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A cross-country panel approach to exploring the determinants of educational equity through PISA data

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Abstract The main aim of the paper is to analyse the effect of country and school factors on a new measure of educational equity defined as the country proportion of resilient students, i.e. those who, despite their disadvantaged socioeconomic background, are able to obtain good educational results. We construct a cross country panel dataset by merging the five editions of OECD PISA (Programme for International Student Assessment). The panel analysis allows to exploit country and time level variation in the proportion of resilient students controlling for systematic and institutional differences. Our findings suggest that educational funding can help disadvantaged students to obtain the opportunities that they are otherwise lacking. In addition, this effect seems to be heterogeneous, and particularly driven by those countries whose economic development (in terms of per capita GDP) is lower.

Keywords School equity · Resilient students · FE models

JEL Classifiaction I21

1 Introduction and background

The investigation of the factors that affect educational outputs is an interesting topic since the seminal contribution of Coleman et al. (1966), whose Report indicated that the students' own background is more influent than the role of schools in determining academic results. Economists paid a great attention to this topic, because of the link between education, human capital formation and economic growth. In this perspective, the comparison

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of the performance of educational systems with their "institutional" features and resources (Hanushek 1986; Clements 2002) is an interesting research area since it allows to search for those settings that—together with individual and school factors—can contribute the most in "producing" better educational results. In the vast literature about educational production functions (EPFs), the concept of educational effectiveness refers to the ability of maximizing the achievement, as measured through indicators such as completion rates or scores in standardised tests (for a review, see Hanushek and Woessmann 2011). In other words, an educational system is effective when—through its rules and institutions—it is able to contribute positively to students' achievement, all else (students and schools' characteristics) being equal. A well-known stream of the literature suggests that some characteristics of the educational systems do indeed make a difference, while others do not; for instance, accountability, choice and competition are seen as positively related with effectiveness (Woessmann 2007) whereas resources are not statistically correlated with achievement scores, and this holds for both developed and developing countries (Hanushek and Luque 2003).

With reference to educational equity, instead, two different perspectives can be considered: (i) the reduction of disparities in academic achievement among students of the same class, school, region or country, or (ii) the ability of an educational system to reduce the impact of students' background on their academic results. The latter definition seems more in line with that of "equality of educational opportunities" *a là* Roemer (1998), and it is more able to deal with the wider socioeconomic topic of social mobility (Corak 2013).

This paper nests in the literature that studies empirically the association between the characteristics of educational systems and their equity, taking advantage of large administrative or specialised datasets, especially in a cross-country comparison. A first challenge is how to define and measure the concept of "educational equity". An empirical approach proposed by Woessmann et al. (2009) measures the correlation between: (i) the interaction of students' Socioeconomic Status (SES) and institutional features, on one side, and (ii) academic results in standardised test scores (using OECD-PISA[1] 2003 data) on the other side—the higher this association, the stronger the adverse effect on equity. Their results generally show that *'there is very little evidence that those aspects of accountability, autonomy and choice that are associated with higher levels of student achievement across countries have adverse consequences for the equity (…). To the contrary, the choice created by public funding for privately operated schools in particular is associated with a strong reduction in the dependence of student achievement on SES'* (p. 101).

A similar approach is proposed by Ammermueller (2012), who adopts a difference-in-difference strategy by employing OECD-PISA and IEA-PIRLS[2] data; his results indicate that '*streaming and private schools rather benefit the performance of students from a better social background. [while] The time students spend in schools seems to limit the effect of social origin upon student performance while higher school autonomy is associated with higher parental influence'* (p. 207).

The present paper uses a direct measure of educational equity, which is the proportion of "resilient students", the latter defined as those students who, despite their disadvantaged socioeconomic background, obtain good results in standardised test scores. Intuitively, the higher the proportion of resilient students in a country educational system, the higher its

[1] Programme for International Students Assessment (PISA) is a triennial international survey conducted by the Organisation for Economic Cooperation and Development (OECD).

[2] Progress in International Reading Literacy Study (PIRLS) is a recurring study conducted by the International Association for the Evaluation of Educational Achievement (IEA).

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ability of pursuing the equality of educational opportunities (all else being equal). Indeed a high proportion of resilient students also means that the good performance of many disadvantaged students does not reflect their starting unfavourable background.

The main aim of our analysis is then to identify those country-level factors that are statistically related to the proportion of resilient students. Previous research work has shown that the proportion of resilient students is positively correlated with the average score in standardised tests (Agasisti and Longobardi 2014a, b; OECD 2011); in this sense, the study of the determinants of resilience not only can be useful for equity purposes, but it can also contribute positively to efficiency.

Following this hypothesis, we have pooled the data of five PISA editions at country level in order to estimate the time-variant factors that are associated with a higher/lower proportion of resilient students. The aggregation of data at country level addresses the potential distorting effects of the endogenous sorting of students across schools within country. A similar approach has been proposed by Brunello and Rocco (2013) and, in a different fashion, by Hanushek et al. (2013).

To anticipate our results, the empirical analysis shows that resource investments matter for improving the equity of an educational system. More specifically, the countries that invest more in education as a percentage of total public spending, and that show better indicators about the quality and quantity of educational services, also show higher proportions of resilient students. This finding suggests that increases in the resources devoted to education may be unrelated to the absolute levels of achievement as found by Hanushek and Luque (2003) though they can have a beneficial effect on the performances of the worse-off students. More specifically large educational resources can help the disadvantaged students to obtain the opportunities that they are otherwise lacking. In addition, our results suggest that this effect seems to be heterogeneous, and particularly driven by those countries whose economic development (in terms of per capita GDP) is lower.

