An Analytical Approach to Study Socioeconomic Gradients:

Ten Hypothesis Tests in PIRLS 2006

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Abstract

The paper proposes an analytical methodology to study academic achievement disparities related to family socioeconomic status (SES). Drawing on the work of Willms (2002, 2003, 2006), it evaluates ten hypothesis about socioeconomic gradients, that is, the gradual relationship between family SES and academic achievement. For each hypothesis, the underlying theory, statistical model, and critical model test are presented and the results are discussed. The data stem from PIRLS 2006 and the hypotheses are evaluated with two-level and three-level hierarchical linear models (HLM). The methodology can be generalized to other studies and datasets. The results help to understand how inequalities are configured at the within- and between-country level.

Keywords: Socioeconomic status (SES), hierarchical linear models (HLM), PIRLS 2006.

Introduction

Willms (2002, 2003, 2006) introduced the socioeconomic gradients framework to investigate disparities related to family socioeconomic status (SES), how they are configured, and can be altered. His work provides a readily applicable method to measure family SES, characterize socioeconomic gradients, and investigate the processes that give rise to socioeconomic gradients with hierarchical linear models (HLM) (Willms & Shields, 1996; Willms, 2002, 2003, 2006). In recent work, the first author of this paper proposes a methodology to estimate family SES in PIRLS 2006 and discusses some of the practical contributions of SES studies (Caro, 2010a). This paper draws on these previous studies to present an analytical method to study socioeconomic gradients. Using data from PIRLS 2006, it evaluates ten hypothesis regarding socioeconomic gradients with two-level and three-level HLM.

With this, the paper seeks to stimulate interest and reflection on the potential benefits of adopting the socioeconomic gradients framework in IEA studies and, more generally, in national and international assessment studies of student achievement. The analytical method consists of presenting the underlying theory, statistical model, and critical model test for each hypothesis. Then the hypothesis is evaluated with HLM and the results are reported and discussed. This method provides a simple framework for testing sociological theories relating family SES to academic achievement.

The ten hypotheses are: (1) Family SES is positively and significantly related to reading performance; (2) Socioeconomic gradients are curvilinear or the influence of family SES is not constant across the range of SES; (3) The influence of family SES varies by the level of parent-child communication; (4) The cultural capital in the family mediates the relationship between family SES and academic achievement; (5) The school SES is positively related to the reading

performance of students even after accounting for family SES; (6) Differences between urban/rural schools reflect partly differences in SES of the student intake; (7) The country's socioeconomic context influences reading performance even after family SES and school SES are taken into account; (8) The relationship between family SES and academic achievement changes for the national income level of countries; (9) The relationship between school SES and academic achievement changes for the national income level of countries; (10) Segregation of schools in terms of SES varies for the country's welfare regime.

The first six hypotheses are tested within countries with two-level models of students nested in schools. The last three hypotheses are evaluated between countries with three-level models of students nested in schools and schools nested in countries. The next section describes the data, the criteria for selecting countries for two-level analysis, the measures, and modeling strategy.

Data

The data stem from the Progress in International Reading Literacy Study (PIRLS) 2006 managed by the by International Association for the Evaluation of Educational Achievement (IEA; Mullis, Martin, Kennedy, & Foy, 2007). PIRLS 2006 is the second and latest study assessing reading literacy of 4th graders. Participants of PIRLS are 40 countries and 5 Canadian provinces. Five PIRLS 2006 participating countries are selected for within-country hypotheses (i.e., two level models) according to their income per capita and SES data availability. These are the two highest income per capita countries, Norway and Luxemburg, the two lowest income per capita countries, Moldova and Indonesia, and the country closest to the average income per capita, Hungary. Three-level analyses include 30 participating countries and 5 Canadian

provinces and exclude countries with more than 30 percent missing data in the family SES indicator.

Final analytic samples for two-level models include 3,609 students in 213 classes in Norway, 5,101 students in 336 classes in Luxemburg, 3,851 students in 180 classes in Moldova, 4,683 students in 165 classes in Indonesia, and 3,847 students in 186 classes in Hungary. The final sample for three-level models consists of 155,389 students in 8,019 classes.

Measures

Reading literacy: PIRLS uses item response theory (IRT) scaling methods to measure reading literacy in a single composite scale. The scale has an average score of 500 and a standard deviation of 100. Five plausible scores based on responses of students to sub-tests are provided and used simultaneously in the analysis.

