

TECHNICAL NOTES ON MULTILEVEL REGRESSION ANALYSIS FOR PERFORMANCE-RELATED PAY FOR TEACHERS

1. The relationship between performance-related pay for teachers, teachers' salaries and student performance in reading presented in Figure 2 is examined based on a multilevel analysis. A three-level regression analysis is conducted using HLM 6.08, with students serving as level 1, schools as level 2 and countries as level 3. The model coefficients and statistics are estimated using Maximum Likelihood method procedure. Five plausible values for performance in reading (PV1READ to PV5READ) are used.

Data

2. The data file used for this analysis includes 212 836 students from 7 638 schools in 27 OECD countries. Canada, Chile, France, Mexico, New Zealand, the Slovak Republic and Turkey are not included, as data for performance-related pay for teachers and/or teachers' salaries are not available. All variables used at the student and school levels of the models are from PISA 2009 student and school questionnaires. Country-level indicators are either from *Education at a Glance 2011: OECD Indicators* (OECD, 2011) or are extracted from the PISA system-level data collection 2010.

3. Table 1 presents the use of criteria related to teachers' qualifications, training and performance for the decisions on payments for teachers in public institutions. The variable of performance-related pay for teachers in Table 2 is based on columns (7), (8) and (9) in Table 1. This variable is 1, if "outstanding performance in teaching" is used for deciding at least one of the following: position in base salary scale, supplemental payments that are paid every year, or supplemental incidental payments. For Belgium and the United Kingdom, the average value is used. The second column in Table 2 presents the weighted average of upper and lower secondary school teachers. The average is computed by weighting teachers' salaries for upper and lower secondary school according to the respective 15-year-old students' enrolment.

4. Socio-economic and demographic background variables are included in some models in order to examine the net effects of performance-related pay for teachers and teachers' salaries. The background variables at the system-level used in the models are GDP per capita and cumulative expenditure by educational institutions per student aged 6 to 15. These are presented in the third and fourth columns in Table 2, respectively. At the school level, school average *PISA index of economic, social and cultural status* (ESCS), school size and school location are included. At the student level, ESCS, gender, language spoken at home and immigrant status are included.

Student weights

5. Data files are weighted at the student level with "normalised student final weights", which are computed based on the student final weights (W_FSTUWT) in the PISA 2009 dataset. The student final weights (W_FSTUWT) are normalised at the international level, including 27 OECD countries, to make the sum of the weights across the 27 countries equal to the number of students across the 27 countries in the dataset; maintain the same proportion of weights as in the student final weights (W_FSTUWT) within each country; and ensure that each individual country's contribution to the analysis is equal by introducing a country factor (i.e. the sum of the weights within each country is the same for all 27 countries).

Table 1
Decisions on payments for teachers in public institutions (2009)
Criteria for base salary and additional payments awarded to teachers in public institutions

	Criteria related to teachers' qualifications, training and performance																	
	Holding an initial educational qualification higher than the minimum qualification required to enter the teaching profession			Holding a higher than minimum level of teacher certification or training obtained during professional life			Outstanding performance in teaching			Successful completion of professional development activities			Reaching high scores in the qualification examination			Holding an educational qualification in multiple subjects		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
OECD																		
Australia	—			—														
Austria									Δ									
Belgium (Fl.)	—				▲													
Belgium (Fr.)	—			—														
Canada	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m
Chile				—					Δ	—							▲	
Czech Republic							—	▲	Δ									
Denmark	—	▲	Δ	—	▲	Δ		▲	Δ	—	▲	Δ				—	▲	Δ
England	—	▲	Δ				—	▲	Δ									
Estonia	—			—				▲	Δ	—							▲	Δ
Finland	—			—	▲			▲			▲					—		
France										—								
Germany																		
Greece	—				▲													
Hungary	—			—					Δ	—							▲	
Iceland	—	▲	Δ	—	▲	Δ					▲	Δ			Δ			Δ
Ireland	—	▲		—	▲													
Israel	—			—							▲							
Italy																		
Japan																		
Korea												Δ						
Luxembourg				—						—								
Mexico	—	▲		—	▲		—	▲		—	▲		—	▲		—	▲	
Netherlands	—	▲	Δ	—	▲	Δ	—	▲	Δ	—	▲	Δ	—	▲	Δ	—	▲	Δ
New Zealand	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m
Norway	—	▲			▲			▲			▲			▲			▲	
Poland	—	▲	Δ					▲	Δ	—					Δ			
Portugal	—			—						—			—					
Scotland				—														
Slovak Republic								▲	Δ	—	▲							
Slovenia		▲			▲				Δ	—								
Spain					▲					—								
Sweden	—			—			—			—			—					
Switzerland																		
Turkey	—				▲		—		Δ		▲							
United States	—	▲		—	▲				Δ	—	▲							