The remainder of the paper is organised as follows: in Sect. 2 we provide a description of the dataset used for this research. Section 3 introduces the strategy for identifying resilient students while Sect. 4 contains a complete discussion of the methodological approach. The results of the analysis are included in Sect. 5 and the concluding remarks are in Sect. 6.

2 Description of dataset

The analysis of resilient students as a measure of school equity draws upon the OECD PISA (Programme for International Student Assessment) data. The aim of the OECD-PISA is to collect highly standardised data that can be used to compare the competencies of representative samples of 15-year-old students in the three main domains of reading, mathematics and science, both within and between countries. Since the first cycle in 2000, PISA has been taking place every 3 years with a growing number of participating countries and each of these cycles looks in depth at a major domain. We focus our attention on PISA database because it includes not only the outcomes of the achievement tests of the students but also additional information about their family background together with information on the school characteristics collected through a questionnaire addressed to the headteachers.

The first step of our empirical analysis relies on the construction of a panel dataset at the country level by merging the five editions of OECD PISA. The panel dataset covers 58 countries over the period 2000–2012. It allows to exploit country and time level variation in the proportion of resilient students accounting for school system difference, while

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controlling for systematic and institutional differences including country and time fixed effects. Thus, the dependent variable is the proportion of resilient students at country level (PERC_RESIL); the following Sect. 3.1 explains how this definition is put into effect—it is important here only to remind the general concept, that is the share of students who, despite their socioeconomically disadvantaged background, report good educational outcomes.

The covariates, to be used as factors for describing and explaining the proportion of resilient students at country level, must be available in all the PISA editions and moreover their definition must remain unchanged over the editions. This constraint may reduce the potential explanatory power of our empirical model, though it allows improving the reliability of the panel modeling.

Also, we integrated the PISA dataset with additional indicators and variables from other sources, such as the data provided by UNESCO Institute for Statistics (UIS) and International Monetary Fund (IMF).

The explanatory variables are classified in four categories, which reflect the main groups of variables that the literature showed to be statistically correlated with educational achievement and thus can be of interest also for explaining resilience: (a) school system inputs, which are our key variables of interest, (b) students' characteristics (socioeconomic background), (c) economic performance of the country, and d) educational system and schools' characteristics. In Table 1 the definitions of the explanatory variables used in this study are provided.

The key independent variable of interest is the amount of resources invested in the educational sector measured by the public expenditure on education as a percentage of total government expenditure (EXP_GOV). Although also the amount of private resources invested in the sector is likely to have an effect on (poor) students' achievement, there are two reasons why we focus just on public expenditure. First, public spending is the key policy leverage in the hands of governments (in this sense, understanding its effect on the equity of educational system is the main aim of this study) and, second, private spending is not a major source of funding for primary and secondary schooling levels while its role is definitely more important in higher education. Lastly, EXP_GOV allows to detect more education-oriented countries, if we assume that the countries that invest more in education, net of GDP effects, are more politically committed to the important role of human capital in modern economies.

As a control for the different levels of economic development and performance across countries, we include the per capita GDP (calculated in Purchasing Power Parity—PPP units). This variable plays an important role in our analysis since we assume that the economic development affects the proportion of resilient students and therefore the equity of the education system of a country.

The effect of the socio economic background is accounted for by (i) the share of students with migration background (STUD_IMMIG), and (ii) the proportion of students whose father has a full time job (FATHER_FULL).

Six explanatory variables cover various dimensions of the characteristics of both the country educational system and the single schools. The SCMATEDU[3] index reflects the

[3] The index of quality of school educational resources (SCMATEDU) was derived from six items measuring school principals' perceptions of potential factors hindering instruction at their school. These factors are: (i) shortage or inadequacy of science laboratory equipment; (ii) shortage or inadequacy of instructional materials; (iii) shortage or inadequacy of computers for instruction; (iv) lack or inadequacy of Internet connectivity; (v) shortage or inadequacy of computer software for instruction; and (vi) shortage or inadequacy of library materials. As all items were inverted for scaling, higher values on this index indicate better quality of educational resources.

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Table 1 Explanatory variables used in the study

Category	Variable	Label	Description	Source
School system input	Education expenditure (% Gov)	EXP_GOV	Education (public) expenditure as a % of the total government expenditure	UNESCO Institute of Statistics
Students' characteristics	% Immigrants	STUD_IMMIG	Percentage of students born in a foreign country	OECD (PISA)
	% Fathers employed	FATHER_FULL	Percentage of students whose father works with a full time job	OECD (PISA)
Economic performance	Per capita GDP	GDP	GDP per capita, calculated as purchasing power parity (PPP)	International Monetary Fund (IMF)
Educational system's characteristics	Index of school educational resources	SCMATEDU	Country mean of the index measuring the quality of school educational resources	OECD (PISA)
	Private schools	PRIVATE	Proportion of private schools	OECD (PISA)
	Funds from government	GOV_FUNDS	Share of school funds coming from government (Country mean)	OECD (PISA)
	Autonomy in budget	BUDGET	Proportion of school principals who report the school having a major responsibility in budget formulation	OECD (PISA)
	Autonomy in assessment	ASSESS	Proportion of school principals who report the school having a major responsibility in establishing student assessment policy and practice	OECD (PISA)
	School life expectancy	SCH_LIFE	Total number of years of schooling (primary to tertiary) that a child can expect to receive	UNESCO Institute of Statistics

