Evaluation of students' performance at lower secondary education. An empirical analysis using TIMSS and PISA data.

L'impatto della scuola secondaria di I grado sul rendimento degli studenti. Un'analisi empirica con l'impiego dei dati TIMSS e PISA.

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Abstract The present paper aims to investigate the net impact of lower secondary education on the level of literacy in mathematics, using the international assessment of educational systems provided by TIMSS in 2007 and PISA in 2012, across OECD countries and partners. We apply a pseudo–panel approach, linking PISA achievements of 15-year-old students in 2012 with those of the same cohort in the 2007 edition of TIMSS, since *the same generation* of students is taken into account. From this perspective, we are able to assess the cumulative effects of education of students at 4th grade in 2007 on performance at 9th grade in 2012.

Abstract *Il presente lavoro ha lo scopo di individuare l'impatto della scuola secondaria di I grado sul rendimento degli studenti, misurati dalle rilevazioni internazionali TIMSS e PISA, nei paesi appartenenti all'OCSE. L'analisi si basa sulla costruzione di uno pseudo–panel in cui i risultati forniti da PISA nel 2012 vengono collegati ai dati TIMSS raccolti nel 2007, poiché la stessa coorte di studenti è stata sottoposta alle rilevazioni. Da questo punto di vista, siamo in grado di valutare l'effetto cumulativo dei cicli di istruzione, dalla scuola primaria (4 grado di istruzione) alla scuola secondaria di secondo grado (9 grado di istruzione).*

Key words: Evaluation of students' performance, pseudo–panel approach, causal inference.

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1 Introduction

Lower secondary school is a key stage of the educational path since it gives the best opportunity to strengthen basic skills and to protect students against the risk of lack of competences and educational failure in the transition between primary and upper secondary school. Preteen students go through a complex shift in their social, physical and intellectual development, as they leave childhood behind and prepare for adult responsibilities. These years are a critical point for maturation as children's roles in school and society change [4].

The present paper aims to investigate the net impact of lower secondary education on the level of literacy in mathematics, using the international assessment of educational systems provided by TIMSS[1] in 2007 and PISA[2] in 2012, across OECD countries and partners[3].

2 Methodology

We apply a pseudo–panel approach [3], linking PISA achievements of 15-year-old students in 2012 with those of the same cohort in the 2007 edition of TIMSS, since *the same generation* of students is taken into account. From this perspective, we are able to assess the cumulative effects of education of students at 4th grade in 2007 on their performance at 9th grade in 2012.

Following [1], we employ a two-step procedure:

1. For each subject i, we first estimate the impact of time-invariant observables[4] of 4th-graders, $Z_i^{(4)}$, on the performances of students' in 2007 by a linear model

$$y_{i,2007}^{(4)} = \gamma^T Z_i^{(4)} + \varepsilon_{i,2007} \tag{1}$$

where $y_{i,2007}^{(4)}$ is the score obtained by student i in TIMSS at 4th-grade and γ^T denotes the vector of coefficients attached to the time-invariant individual characteristics at grade 4.

In order to predict the test scores at grade 4 for the 9th-graders in 2012, we substitute the appropriate Z_i values for the time-invariant variables of 9th-graders, K_i, employing the vector of coefficient estimated using TIMSS data

[1] Trends in International Mathematics and Science Study

[2] Programme for International Student Assessment

[3] We collected data from the following countries: Australia, Austria, Czech Republic, Denmark, England, Germany, Hong Kong, Hungary, Italy, Japan, Kazakhstan, Latvia, Lithuania, Netherlands, Norway, New Zealand, Qatar, Slovakia, Russia, Scotland, Singapore, Sweden, Taiwan, Tunisia, United States

[4] I.e., gender, year of birth, family composition and specific items to catch the socioeconomic status of students.

$$\hat{y}^*_{i,2007} = \hat{\gamma}^T K_i^{(9)} \tag{2}$$

2. We include the predicted score at 4th grade as a proxy of the entry-level of students in secondary schools, with the aim to understand how sociodemographic characteristics affect students achievement at the beginning of upper secondary school. Therefore, we employ a model where we control for the learning gaps by the end of grade 4, including time-variant characteristics, $\hat{\gamma}^T K_i^{(9)}$, with time-invariant observables.

$$y^{(9)}_{i,2012} = \alpha \hat{y}^*_i + \gamma^T K_i^{(9)} + \beta^T X_i^{(9)} + u_i \tag{3}$$

where $y^{(9)}_{i,2012}$ is the score obtained by student i in PISA at 9th-grade.