Criteria for:

Decisions on position in base salary scale

Decisions on supplemental payments which are paid every year

Decisions on supplemental incidental payments

m: Data are not available.



Source: Table D3.5a in Education at a Glance (OECD, 2011).

Table 2.
Country-level indicators and average student performance

	Performance-related pay for teachers	Teachers' salaries relative to GDP/capita (weighted average of upper and lower secondary school teachers)	GDP per capita (1 000 USD. In equivalent USD converted using PPPs)	Cumulative expenditure by educational institutions per student aged 6 to 15 (1 000 USD. In equivalent USD converted using PPPs)	Mean student performance on the reading scale	
					Mean	S.E.
	TPP (1)	YSALARY (2)	YGDP (3)	EXPEND (4)	(5)	
Australia	0	1.27	37.62	72.39	515	(2.3)
Austria	1	1.13	36.84	97.79	470	(2.9)
Belgium	0	1.35	34.66	80.14	506	(2.3)
Canada	m	m	36.40	80.45	524	(1.5)
Chile	1	m	14.11	23.60	449	(3.1)
Czech Republic	1	0.94	23.99	44.76	478	(2.9)
Denmark	1	1.16	36.33	87.64	495	(2.1)
Estonia	1	0.61	20.62	43.04	501	(2.6)
Finland	1	1.15	35.32	71.38	536	(2.3)
France	m	1.05	32.49	74.66	496	(3.4)
Germany	0	1.69	34.68	63.30	497	(2.7)
Greece	0	1.13	27.79	48.42	483	(4.3)
Hungary	1	0.92	18.76	44.34	494	(3.2)
Iceland	0	0.74	36.33	94.85	500	(1.4)
Ireland	0	1.26	44.38	75.92	496	(3.0)
Israel	0	0.82	26.44	53.32	474	(3.6)
Italy	0	1.13	31.02	77.31	486	(1.6)
Japan	0	1.44	33.63	77.68	520	(3.5)
Korea	0	2.01	26.57	61.10	539	(3.5)
Luxembourg	0	1.18	82.46	155.62	472	(1.3)
Mexico	1	m	14.13	21.17	425	(2.0)
Netherlands	1	1.35	39.59	80.35	508	(5.1)
New Zealand	m	1.42	27.02	48.63	521	(2.4)
Norway	1	0.66	53.67	101.26	503	(2.6)
Poland	1	0.96	16.31	39.96	500	(2.6)
Portugal	0	1.55	22.64	56.80	489	(3.1)
Slovak Republic	1	m	20.27	32.20	477	(2.5)
Slovenia	1	1.18	26.56	77.90	483	(1.0)
Spain	0	1.49	31.47	74.12	481	(2.0)
Sweden	1	0.92	36.79	82.75	497	(2.9)
Switzerland	0	1.58	41.80	104.35	501	(2.4)
Turkey	1	m	13.36	12.71	464	(3.5)
United Kingdom	0.5	1.32	34.96	84.90	494	(2.3)
United States	1	1.00	46.43	105.75	500	(3.7)

Note: Column (1) is based on Columns (7) (8) (9) in Table 1. This indicator is 1, if "outstanding performance in teaching" is used for deciding at least one of the followings: position in base salary scale, supplemental payments which are paid every year, or supplemental incidental payments. For Belgium and the United Kingdom, the average value is used. Column (2) is the weighted average of upper and lower secondary school teachers. The average is computed by weighting teachers' salaries for upper and lower secondary school according to the respective 15-year-old students' enrolment.