headteachers' perception of the adequateness of educational physical resources such as equipment, laboratories, etc. For this reason this indicator can be considered a proxy for the physical inputs of the school. The share of private schools (PRIVATE) measures indirectly the degree of competition in the educational sector, as well as the plurality of offer that can be selected by the students. The degree of (financial) dependence of the schools from the government is expressed by the covariate GOV_FUNDS, it was derived from the PISA headteachers' questionnaire which reports the proportion of funds coming from the government. At country level this indicator measures the control exerted by the government on schools' activities; its effect on the proportion of resilient students can be negative or positive depending upon how much the government targets its policies and actions toward disadvantaged students. Two variables are intended to account for the role of school autonomy: (i) the share of schools that report a "high"/"total" degree of autonomy in formulating the budget (BUDGET), and (ii) the share of schools that report a "high"/"total" degree of autonomy in establishing student assessment policies (ASSESS). Lastly, the total number of years of schooling (primary to tertiary) that a child can expect to receive (school life expectancy—SCH_LIFE) is a proxy of the quantity of education that the students of every country are likely to receive after the primary level (assuming that the probability of them being enrolled in school at any particular future age is equal to the current enrolment ratio at that age).

In order to exploit suitably the longitudinal dimension of the data we selected just the countries that have participated in at least three out of five editions of PISA study. Then, due to the presence of missing values in the covariates for the selected years and the impossibility to impute them by using the values of adjacent years, a further selection of countries has been made. The final analysis was conducted on an actual sample of 36 countries. All the OECD countries are included in the present study with the exceptions of Australia, Austria, Canada, France, Luxembourg, Slovenia and Turkey. Conversely, among the non-OECD countries that are involved, there are Latin America countries (Argentina and Colombia), Asian countries (Hong Kong, Indonesia and Thailand) and Eastern Europe countries (Bulgaria, Latvia, Lithuania and Serbia).

Therefore, our analysis focuses on this particular set of countries and the inferential results are restricted to the behaviour of these specific countries. To this end, we use the Fixed Effects (FE) model (see Sect. 4) as this is an appropriate methodological framework when inference is conditional on the specific set of units that are observed (Baltagi 2008).

3 Resilience in OECD-PISA countries

3.1 Identifying the resilient students

In general terms, a resilient student is someone who, despite his/her disadvantaged socioeconomic background, obtains high academic performance. In this empirical analysis, we adopt a "relative" definition of resilient students applicable across countries. Our attention is on a specific category of resilient students, namely those who derive from a low socio-economic background both at family and school-level.

The identification process of resilient students is articulated in three steps. First, in each country we select the schools where the average socio-economic condition of the students is low. The socio-economic condition is measured through the ESCS (Economic, Social and Cultural Status) indicator, provided by OECD. This indicator is built to have an OECD

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mean of zero and a standard deviation of one and it captures both students' family and home characteristics (i.e. goods possession) describing their socioeconomic background (more technical details can be found in OECD 2012). In each country, the schools where the ESCS of the students is below the 33th percentile of the ESCS within-country distribution are classified as disadvantaged schools. The choice of focusing not simply on all the disadvantaged students, but specifically on the subsample of these students attending disadvantaged schools is motivated on a policy rationale. Students with a disadvantaged background could be helped by attending a school where their classmates are more socioeconomically affluent; thus, the consequent benefits would not be as much the result of resource allocation or instructional policy, but rather the outcome of positive peer effects related to a more favourable socioeconomic composition of the schools.

Confining the analysis to the disadvantaged schools allows us to eliminate the effect of attending a school populated by affluent students. However it can be the case that a relatively better-off student attends a relatively disadvantaged school. In order to drop these students from the analysis, within the subsample of disadvantaged schools, at the second step we further select the students with an ESCS indicator lower than the third quartile of the new, within country, ESCS distribution. Therefore, this procedure allows to select only the disadvantage students in disadvantaged schools. It is relevant to note that the notion of "socially disadvantage" is a relative one: the students are disadvantaged when compared with other students in the same country. Such choice must be considered as important for neutralising the structural differences of economic resources across countries, which are further reduced by including also an indicator of country economic performance in the empirical analysis. If we chose to select disadvantaged students in the overall distribution across countries, we would pick up a disproportionate number of students from certain countries—where the average ESCS is lower.

At the third step the academic performance (PISA score)[4] of each disadvantaged student is compared with that predicted by the average relationship with ESCS among disadvantaged students across countries. Here the definition of "high" academic performance is related to the test score distribution of all the students across all the countries instead of being related to each country's average test score.

Operationally, we estimated the following equation:

$$y_i = \alpha_0 + \alpha_1 ESCS_i + \varepsilon_i \quad (1)$$

where y_i is the score in the main domain of the PISA edition obtained by the i_{th} student, $ESCS_i$ is the indicator of socioeconomic background, and ε_i is a randomly distributed error.