Parent-child communication (TALK): Parents reported the frequency they *talked to children about things they have done* on a Likert scale (1-4).

Number of books (BOOKS): Parents reported the number of books at home in 5 categories (1=0-10 books; 2=11-25 books; 3=26-100 books; 4=101-200 books; 5=more than 200).

Library/bookstore visits (LIBRARY): Parents reported the frequency they go with children to visit libraries or bookstores on a Likert scale (1-4).

Family SES: Caro (2010a) describes the methodology for estimating family SES. The SES measure is a composite of father's and mother's highest completed level of education, father's and mother's occupational status, home possessions, and parents' perception on their financial situation summarized into a single measure with Principal Component Analysis (PCA).

The variable was standardized to have a mean of 0 and standard deviation of 1 for the population of students included in the analysis.

School location (RURAL): Principals reported information on school location (rural/urban/suburban). Responses were recoded into two categories (1=rural; 0=urban/suburban).

GNI per capita: The gross national income per capita in 2006 with comparable purchasing power across countries (PPP). Data source is the World Bank.

Gini coefficient: Measures the degree of income inequality. The coefficient ranges from 0 to 100, where 0 corresponds to perfect equality and 100 to complete inequality. Data source is United Nations for years data were available between 1992-2007.

Models

Two-level and three-level HLM account for the multilevel structure of the data while evaluating within- and between-country hypotheses (Raudenbush & Bryk, 2002). These models enable us to distinguish group effects and between group effects and are well-suited for the analysis of family SES influences within classes and between schools as well as for the study of contextual effects. Different variable centering schemes yield distinct types of group effects. Mainly, hypotheses here deal with pure within-group and between-group effects and therefore covariates are group-mean centered (Enders & Tofighi, 2007). But covariates were also grand-mean centered for hypotheses related to contextual effects, namely, when controlling for family SES influences was necessary. The reader may consult Raudenbush and Bryk (2002) and Enders and Tofighi (2007) for HLM notation and the effects of centering.

Multiple imputation techniques were employed to impute missing data in level 1 covariates. Particularly, the multiple imputation by chained equations (MICE) method was

carried out to generate 5 imputed versions of variables within each country (Royston, 2004, 2005).

Hypothesis testing

Hypothesis 1: The hypothesis of a socioeconomic gradient

Hypothesis.

The first and most basic hypothesis states that *family SES is positively and significantly related to reading performance*.

Extensive research shows that students from lower socioeconomic background tend to perform worse than their peers from more affluent families (Sirin, 2005; White, 1982). The literature refers to this relationship as a *socioeconomic gradient* because it is gradual and increases across the range of family SES or a *socioeconomic gap* because it reflects a gap in academic achievement between students of high and low SES families. Socioeconomic gradients capture the extent to which achievement inequalities are unequally distributed among students of varying family SES.

Model.

The hypothesis is tested for each student *i* in class *j* by estimating

$$Y_{ij} = \beta_{0j} + \beta_{1j} SES_{ij} + r_{ij} \quad \ldots(1)$$

where Y_{ij} is reading performance and r_{ij} the error term. Parameters β_0 and β_1 are defined for each class *j*. Parameter β_0 is the expected reading score for a student attending class *j* with a family SES equal to the school mean SES. Parameter β_1 captures the degree of the relationship between family SES and reading performance in terms of variation in reading performance for a one unit increment in SES (1 SD).

For each class *j*, parameters β_0 and β_1 represent the socioeconomic gradient level and SES slope, reflecting educational quality and inequality.

The model is hierarchical in that level 1 parameters depend on level 2 parameters. That is, the β_0's can be expressed as an average gradient level plus a class random error:

$$\beta_{0j} = \gamma_{00} + \mu_{0j} \quad \ldots(2)$$

where γ_{00} is the grand mean gradient level and μ_0 is the class deviation from the grand mean. Similarly, the SES slope may vary between classes and can be expressed as an average slope plus a random deviation:

$$\beta_{1j} = \gamma_{10} + \mu_{1j} \quad \ldots(3)$$

where γ_{10} is the grand mean slope and μ_1 is the class deviation from the grand mean. In simpler specifications the SES slopes may be held fixed, that is, μ_1 can be omitted.