Preliminary results for Italy

To verify our approach, we first run the analysis for Italy, since the recent research conducted by [2], shows that the performance of the Italian lower secondary schools is quite worrying. Further, this gap is difficult to fill at the secondary schools level, especially for students enrolled in vocational high school, and this mechanism could be responsible for disparities in both educational prospective and results of students.

Table 1 reports the time-invariant factors observed in both dataset. Unfortunately, TIMSS data at grade 4 does not include information on the educational level of parents, therefore we use the number of books at home and three specific country's item as a proxy of the indicator of sociocultural background of students', since there is a strong association among these covariates and the parents' educational attainment.

Table 1 Descriptives of the Italian sample: time-invariant factors

	TIMSS	**PISA**
N. of Obs.	4,470	31,073
Variables (%)		
Female	51.3	49.1
Born in the country	95.1	92.4
Age of arrival in Italy		
$<$ 1 year old	35.5	29.5
Btw. 1 and 5	41.5	27.2
$>$5 years old	23.0	43.3
Father born in the country	91.4	88.2
Mother born in the country	90.3	86
Books at home		
0 – 10	14.4	11.7
11 – 25	30.8	19.6
26 – 100	30.4	29.8
101 – 200	12.0	17.9
$>$ 200	12.4	21.0
Internet Connection	54.5	92.7
Air Conditioning	47.9	55.7
Alarm System	34.2	36.7

Table 2 Estimates of time-invariant observables on test scores at grade 4 (Standard error in brackets).

Variables	**Model 1**	**Model 2 (With fixed effects)**
Sex (Male=1)	-16.747^{***} (2.254)	-13.599^{***} (1.929)
Born in the Country (=1)	26.935^{*} (8.564)	28.811^{***} (7.676)
Age of arrival in Italy (*Ref. Btw. 1 and 5*)		
<1 year old	1.108 (13.282)	1.253 (11.604)
>5 years old	32.636^{*} (11.648)	23.026^{*} (9.983)
Father born in the country (=1)	12.031^{*} (4.843)	13.906^{**} (4.256)
Mother born in the country (=1)	1.616 (4.609)	3.971 (4.530)
Books at home (*Ref.* $0-10$)		
$11-25$	21.204^{***} (3.520)	8.970^{**} (3.044)
$26-100$	38.692^{***} (3.557)	20.975^{***} (3.108)
$101-200$	41.623^{***} (4.411)	23.766^{***} (3.865)
>200	36.641^{***} (4.380)	17.232^{***} (3.854)
Internet Connection	8.485 (2.345)	1.623 (2.103)
Air Conditioning	-5.507^{*} (2.300)	-3.350 (2.020)
Alarm System	2.219 (2.446)	.764 (2.153)
Self-perception of ability	No	Yes
% students disadv. SE background	No	Yes
Area of residence fixed effect	No	Yes
School fixed effect	No	Yes
Constant	445.230^{***} (8.588)	429.51^{***} (14.500)
# Observations	4,470	4,470
R-squared	0.062	0.378

$^{***}\ p < .001$; $^{**}\ p < .01$; $^{*}p < .05$

Table 2 reports the estimates of time-invariant observables, $\hat{\gamma}^T$, on test scores at grade 4 (Model 1). As a robustness check we repeat the estimation including time-vaying individual variables (e.g., the self-perception of ability of students' and the percentage of students' with disadvantaged socioeconomic background), the area of residence and school fixed effects (Model 2). We find that parameters do not change significantly and the R-squared improves considerably. In order to predict the entry level of students in 2012 we only include in equation (2) the significant coefficients estimated in Model 1.