The regression model considers the five plausible values for the students' performance. The estimation is made separately for each PISA edition on the subsample of the disadvantaged students, as defined above. Student performance levels are then defined by means of the residuals ε_i of Eq. (1); the residuals are divided into equal thirds, and accordingly the students are divided into three groups—namely successful, average, and low-performers—by looking at their performance in comparison to peers of the other countries sharing similar socioeconomic background. Students are defined as "resilient students" if they are disadvantaged students who perform in the top third of the performance distribution, after accounting for their socio-economic background.

We assumed that the relationship between achievement and social (disadvantaged) background is not substantially different across countries. An alternative choice would be

[4] The main domain of each PISA edition is used to assess the student performance, i.e. reading for PISA 2000 and 2009, mathematics for PISA 2003 and 2012, science for PISA 2006.

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to consider a single country perspective, using a national benchmark for both SES and performance, but, in this way, the successful disadvantaged students in one country may be seen as poorly performing students in other countries and vice versa. It follows that relative performance within a single system would not be useful for making comparisons across systems.[5]

Finally, the proportion of resilient students in each country is computed by dividing the number of resilient students by the total number of students.[6] In this way, this proportion reveals the capacity of each country to provide the disadvantaged students with the chance of overcoming their background and keeping up with other students with similar socio-economic status at international level.

Methodologically, it is relevant to discuss more on the thresholds used for defining resilient students. The choice of the specific values, however arbitrary, represents to our advice a suitable compromise between the need of selecting the observations in order to capture properly the phenomenon under study and the requirement of an adequate final sample size. Nevertheless, the chosen combination of thresholds at the three steps has been compared with plausible alternatives with the aim of evaluating the robustness of the implemented strategy. To this end, three alternative thresholds at every step have been defined: they are the 25th, 40th and 50th percentiles (besides the 33th one, which represents the chosen threshold) of the distribution of mean ESCS within school at the first step, the 66th, 80th and 90th percentiles (besides the 75th one) of the distribution of students' ESCS at the second step and the 50th, 75th and 80th percentiles (besides the 66th one) of the distribution of residuals from the regression of test scores on students' ESCS at the third step. There are 64 different combinations in total. Then the Spearman correlation coefficients between the share of resilients computed through the chosen strategy and the share of resilients arising from every other combination of thresholds have been derived for every PISA edition. The results indicate that for all editions the average correlation across all the 63 alternative combinations ranges between a minimum of 0.964 (in 2009) and a maximum of 0.987 (in 2000), which suggests that the ranking of the different countries according to the share of resilient students remains almost unchanged when the chosen thresholds are replaced by alternative, plausible values. Indeed, all the distributions used to outline disadvantaged schools, disadvantaged students in disadvantaged schools and resilient students do not show irregularities (neither asymmetry nor zero inflation).

For each country, the share of resilient students across time is reported in Table 2. The values range between less than 2 % (Bulgaria in 2000 and Argentina in 2012) and more than 18 % (Finland in 2000 and Hong Kong in 2009). In every year the average share across the countries is around 9 %.

The descriptive statistics of covariates are reported in Table 3.

[5] As a robustness check, we estimated the Eq. (1) separately by country, and the main results of the final model (in terms of both sign and significance) remain nearly unchanged—we do not report them here because of space constraints, though they are available on request from the authors.

[6] An alternative way to compute the share of resilient students in each country would be to divide the number of resilient students by the number of disadvantaged students. This choice does not influence the ranking of the countries according to the share of resilient students since the number of disadvantaged students in a country is a constant proportion (based on a predetermined threshold) of the total student sample. Indeed the correlation coefficient between the two measures is very high (0.9).

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Table 2 Proportion of resilient students by country and PISA edition

Country	2000	2003	2006	2009	2012
Argentina	4.69	m	2.70	3.52	1.95
Belgium	8.35	8.98	7.65	7.89	7.86
Bulgaria	1.42	m	2.51	2.82	2.65
Chile	3.23	m	6.17	8.57	5.38
Colombia	m	m	5.34	7.57	4.38
Czech Republic	5.83	8.12	9.34	6.96	8.52
Denmark	9.16	10.38	8.19	8.58	7.71
Estonia	m	m	14.66	12.02	14.06
Finland	18.26	15.23	17.90	15.63	11.89
Germany	4.51	6.72	6.13	5.36	6.60
Greece	7.23	4.21	6.81	8.67	7.14
Hong Kong SAR, China	17.43	17.13	16.90	18.48	17.52
Hungary	5.07	3.92	8.40	8.40	7.40
Iceland	11.48	9.82	8.97	11.60	7.98
Indonesia	2.19	2.82	4.13	7.69	7.06
Ireland	13.21	9.95	10.88	9.98	12.54
Israel	3.49	m	4.10	7.55	7.60
Italy	7.34	8.16	6.91	8.38	8.25
Japan	m	11.51	10.87	11.14	12.63
Korea, Rep.	15.23	13.43	11.79	17.18	15.02
Latvia	5.93	7.07	10.30	10.55	10.15
Lithuania	m	m	8.96	7.55	7.51
Mexico	6.13	5.66	6.83	9.79	7.27
Netherlands	9.11	9.94	7.92	8.38	6.41
New Zealand	12.35	10.82	11.67	12.15	10.11
Norway	10.18	6.30	7.86	10.79	10.33
Poland	5.34	8.99	12.76	13.95	13.96
Portugal	7.52	10.18	12.06	11.31	9.94
Serbia	m	m	2.98	4.20	4.44
Slovak Republic	m	7.36	7.65	6.81	3.66
Spain	13.47	11.53	13.29	12.15	11.49
Sweden	11.41	9.58	10.04	10.42	9.06
Switzerland	8.23	11.46	10.20	10.29	10.43
Thailand	13.15	8.12	8.93	10.04	9.98
United Kingdom	10.17	8.68	9.25	8.47	9.45
United States	6.76	5.21	7.40	9.92	10.10
Total	8.60	8.97	8.85	9.58	8.85

m missing information, *source* authors' calculations based on the methodology described in Sect. 3.1