It is expected that the average socioeconomic gradient across classes (γ_{10}) will be positive and statistically significant. The critical test for the hypothesis of a socioeconomic gradient is:

$$\begin{aligned} H_0 &: \gamma_{10} \leq 0 \\ H_1 &: \gamma_{10} > 0 \end{aligned} \quad \ldots(4)$$

Results.

The hypothesis of a socioeconomic gradient holds in all five countries (see model 1 in Tables A1 to A5). Parameter γ_{10} is positive and statistically significant in Luxemburg (γ_{10}=23.16), Norway (γ_{10}=20.72), Hungary (γ_{10}=24.76), Indonesia (γ_{10}=11.96), and Moldova (γ_{10}=14.20). Inequalities within classes associated with family SES are greatest in Hungary and

smallest in Indonesia. Model 1 in Tables A1 to A5 additionally evaluates whether the SES slope varies among classes. Variance estimates of μ_1 indicate that the SES slope varies significantly in Norway, Indonesia, and Moldova.

Hypothesis 2: The hypothesis of diminishing returns

Hypothesis.

This hypothesis states that *the returns of family SES diminish across the range of SES or that the influence of family SES weakens for increasing levels of SES.*

This hypothesis stems from health research, where the possibility for a curvilinear relationship between income and health outcomes has been examined. Studies in the United States and Canada have shown that the marginal influence of income reduces for higher income levels (Boyle & Willms, 1999; Mirowsky & Hu, 1996; Willms, 2003). The importance of income to health outcomes tends to be marked below certain income level and then decreases. Theoretically, policies that reduce inequalities in income would be more effective at improving health outcomes of the lowest income population under this pattern than faced with a linear or increasing returns relationship. Similarly, policies aimed at reducing inequalities in family SES will tend to be more effective at narrowing achievement disparities if socioeconomic gradients exhibit diminishing returns.

Model.

The hypothesis is evaluated simply by adding the SES-squared term into equation (1):

$$Y_{ij} = \beta_{0j} + \beta_{1j} SES_{ij} + \beta_{2j} SES_{ij}^{\ 2} + r_{ij} \qquad \ldots(5)$$

where β_{2j}'s are the curvilinearity coefficients of socioeconomic gradients fixed across classes at γ_{20}. A positive estimate of γ_{20} indicates that socioeconomic gradients become gradually

steeper with increasing levels of SES and a negative estimate that socioeconomic gradients become flatter for higher SES levels or that they exhibit diminishing returns. The critical test for this hypothesis is:

$$H_0 : \gamma_{20} \geq 0$$
$$H_1 : \gamma_{20} < 0 \qquad \ldots(6)$$

Results.

The hypothesis of diminishing returns cannot be validated in any of the selected countries (see model 2 in Tables A1 to A5). Estimates of γ_{20} are positive in Norway (γ_{20}=0.20), Hungary (γ_{20}=0.12), Indonesia (γ_{20}=1.97), and Moldova (γ_{20}=0.27) but non-significant using standard criteria ($p<0.05$). Weak support for this hypothesis is found in Luxemburg, only (γ_{20}=-1.95; $p<0.1$). Assuming the level of confidence is acceptable, then reading inequalities in Luxemburg related to family SES decrease for higher SES levels or the influence of family SES likely becomes more apparent only above certain SES threshold.