Source:

Column (1): Table D3.5a in Education at a Glance (OECD, 2011). See Table 1.

Column (2): Table IV.3.21a in PISA 2009 Results, What Makes a School Successful? Resources, Policies and Practices (Volume IV) (OECD, 2010a).

Column (3): Table IV.3.21c in PISA 2009 Results, What Makes a School Successful? Resources, Policies and Practices (Volume IV) (OECD, 2010a).

Column (4): Table IV.3.21b in PISA 2009 Results, What Makes a School Successful? Resources, Policies and Practices (Volume IV) (OECD, 2010a).

Column (5): Table I.2.3 in PISA 2009 Results, What Student Know and Can Do: Student performance in reading, mathematics and science (Volume I) (OECD, 2010b).

Treatment of missing data

6. While countries with missing values in the system-level variables are not included in the analysis, missing values in the background variables at the school and student levels are imputed. Even though the missing rate is less than 5% for most of the variables, a list-wise deletion of observations that have a missing value of at least one variable would have reduced the sample size by 9.6%, since around 13 variables are included in the models. Therefore, missing values are imputed in order to include the maximum number of cases in the analysis.

7. Since the missing rates are not high for most of the background variables and only background variables are imputed, a simple imputation approach was used to circumvent the problem of missing data: predictors at the individual and school levels were imputed using a dummy variable adjustment (Cohen and Cohen, 1985). It is known that this imputation method generally produces biased estimates of coefficients (Jones, 1996), and that standard errors of those variables that contain missing values are underestimated since they do not account for the uncertainty introduced through imputation. However, given that less than 5% of the data are missing on most variables, this bias is considered negligible. Furthermore, system-level variables that are the main focus of the models are not imputed.

8. As a first step of the imputation, a so-called “missing dummy” variable is created for all variables with missing values, regardless of whether a variable was continuous, categorical or dichotomous. A missing dummy variable is set to 1 if the data were missing on that variable; it was set to 0 if the data are not missing. Three missing dummies (for school average ESCS, school location and school size) are created at the school level. Four missing dummies (for ESCS, gender, language spoken at home and immigrant status) are created at the student level.

9. As a second step, missing values are imputed for continuous variables. Missing values are replaced by the weighted school average of the variable. If all data on the respective variable are missing in one school, such that the weighted school mean could not be computed, the weighted country mean is imputed. Missing values for dichotomous variables are replaced by zero.

Modelling student performance

10. In order to examine how the system-level performance-related pay for teachers and teachers' salaries are related to students' performance in reading before and after accounting for background characteristics of students, schools and systems, four models are developed. Model 1 in Table 3 is the simplest model that contains only the variable of performance-related pay for teachers at the system-level without any background variables. In Model 2, background variables at the system, school and student levels are added to Model 1. In Model 3, the variable of teachers' salaries is added to Model 2. In Model 4, an interaction effect between performance-related pay for teachers and teachers' salaries is added to Model 3.

11. In all models, all the slopes are fixed and only the intercepts are randomised at all three levels. The variables of GDP per capita and cumulative expenditure are grand mean centred (i.e. the mean of YGDP and EXPEND across 27 countries are sent to zero), and all other variables are uncentred.

12. In the 27 OECD countries with available data, there is no clear relationship between having performance-related pay schemes and average student performance. There is no performance difference between countries with and without such a scheme both before accounting for background characteristics (Model 1) and after accounting for the socio-economic backgrounds of students, schools and countries (Model 2).