3.2 Describing the patterns of resilience

In this section we explore the dynamic of PERC_RESIL (P_{wt}) over time, both between and within countries. The main aim is to show that our measure is not dependent on random circumstances, but rather it is able to capture structural differences, as well as time-dependent variations. In Table 4 we report the Pearson correlation coefficients between the resilience

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Table 3 Descriptive statistics of the explanatory variables

Variable	Source	Mean	SD	Min	Max	Obs.
EXP_GOV	Overall	14.15	4.02	7.16	31.5	N = 160
	Between		3.75	8.1	23.5	n = 36
	Within		1.38	7.85	22.15	
GDP	Overall	25,253	11,642	2433	54,343	N = 166
	Between		11,048	3529	47,540	n = 36
	Within		3980	13,870	38,009	
STUD_IMMIG	Overall	5.69	5.65	0	30.14	N = 164
	Between		5.07	0.11	22.75	n = 36
	Within		2.42	−1.01	28.41	
FATHER_FULL	Overall	73.17	10.88	37.7	90.89	N = 166
	Between		10.67	45.07	87.85	n = 36
	Within		2.78	61.76	81.39	
SCMATEDU	Overall	−0.06	0.45	−1.63	0.96	N = 166
	Between		0.32	−1.22	0.35	n = 36
	Within		0.34	−1.03	1.56	
PRIVATE	Overall	20.41	23.17	0.44	93.26	N = 163
	Between		21.46	0.75	69.86	n = 36
	Within		8.3	−32.69	55.66	
GOV_FUNDS	Overall	84.75	16.21	33	100	N = 166
	Between		16.06	42.36	99.92	n = 36
	Within		3.32	69.08	95.31	
BUDGET	Overall	72.97	20.73	8.61	99.79	N = 165
	Between		17.79	30.99	96.4	n = 36
	Within		11.54	23.88	119.34	
ASSESS	Overall	86.65	15.33	0	100	N = 165
	Between		12.32	37.35	99.62	n = 36
	Within		8.93	47.08	141.76	
SCH_LIFE	Overall	6.63	1.23	3.35	9.42	N = 166
	Between		1.15	4.09	8.84	n = 36
	Within		0.45	5.34	8.61	

Table 4 Serial correlation coefficients for the dependent variable (PERC_RESIL)

	2000	2003	2006	2009	2012
2000	1				
2003	0.825	1			
2006	0.805	0.846	1		
2009	0.769	0.734	0.869	1	
2012	0.715	0.678	0.852	0.892	1

measurements over all PISA editions (they are useful also for assessing the consistencies in the measurements for the countries, as well as their stability over time). In order to analyse the statistical dependencies over time, we focus on two types of correlation coefficients. The first

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one, Corr (P_{wt}, P_{wt-1}), correlates the percentage of resilient students in each t-th edition with the value of the same variable in the previous edition (t − 1). These correlation coefficients can be observed directly below the main diagonal of the correlation matrix. For example, the correlation between the percentage of resilient students observed in 2003 and the percentage observed in 2000 amounts to 0.822, a very high figure—that even increases to values of between 0.845 and 0.894 in the subsequent editions. This is a clear indication of statistical dependencies between the panel measurements.

The second type of Pearson correlation coefficient, Corr (P_{wt}, P_{w1}), correlates PERC_RESIL of each t-th edition with that of the first edition of PISA (these correlation coefficients can be seen in the first column of the correlation matrix). According to this measure, statistical dependencies decrease, as expected, the greater the time interval between t = 1 and t > 1. The interpretation is that the (although limited) variation of PERC_RESIL over time is cumulative, in the sense that differences over time in PERC_RESIL grow with the distance from the first edition.

The presence of a high degree of autocorrelation leads to use a panel approach in order to analyse the level and the dynamic of resilience across country and across time.

4 Empirical analysis: the methodological approach

The pooling of the five available PISA waves (2000, 2003, 2006, 2009 and 2012) on a cross-section of countries allows exploiting the potential of panel data in investigating the determinants of the resilience. To this end we have specified the following panel data regression model with unobserved (fixed) effects (Eq. 2):

$$P_{wt} = \alpha + \mathbf{X}_{wt}^{'}\boldsymbol{\beta} + \varepsilon_{wt}; \quad w = 1, 2, \ldots, N \; ; \; t = 1, 2, \ldots T \tag{2}$$

where P_{wt} is the proportion of resilient students in the country w in the edition t, $\mathbf{X}_{wt}$ is a K × 1 vector of country's educational and socioeconomic characteristics (as described in Sect. 2), α is a scalar whereas $\boldsymbol{\beta}$ is a K × 1 vector of coefficients to be estimated. The disturbance term ε_{wt} can be written as a two-way error component (Eq. 3):

$$\varepsilon_{wt} = \mu_w + \lambda_t + \nu_{wt} \tag{3}$$

where μ_w is the time-invariant unobservable country specific effect, accounting for any effect at a country level that is not included in the explanatory variables, λ_t represents the country-invariant unobserved time effect allowing for any shocks across waves whereas ν_{wt} is the usual stochastic disturbance term. Focusing on a given set of N countries, the specification of model (2) leads to the so-called Fixed Effect (FE) model, where both the country effect and the time effect are treated as fixed parameters to be estimated, accounting for unobserved heterogeneity across countries and across time. Moreover the country specific effect μ_w is allowed to be correlated with the explanatory variables. Finally the stochastic component ν_{wt} is assumed independent of the explanatory variables for all w and t (Baltagi 2008).