Figure 1. Socioeconomic gradients in reading achievement

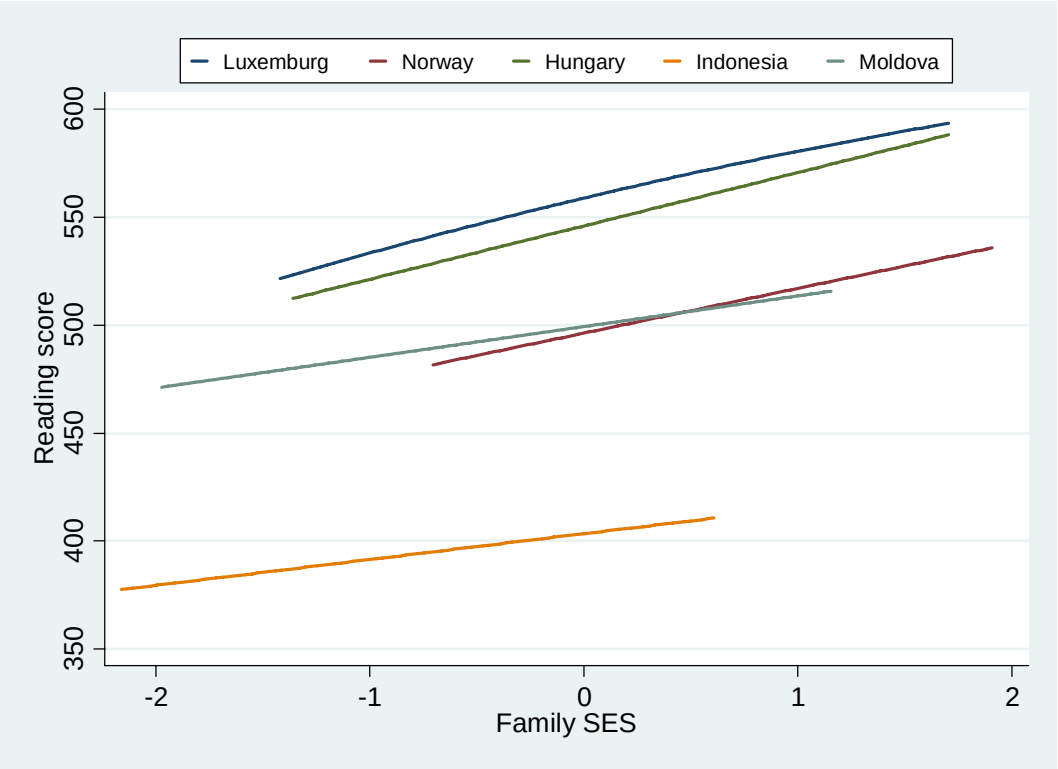


Figure 1 depicts socioeconomic gradient lines for the five countries. The relationship was plotted for students between the 5th and 95th SES percentile to avoid influence of outliers. Estimates of within-class inequalities (γ_{10}) in the previous hypothesis underlie gradient lines. The gradient in Luxemburg is slightly curvilinear. Otherwise, gradients are clearly linear. Interestingly, higher SES students perform better in Norway than in Moldova, but lower SES students perform better in Moldova.

Hypothesis 3: The hypothesis of family SES by parent-child communication interaction

Hypothesis.

The hypothesis of family SES by parent-child communication interaction maintains that *the influence of family SES varies by the level of parent-child communication*.

Specifically, it anticipates a greater influence of family SES for more frequent communication and interaction between parents and children. The hypothesis stems from research on family social capital. Scholars have shown that parent-child communication, parental encouragement for academic success, and other forms of social capital are a more effective force affecting a student's academic achievement when parents possess economic, human, and cultural capital (McNeal, 1999; Park, 2008). The critical mechanism for the differential effect of social capital by family SES is parental education. It is expected that students will benefit more from interactions with parents the more educated they are. Thus, this hypothesis essentially evaluates whether parent-child communication somewhat explains the transmission of human capital.

Model.

The parent-child communication variable (TALK) reflects the frequency parents talk to children irrespective of content and intent of communication. The hypothesis is evaluated by estimating:

$$Y_{ij} = \beta_{0j} + \beta_{1j} SES_{ij} + \beta_{2j} TALK_{ij} + \beta_{3j} SES_{ij} TALK_{ij} + r_{ij} \quad \ldots(7)$$

The critical test is:

$$\begin{aligned} H_0 &: \gamma_{30} \leq 0 \\ H_1 &: \gamma_{30} > 0 \end{aligned} \quad \ldots(8)$$

where γ_{30}, the interaction coefficient of family SES and TALK fixed among classes, is expected to be positive and statistically significant.

Results.

The hypothesis cannot be supported with the data in any of the selected countries (see model 3 in Tables A1 to A5). The interaction coefficient is positive in Luxemburg (γ_{30}=0.61), Hungary (γ_{30}=2.17), and Moldova (γ_{30}=1.31), but in neither case is it statistically significant.

Hypothesis 4: The hypothesis of the mediating role of cultural capital

Hypothesis.

The hypothesis maintains that *the cultural capital in the family mediates the relationship between family SES and reading performance*.

