time period from 2003 to 2019, which implies that it covers five TIMSS waves. Note that not every country is participating with both grade levels in each TIMSS wave, which implies that the number of country-grade-wave cells in our sample is 106 instead of 150 (which would be the case with 15 countries $\times$ 5 waves $\times$ 2 grades).

[10] See https://www.gov.uk/government/statistics/schools-pupils-and-their-characteristics-january-2019.