For the identification of the parameters, the FE model exploits the within-country and the within-time variation of the observations. For this reason, some restrictions are imposed on the regressors: they can include neither time-invariant nor country-invariant variables.

A consistent estimate of the parameters of FE model (2) is provided by the Within Estimator, which corresponds to the ordinary least squares (OLS) estimator of a new model

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where every original variable is replaced by its deviation from the country-specific mean over time (Eq. 4)

$$(\mathrm{P_{wt}} - \bar{\mathrm{P}}_w) = [\mathbf{X_{wt}} - \bar{\mathbf{X}}_w]' \boldsymbol{\beta} + (\varepsilon_{\mathrm{wt}} - \bar{\varepsilon}_w), \quad \mathrm{w} = 1, 2, \ldots, \mathrm{N}\ ; \mathrm{t} = 1, 2, \ldots \mathrm{T} \qquad (4)$$

where $\bar{\mathrm{P}}_w = \frac{1}{\mathrm{T}} \sum_{t=1}^{T} \mathrm{P_{wt}}; \bar{\varepsilon}_w = \frac{1}{\mathrm{T}} \sum_{t=1}^{T} \varepsilon_{\mathrm{wt}}$ and $\bar{\mathbf{X}}_w$ is the vector of the means over time of every predictor. The $\boldsymbol{\beta}$ coefficients represent the effect of changes over time in the predictors on changes over time in the share of resilient students. In this basic formulation they are assumed to be identical across countries.

In the empirical analysis, a stepwise (or "incremental") regression approach has been followed, which is quite common in this kind of academic research (Dronkers and Robert 2008). This approach allows us not only to test whether and how the covariates change their statistical significance and magnitude, but also to see which groups of variables add more explanatory power to the analysis. The baseline first model (Model 1) considers only the expenditure variable as explanatory factor of the resilience. Model 2 adds the variables representing students' characteristics, educational systems' features and countries' economic performance. With the aim of testing if the effect of public expenditure on resilience changes with the level of economic development, Model 3 introduces the interaction term between the educational expenditure and a dummy variable (D_GDP12) that takes value = 1 if the country's GDP in 2012 is higher than the median computed on the subsample of 36 countries included in the analysis. In practice, this procedure identifies two groups of countries, labelled as "low GDP" and "high GDP". The coefficient of the interaction term informs whether the "main effect" of the educational expenditure changes when passing from a low GDP country to a high GDP country (all other variables are held constant). Model 4 adds also the interactions of educational system's characteristics with D_GDP12. Lastly, Model 5 includes all the interactions between educational expenditure and educational system's characteristics. In order to facilitate the interpretation of the interaction terms, every explanatory variable has been first "centered" with respect to its overall mean. Then the coefficients of these interactions inform about any change in the "main effect" of educational expenditure associated with levels of the interacting variable being either above or below their mean.

5 Results

The results of our empirical analysis are presented in Table 5. For every model specification the F tests for fixed effects return the same results, namely the null hypothesis of no joint significance of both country and time effects has to be rejected—thus, the pooled OLS model with no fixed effects would not be appropriate. Similarly, a one-way fixed effect model with either only the country effects or only the time effects has to be rejected too. In other words, the factors that affect the proportion of resilient students include also (i) structural differences between countries and (ii) time effects.

In Table 5, we report the results of the baseline Model 1, where only the main variable of interest (EXP_GOV) is included, together with time dummies and country fixed effects. The coefficient of the expenditure on education is not significant, which suggests that, when accounting for just unobserved heterogeneity and time dimension, changes in the relative incidence of public expenditure on education do not influence significantly the changes in the share of resilient students. The effect of educational expenditure on resilience remains not statistically significant even when other covariates are included (Model 2). The

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Table 5 Results of the empirical analysis

Category	Variable	Model 1		Model 2	
		Coef.	SE	Coef.	SE
School system input	Education expenditure (% Gov) [EXP_GOV]	0.126	0.096	0.135	0.087
Students' characteristics	% Immigrants [STUD_IMMIG]			−0.182***	0.035
	% Fathers employed [FATHER_FULL]			0.097*	0.051
Economic performance	GDP per capita [GDP]			−0.179*	0.105
Educational system's characteristics	Index of school educational resources [SCMATEDU]			1.209***	0.385
	Private schools [PRIVATE]			0.007	0.016
	Funds from government [GOV_FUNDS]			0.012	0.033
	Autonomy in budget [BUDGET]			−0.016	0.010
	Autonomy in assessment [ASSESS]			−0.007	0.012
	School life expectancy [SCH_LIFE]			0.463**	0.228
Constant		8.663***	0.396	6.285*	3.393
Time dummies		Yes		Yes	
Country fixed effects		Yes		Yes	
N. parameters estimated (country fixed effects included)		41		50	
N. observations		160		154	
Adjusted R^2		0.087		0.243	
F test for significance of:					
Time effects		$F_{4,119} = 3.60$ (p value = 0.0083)		$F_{4,104} = 4.69$ (p value = 0.0016)	
Country effects		$F_{35,119} = 17.49$ (p value = 0.0000)		$F_{35,104} = 13.59$ (p value = 0.0000)	
Time and country effects		$F_{39,119} = 15.88$ (p value = 0.0000)		$F_{39,104} = 12.36$ (p value = 0.0000)	