The term *mediate* is used in psychological and health research to refer to a factor correlated with a certain predictor variable and that helps to explain its influence on an outcome variable. Mediator variables have to be distinguished from moderator variables, which are uncorrelated with the predictor and whose levels have differential effects on the relationship of the outcome and the predictor variable (Kraemer, Stice, Kazdin, Offord, & Kupfer, 2001; Wu & Zumbo, 2008).

The fourth hypothesis states that the cultural capital in the family is correlated with family SES and helps to explain its relationship with overall reading achievement. Tramonte and Willms (2010) distinguished between a static form of cultural capital related principally to the possession of cultural resources at home and a dynamic form of cultural capital emanating mainly from cultural interactions and communication between parents and children. With data from PISA 2000, they found that both were related to reading performance even after controlling for family SES and that dynamic cultural capital exerted greater influence.

Model.

The hypothesis is tested by adding BOOKS and LIBRARY into equation 1:

$$Y_{ij} = \beta_{0j} + \beta_{1j} SES_{ij} + \beta_{2j} BOOKS_{ij} + \beta_{3j} LIBRARY_{ij} + r_{ij} \quad \ldots(9)$$

with equations (2) and (3) for the intercept and SES slope. Variables BOOKS and LIBRARY reflect static and dynamic cultural capital. Coefficients β_2 and β_3 are held fixed between classes at γ_{20} and γ_{30}. The hypothesis holds if γ_{10} reduces from (1) to (9) and γ_{20} and γ_{30} are positive and statistically significant.

$$H_0 : \gamma_{20}, \gamma_{30} \leq 0$$
$$H_1 : \gamma_{20}, \gamma_{30} > 0 \quad \ldots(10)$$

Results.

The hypothesis of the mediating role of cultural capital holds in all selected countries (see model 4 in Tables A1 to A5). Measured by the reduction of the family SES coefficient from model 1 to 4, the mediating power of the static and dynamic cultural capital variables amounts to 41 percent in Luxemburg, 19 percent in Hungary, 18 percent in Norway and Moldova, and 3 percent in Indonesia. The mediating contribution of cultural capital is mostly explained by the static cultural capital while the dynamic cultural capital plays a less important role. In fact, only weak evidence for a positive relationship between LIBRARY and reading performance is found in Luxemburg and Moldova ($p<0.1$).

Hypothesis 5: The hypothesis of school's contextual effects or *double jeopardy*

Hypothesis.

The hypothesis states that *the school SES is positively related to the reading performance of students even after accounting for family SES.*

The learning conditions are of great relevance when examining influences on cognitive and non-cognitive outcomes in educational contexts (Baumert et al., 2006; Dreeben & Barr, 1988; Hattie, 2002; Köller, Schnabel & Baumert, 2000; Marsh, 1987). Many contextual factors such as percentages of students with migration background (Walter & Stanat, 2008) and cognitive compositions of classes (Lehmann, 2006) have been looked into in describing the effects of learning environments on individual outcomes.

Research has also provided evidence that family SES not only influences student outcomes on individual level but also at the school level. That is, the school's SES context, typically measured by the average student SES, bears effects on achievement outcomes over and above the student SES. In other words, given two students with comparable levels of family SES, the one attending a more socially disadvantaged school is also more likely to perform worse in school. In the literature on social discrimination this twofold disadvantage is usually referred to as *double jeopardy* (Willms, 2003, 2006).

Model.

The hypothesis is tested by adding the average school SES into equation (2):

$$\beta_{0j} = \gamma_{00} + \gamma_{01}\overline{SES}_j + u_{0j} \quad \textbf{...}(11)$$

with equation (1) at level 1. Family SES at level 1 is grand-mean centered such that γ_{10} captures the contextual effect directly (Raudenbush & Bryk, 2002; Enders & Tofighi, 2007). The critical test for this hypothesis is:

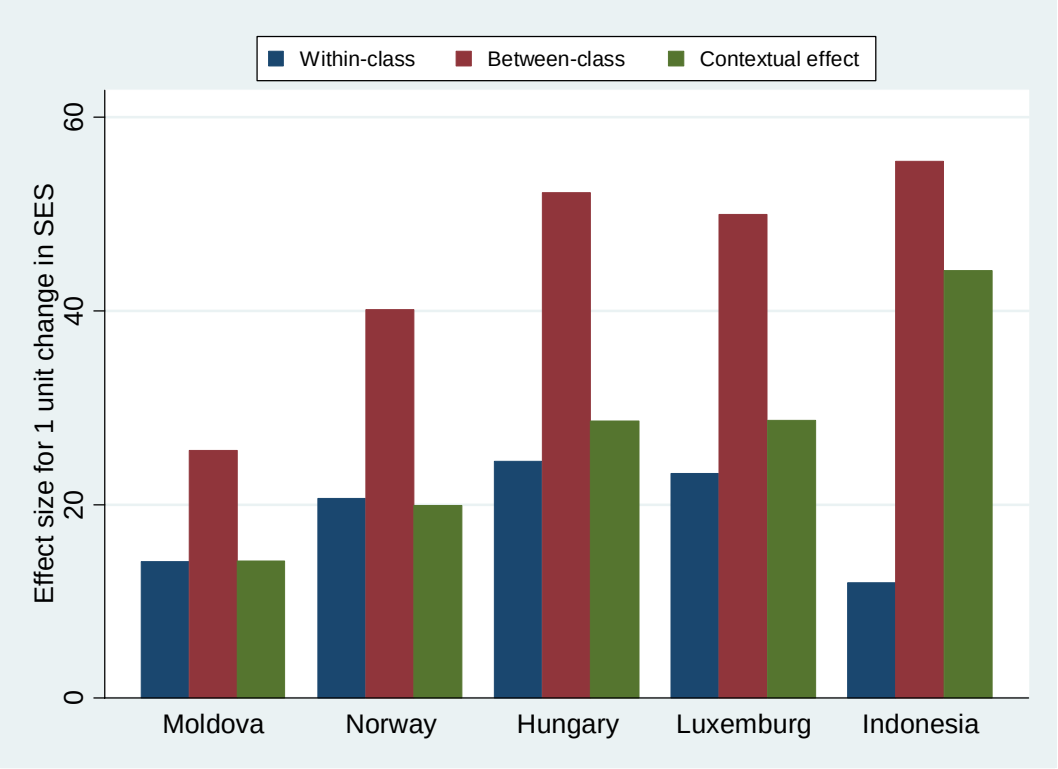
$$\begin{aligned} H_0 &: \gamma_{10} < 0 \\ H_1 &: \gamma_{10} \geq 0 \end{aligned} \quad \ldots(12)$$

Results.

The hypothesis of contextual effects or *double jeopardy* is supported in all examined countries.

Figure 2 shows estimates of contextual effects (γ_{10}) and pure within- and between-class SES coefficients. The coefficient that captures contextual effects is greatest in Indonesia (γ_{10}=44.12) and smallest in Moldova (γ_{10}=14.17) and is statistically significant in all five countries. Pure within- and between-class SES coefficients are reported in model 5 (see Tables A1 to A5). There, the difference γ_{01}-γ_{10} closely approximates the contextual effect (Raudenbush & Bryk, 2002).

Figure 2. The association with SES at the within-class and between-class level, and the derived contextual influences



The school SES accounts for a considerable amount of class variance in reading achievement. The explained variance ranges from 17 percent in Moldova and 22 percent in Norway over 33 percent in Indonesia to as much as 42 percent in Luxemburg and 67 percent in Hungary.

Hypothesis 6: The hypothesis of urban/rural differences explained by the school's SES

Hypothesis.

The hypothesis states that *differences between urban/rural schools reflect partly differences in SES of the student intake*

Achievement differences between rural and urban areas are often explained by SES. In developing countries, for example, underperformance of students in rural areas reflects high levels of centralization and strong regional disparities in SES. On the contrary, in more industrialized societies, major cities tend to attract low SES families with migration background, resulting in underachievement of students in urban areas (Mullis et al., 2007). Irrespective of the direction of the gap, it is expected that the achievement gap between urban and rural schools will be partly explained by differences in SES of the student intake.

Model.

The hypothesis is tested by comparing

$$\beta_{0j} = \gamma_{00} + \gamma_{01} RURAL_j + u_{0j} \quad \ldots(13)$$

with equation (1) at level 1 and

$$\beta_{0j} = \gamma_{00} + \gamma_{01} RURAL_j + \gamma_{02} \overline{SES}_j + u_{0j} \quad \ldots(14)$$

The hypothesis is supported if γ_{01} reduces from equation (13) to (14).

Results.