13. The picture changes when the overall level of teachers' salaries is considered together with performance-related pay schemes for teachers. The ratio of statutory teachers' salaries to GDP per capita is one way of placing teachers' salary levels in the context of a country's wealth. This facilitates comparison across countries. In Estonia and Norway, the salaries of teachers with 15 years of experience are two-thirds or less of the GDP per capita; in Germany, Korea, Portugal and Switzerland, those salaries are 1.5 times or more of GDP per capita (Table 2).

14. After accounting for the level of teachers' salaries in addition to socio-economic background, performance-related pay for teachers is not significantly related to performance (Model 3). In the same model, the level of teachers' salaries is positively related to performance ($p=0.00$). Compared with countries where teachers' salaries are similar to GDP per capita, those countries where teachers' salaries are twice as much as GDP per capita tend to perform 35 score points higher in the PISA reading assessment.

15. The relationship between performance-related pay for teachers and student performance seems to vary according to the general level of teachers' salaries. In Model 4, the interaction between teachers' salaries and performance-related pay for teachers is added to Model 3. Performance-related pay for teachers is positively related to student performance ($p=0.07$), as are teachers' salaries ($p=0.00$). It is also evident that the interaction between these two indicators is negatively related to student performance. This implies that among the countries with relatively lower teachers' salaries, those countries that offer performance-related pay to teachers tend to perform better than countries without it, while among the countries that pay teachers higher salaries, the relationship is the reverse: those countries that do not offer performance-related pay tend to perform better than countries that do.

16. The robustness of the results is examined by including further system-level variables. The following four intuitional variables were found to be related to student performance at the system level: the percentage of students who repeated one or more grades; the percentage of students in schools that transfer students to other schools due to low achievement, behavioural problems or special learning needs; the percentage of students in schools that group students by ability in all subjects; and the average index of school responsibility for curriculum and assessment (See *PISA 2009 Results Volume IV*, OECD, 2010a). First, grade repetition is included in Model 4 in Table 3. After accounting for the percentage of students who repeated one or more grades in addition to the socio-economic background of students, schools and countries, the results show that the coefficient for TPP (i.e. performance-related pay for teachers) is 6.0 ($p=0.091$), the coefficient for (YSALARY-1) (i.e. teachers' salaries relative to GDP per capita) is 48.1 ($p=0.00$), and the coefficient for TPP*(YSALARY-1) (i.e. the interaction between previous two variables) is -40.7 ($p=0.002$). These results are similar to the results of Model 4. Second, after accounting for all four institutional variables in addition to the socio-economic background of students, schools and countries, the results show that the coefficient for TPP (i.e. performance-related pay for teachers) is 5.6 ($p=0.168$), the coefficient for (YSALARY-1) (i.e. teachers' salaries relative to GDP per capita) is 47.7 ($p=0.00$), and the coefficient for TPP*(YSALARY-1) (i.e. the interaction between previous two variables) is -41.4 ($p=0.008$).