Table 3 shows the estimates of the test scores' determinants at 9th-grade, accounting for the entry level of students in secondary schools, personal and sociodemographic characteristics of students. The number of observations drops from $31,073$ to $20,320$ due to missing values. The indicators of sociocultural background is at the center of our investigation on the influence of family on achievement and educational choices. Thus, we consider the education attainment of parents as a proxy of the amount and quality of family inputs and we find that the lower educational level of parents negatively affects the performance of students. According to the relevant literature, the type of high school impacts on the achievements of students: vocations schools negatively influence students' performance, while lyceum positive affects students' results. We also include the PISA index of Economic, Social and Cultural Status (ESCS) of students finding that better status corresponds to higher performance. The analysis takes into account the confidence of students towards mathematics, measured throughout the mathematics anxiety index where

Table 3 Estimates of the test scores' determinants at grade 9

Variables	**Coeff.**	**Std. error**
Estimated entry level at grade 4	.708***	.0368
Sex (Male=1)	40.712***	1.204
Native students (=1)	7.293**	2.176
Age of arrival in Italy (*Ref. Btw. 1 and 5*)		
$<$ 1 year old	−11.989**	4.055
$>$5 years old	−17.298***	3.368
Father Education (Ref. Higher)		
Lower secondary or less	−4.294*	1.844
Upper secondary education	2.302	1.844
Mother Education (*Ref. Higher ed.*)		
Lower secondary or less	−6.261***	1.348
Upper secondary education	−5.952***	1.133
Type of high school ((*Ref. Technical*)		
Vocational	−53.322***	1.483
Lyceum	36.276***	1.198
ESCS Index	3.865***	.7618
Math anxiety	−26.501***	.5609
Disciplined clima	8.0357***	.502
Italian Region (*Ref. Abruzzo*)		
Basilicata	−24.500***	2.585
Calabria	−53.510***	2.225
Campania	−41.456***	2.619
Emilia Romagna	19.259***	2.619
FVG	25.373***	2.626
Lazio	−21.866***	2.627
Liguria	-4.397	2.656
Lombaridia	20.816***	2.594
Marche	13.150***	2.623
Molise	−37.849***	2.864
Piemonte	13.994***	2.245
Puglia	−8.240**	2.575
Sardegna	−31.626***	2.722
Sicilia	−42.910***	2.656
Toscana	14.360***	2.698
Trentino Alto Adige	21.388***	2.364
Umbria	1.217	2.671
Veneto	36.949***	2.378
Constant	428.740***	3.509
Observations	20,320	
R-squared	0.4138	

*** $p < .001$; ** $p < .01$; *$p < .05$

higher difficulty corresponds to higher level of anxiety, that negatively affects the results of students. Moreover, the information on disciplinary climate in the classroom, based on five items, reveals that students better learn in disciplined contexts. Finally, we consider the impact of the Italian regions where students are enrolled on their performance. We observe high variability among Italian regions, in line with both national and international assessments: students attending schools located in the northern Italian regions outperform their peers enrolled in the South.

Conclusions

Gender gap: the observed gap at 9th grade has been actually generated during the lower secondary school, with respect to what we observed at 4th grade.
Achievements of immigrant: foreign-origin students lag behind Italian native students, and the gap increases from primary to secondary schools.
Family background: students with a disadvantaged background (i.e., parents with at most lower secondary education completed) score lower than their peers with higher educated parents.
The impact of the high school: students attending vocational institutes show lower performance, while the Lyceum increase the results of students. This results confirms that students' achievements are extremely diversified across types of secondary schools (Bratti et al., 2007).
Economic, social and cultural status of students (ESCS): students with a higher ESCS outperform their peers with lower ESCS.
Students' attitude towards mathematics: the anxiety towards mathematics negatively affects the performance of students.
Disciplinary climate in the classroom: students enrolled in quiet classrooms achieve better performance.
Italian Regions: the analysis highlights the variability existing among Italian regions, when the results of students are considered. According to both the National and International assessments, students in the North of Italy outperform their peers from the South.

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