Table 5 continued

Category	Variable	Model 3		Model 4		Model 5	
		Coef.	SE	Coef.	SE	Coef.	SE
School system input	Education expenditure (% Gov) [EXP_GOV]	0.240***	0.062	0.233***	0.078	0.269**	0.121
Students' characteristics	% Immigrants [STUD_IMMIG]	−0.198***	0.034	−0.156***	0.041	−0.171***	0.046
	% Fathers employed [FATHER_FULL]	0.098**	0.048	0.085	0.055	0.047	0.060
Economic performance	GDP per capita [GDP]	−0.191*	0.098	−0.192*	0.110	−0.301***	0.117
Educational system's characteristics	Index of school educational resources [SCMATEDU]	1.294***	0.378	0.797*	0.436	1.043***	0.403
	Private schools [PRIVATE]	0.009	0.014	0.149***	0.042	0.122***	0.042
	Funds from government [GOV_FUNDS]	0.011	0.030	0.034	0.030	0.033	0.039
	Autonomy in budget [BUDGET]	−0.021**	0.010	−0.010	0.017	−0.015	0.022
	Autonomy in assessment [ASSESS]	−0.008	0.012	−0.028	0.019	−0.025	0.022
	School life expectancy [SCH_LIFE]	0.389	0.245	−0.573	0.403	−0.435	0.429
Interactions with D_GDP12	EXP_GOV × D_GDP12	−0.469*	0.263	−0.439*	0.246	−0.583**	0.235
	SCMATEDU × D_GDP12			0.684	0.565	0.357	0.527
	PRIVATE × D_GDP12			−0.148***	0.047	−0.121***	0.044
	GOV_FUNDS × D_GDP12			0.131	0.133	0.191	0.149
	BUDGET × D_GDP12			−0.019	0.022	−0.019	0.024
	ASSESS × D_GDP12			0.065**	0.032	0.084**	0.033
	SCHLIFE × D_GDP12			1.140***	0.439	1.059**	0.519
Interactions with EXP GOV	SCMATEDU × EXP_GOV					−0.005	0.058
	PRIVATE × EXP_GOV					0.002	0.003
	GOV_FUNDS × EXP_GOV					−0.012**	0.005
	BUDGET × EXP_GOV					−0.005*	0.003
	ASSESS × EXP_GOV					0.001	0.004
	SCHLIFE × EXP_GOV					0.098	0.079

Table 5 continued

Category	Variable	Model 3		Model 4		Model 5	
		Coef.	SE	Coef.	SE	Coef.	SE
Constant		6.491*	3.345	1.398	7.947	3.292	8.858
Time dummies		Yes		Yes		Yes	
Country fixed effects		Yes		Yes		Yes	
N. parameters estimated (country fixed effects included)		51		57		63	
N. observations		154		154		154	
Adjusted R^2		0.275		0.333		0.370	
F test for significance of:							
Time effects		$F_{4,103} = 5.43$ (p value = 0.0005)		$F_{4,97} = 4.86$ (p value = 0.0013)		$F_{4,91} = 5.43$ (p value = 0.0006)	
Country effects		$F_{35,103} = 14.28$ (p value = 0.0000)		$F_{35,97} = 13.15$ (p value = 0.0000)		$F_{35,91} = 13.10$ (p value = 0.0000)	
Time and country effects		$F_{39,103} = 12.98$ (p value = 0.0000)		$F_{39,97} = 12.19$ (p value = 0.0000)		$F_{39,91} = 12.09$ (p value = 0.0000)	

*,** and *** denotes variables that are statistically significant at 10, 5 and 1 % levels respectively

proportion of immigrant students (STUD_IMMIG) is highly significant with a negative sign, thus confirming in a longitudinal framework findings from previous cross-sectional studies, that showed how these students are less likely than natives to overcome their disadvantaged background (Agasisti and Longobardi 2014a, b). In a policy perspective, an important result is the positive and statistically significant effect of SCMATEDU index that measures the headteachers' perceptions about the quality and quantity of educational resources. Indeed, it identifies a possible factor related to the organisation of the educational system that can act positively on its equity; improving the quality and quantity of educational resources is not the same than improving the level of resources *per se*. In other words, this finding highlights how the type of spending matters; when the resources are budgeted for educational purposes (and not for other purposes such as supporting services, etc.), these can help disadvantaged students in obtaining good academic results. While the specific (causal) mechanisms behind this positive effect are not investigated here, this evidence constitutes a further step in modelling the relationship between spending, educational activities and results. Positive effects are also estimated for FATHER_FULL and SCH_LIFE, thus providing evidence that increases in the share of students whose father works with a full-time contract as well as in the exposition to schooling seem benefiting the equity of the educational systems. Lastly, per capita GDP has a negative sign, suggesting that the higher the economic development, the lower the equity of the educational system as measured through resilience.