17. Nine of the 13 countries with the lowest levels of teachers' salaries relative to GDP per capita use performance-related pay initiatives, while four of the 14 countries with the highest level of teachers' salaries related to GDP per capita use the initiatives (Table 2). There are no countries with performance-related pay initiatives among the countries where teachers' salaries are 1.36 times GDP per capita or more. In order to examine the robustness of the results in Model 4 in Table 3, the variable of teachers' salaries relative to GDP per capita is replaced by a dichotomous variable of high levels of teachers' salaries relative to GDP per capita (1=teachers' salaries over 1.151 times GDP per capita; 0=teachers' salaries are 1.151 times GDP per capita or less). With this dichotomous teachers' salaries variable, the coefficient for TPP (i.e. performance-related pay for teachers) is 11.60 ($p=0.056$), the coefficient for HIGHSAL (i.e. high levels of teachers' salaries relative to GDP per capita) is 31.68 ($p=0.001$), and the coefficient for the interaction between two variables is -29.94 ($p=0.010$). These results suggest that among the countries with low teachers' salaries, countries with performance-related pay initiatives tend to perform 12 score points higher than countries without them, while among the countries with high teachers' salaries, those with performance-related pay initiatives tend to perform 18 score points lower than countries without them. Another model is also developed to further examine the non-linearity of the interaction between performance-related pay initiatives and teachers' salaries relative to GDP per capita. Quadratic terms of (YSALARY-1) are included in Model 4. The results show that the quadratic terms are not significant: the coefficient for (YSALARY-1)*(YSALARY-1) is 3.72 ($p=0.851$) and the coefficient for (YSALARY-1)*(YSALARY-1)*TPP is -71.34 ($p=0.170$). The coefficient for TPP is 9.74 ($p=0.072$), the coefficient for (YSALARY-1) is 44.13 ($p=0.003$), and the coefficient for TPP*(YSALARY-1) is -44.26 ($p=0.016$). These results are similar to the results of Model 4.

Table 3.
Relationship between performance-related pay for teachers, teachers' salaries and other characteristics of students, schools and systems

		Model 1			Model 2			Model 3			Model 4		
		coeff.	s.e.	p-value	coeff.	s.e.	p-value	coeff.	s.e.	p-value	coeff.	s.e.	p-value
System-level													
Performance-related pay for teachers(1=yes; 0=no)	TPP	-1.56	(8.82)	0.86	-7.97	(7.76)	0.32	3.93	(4.93)	0.43	6.37	(3.36)	0.07
Teachers' salaries relative to GDP per capita (0 means teachers' salaries at the same level as GDP per capita, 0.5 means teachers' salaries 1.5 times more than GDP per capita, and 1 means teachers salaries 2 times more than GDP per capita)	(YSALARY-1)							35.31	(9.76)		46.60	(9.05)	0.00
Performance-related pay for teachers * Teachers' salaries relative to GDP per capita	TPP*(YSALARY-1)										-42.14	(12.20)	0.00
GDP per capita (1 000 USD)	YGDP				0.02	(0.62)	0.98	0.24	(0.42)	0.57	-0.04	(0.38)	0.92
Cumulative expenditure by educational institutions (1 000 USD)	EXPEND				-0.47	(0.33)	0.17	-0.56	(0.21)	0.02	-0.38	(0.19)	0.06
School level													
School average PISA index of economic, social and cultural status	XESCS				62.81	(5.81)	0.00	62.88	(5.76)	0.00	62.87	(5.75)	0.00
School in a city	CITY				-2.40	(2.02)	0.24	-2.37	(2.01)	0.24	-2.39	(2.00)	0.23
School in a small town or village	RURAL				4.02	(2.26)	0.08	4.09	(2.27)	0.07	4.05	(2.27)	0.07
School size	SCHSIZ				1.65	(0.31)	0.00	1.63	(0.30)	0.00	1.63	(0.30)	0.00
Student level													
PISA index of economic, social and cultural status of student (ESCS)	ESCS				18.39	(1.60)	0.00	18.39	(1.60)	0.00	18.39	(1.60)	0.00
Student is a female	FEMALE				33.76	(1.87)	0.00	33.76	(1.87)	0.00	33.76	(1.87)	0.00
Students' language at home is the same as the language of assessment	LANG				12.44	(3.27)	0.00	12.43	(3.27)	0.00	12.43	(3.27)	0.00
Student without an immigrant background	NATIVE				15.11	(3.47)	0.00	15.11	(3.47)	0.00	15.12	(3.47)	0.00
Intercept		491.81	(5.92)	0.00	440.06	(8.35)	0.00	428.98	(5.15)	0.00	426.06	(4.39)	0.00

Note: 1. Values that are statistically significant at the 5% level (p<0.05) are indicated in bold; at the 10% level (p<0.10) they are indicated in italic.

References

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