In order to analyse the complex relationship between spending, economic development and institutional characteristics, we have added some interaction terms to the empirical analyses. In Model 3, we add the interaction between the public expenditure and the D_GDP12 dummy. The coefficient of the expenditure variable becomes now significant and with a positive sign whereas the coefficient of its interaction with GDP is significantly negative. This means that the effect of allocating more resources (in percentage of total government spending) to education has a different impact on resilience depending on the economic development of the country. In poorer countries the impact is positive, being measured by the main effect of EXP_GOV. In richer countries, on the other hand, the impact is negative, being given by the sum of main effect and interaction term. Moreover, unlike the results of Model 2, the variable on school life expectancy loses its significance whereas the effect of the share of schools with autonomy in budget formulation (BUDGET) is now significantly negative.

In Model 4, all the educational system characteristics are interacted with D_GPD12. The coefficient of the share of private school (PRIVATE) becomes now highly significant with a positive sign, indicating that increases in the proportion of private schools are associated with increases in the proportion of resilient students. The available data do not allow investigating whether either direct effects (i.e. attending private schools helps resilience) or indirect ones (competition stimulates school-level actions for poorer students) prevail. Nevertheless, the positive effect is only relevant for poorer countries, being counterbalanced for richer countries by the negative coefficient of the interaction term. In addition, albeit the school life expectancy is no more statistically significant, its interaction with GDP is positive and statistically significant, suggesting that more years of schooling are beneficial for equity only in those countries that are already economically developed. It is important to highlight that the variable about the quality and quantity of educational resources (SCMATEDU) remains significant while its interaction with GDP is not; this suggests that the effect of better resources on educational resilience is positive irrespective of the GDP being low or high.

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The interaction between the school autonomy in assessment policy and the GDP dummy (ASSESSxD_GDP12) is positive, even if small in magnitude; in this light, school autonomy in assessing students' results helps the poorer ones in obtaining good results only in the countries that are economically better-off.

In the last specification (model 5), the variables about the characteristics of the educational system and the schools are interacted with the variable EXP_GOV. The explanatory power of the model increases (R^2 reaches around 37 %) while the magnitude of all the estimated coefficients seems to be unaltered as their significance does. In particular, the effect of public spending maintains its magnitude, as well as its positive sign and statistically significance. Also, the interaction term EXP_GOVxGDP is unchanged, which confirms that increases in the educational expenditure over time play a role for raising the proportion of resilient students only for low GDP countries. Moreover, since the interactions BUDGETxEXP_GOV and GOV_FUNDSxEXP_GOV show negative and significant coefficients, the effect of public spending seems to be further reinforced in those countries, where both the average share of school funds coming from government and the share of schools with autonomy in formulating the budget is below the average.

6 Concluding remarks

This paper addresses the educational equity of a system through the definition of a measure (educational resilience) that accounts for the ability of disadvantaged students to achieve high school performance. More specifically, the disadvantaged condition is defined at both family and school level whereas the performance is derived from PISA score.

The analysis is performed at country level on a macro panel dataset coming from the pooling of five PISA waves (from 2000 to 2012) on a cross-section of countries. The estimation of panel Fixed Effects (FE) models allows to investigate the main determinants of the resilience (expressed as the percentage of resilient students in each country) in a longitudinal framework.

The main result is that the investment in education—in the form of both financial and material resources allocated for educational purposes—does matter for equity. Indeed a growth over time in the public spending on education as well as a better quality endowment of educational resources involve a significant increase in the share of resilient students. In other words, the education systems that benefit from an increase in the share of public expenditure and from more adequate equipment seem to be more able to limit the negative impact of the disadvantaged students' background on their schooling performance. Nevertheless the positive sign for the share of public expenditure is only valid for low-income countries, suggesting that for these countries the priority investment on educational resources can help the overall equity of the system.

A further discussion about the effects of the expenditure variables is worth of attention. The positive sign (and statistical significance) associated with the variable that measures the proportion of public expenditure devoted to education (EXP_GOV) has been interpreted throughout the paper as one indicator of the "intensity" of (financial) investment on education. Actually, this interpretation holds only when considering countries with similar levels of public spending; if this is not the case (as in this paper, that considers a wide and diversified group of countries) the indicator EXP_GOV can capture not only the amount of financial resources, but also the cultural orientation towards education. In other words, those countries where EXP_GOV is higher are not only (or not necessarily) those where

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education receives more money, but those where education is funded more than other public policies. In this sense, the positive effect on the proportion of resilient students is likely not to be driven by a direct financial effect, but instead by an indirect action of the cultural preferences of citizens towards a more equal (or inclusive) educational system. If, for instance, the governments of these countries are stimulated to invest more in education as a key driver for promoting the equality of opportunities, the direct nexus between expenditure and proportion of resilient students is mediated by different policy orientations and activities in the educational system that go beyond expenditure alone.

The discussions about the potential different channels of this effect do not change the central message of the paper: investing public money on education, and specifically on educational core resources for the quality of teaching, can help disadvantaged students to beating the odds, and can support the final goal of making the educational systems positive agents in promoting the equality of opportunities.

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