The hypothesis is supported in Hungary, Indonesia, Moldova, and Norway (see models 6 and 7 in Tables A1 to A5). Data restrictions preclude us from testing this hypothesis in Luxemburg. Model 6 and 7 report estimates of γ_{01} before (equation 13) and after controlling for the school SES (equation 14). Estimates of model 6 indicate that rural/urban differences are greatest in Indonesia (γ_{01}=-39.93) and smallest in Norway (γ_{01}=-12.42). Clearly, urban schools outperform rural schools in the four countries. But urban/rural differences are no longer significant when the school SES is controlled in model 7. Achievement differences related to the school location are thus entirely explained by the school SES.

Hypothesis 7: The hypothesis of country's contextual effect or *triple jeopardy*

Hypothesis.

As with the hypothesis of school's contextual effects, the hypothesis of *triple jeopardy* states that *the country's socioeconomic context influences reading performance even after family SES and school SES are taken into account.*

Extensive analyses indicate a gap in academic achievement between students in low income and high income countries (e.g. Baker, Goesling & Letendre, 2002; Chiu, 2007; Chudgar & Luschei, 2009; Fuller, 1987; Heyneman & Loxley, 1982, 1983; Mullis et al., 2007; Organisation for Economic Co-operation and Development [OECD], 2007, Wößmann, 2003). Although, family and school SES help to explain these differences, students whose families and schools have comparable levels of SES might still perform differently for the national income of their countries. Students in higher income countries are benefited by the quantity and quality of public resources irrespective of their family and school SES, for example (Blossfeld & Shavit,

1993). Next to family and school SES, the independent influence of the broader national socioeconomic context likely introduces a third source of disadvantage for low SES students.

Model.

This and the next three hypotheses are evaluated with three-level HLM.

The national income variable is the natural logarithm of GNI per capita. Model specifications at level 1 and 2 are represented by equations (1) and (11). Level 3 equation (15) is estimated to test the hypothesis of *triple jeopardy*. Predictors at all levels are grand-mean centered:

$$\beta_{00k} = \gamma_{000} + \gamma_{001}\ln(GNI) + u_{00k} \quad \ldots(15)$$

A positive estimate of γ_{001} in equation (15) is expected.

The critical test on the effect of national income when family and school SES are controlled at the student and class level is:

$$H_0 : \gamma_{001} \leq 0$$
$$H_1 : \gamma_{001} > 0$$

Results.

The hypothesis of country's contextual effects or *triple jeopardy* is supported by the data (see model 1 in Table A6). The ln(GNI per capita) coefficient is positive and highly significant (γ_{001}=27.38, p<0.01). The achievement variance at the country level reduces in 83 percent from the null model to model 1. That is, the student SES, school SES, and national income account for most achievement differences between countries. Results of model 1 in Table A6 also indicate that the student and school SES slopes vary significantly between countries.

Hypothesis 8: The hypothesis of varying family SES effects by national income

Hypothesis.

The hypothesis postulates that *the relationship between family SES and academic achievement changes for the national income level of countries.*

Three theories anticipate weaker, similar, or stronger influences of family SES in richer than in poorer countries: the *public resources substitution*, the *social reproduction*, and the *complementary intangibles* theory, respectively (Blossfeld & Shavit, 1993; Chiu, 2007; Schiller, Khmelkov & Wang, 2002).

The *public resources substitution* theory states that the greater quality and quantity of public resources in richer countries reduces the importance of family background and thereby weakens the association between family SES and student achievement. The *social reproduction* theory contends that irrespective of public resources, high SES families use their superior resources to create equivalent advantages for their children across countries. The *complementary intangibles* theory argues that the widespread availability of physical resources in richer countries increases the value of less tangible resources (e.g., family SES).

Model.

The level 1 equation is (1) with family SES group-centered and the level 2 equations include random effects only, as in equations (2) and (3). Level 3 equations are (16) and (17) for the intercept and student SES slope.

$$\beta_{00k} = \gamma_{000} + \gamma_{001}\ln(GNI) + u_{00k} \quad \ldots(16)$$

$$\beta_{10k} = \gamma_{100} + \gamma_{101}\ln(GNI) + u_{10k} \quad \ldots(17)$$

The coefficient γ_{101} captures the interaction of student SES and the country's national income. It is expected that γ_{101} will be statistically significant from zero. The critical test is:

$$H_0 : \gamma_{101} = 0$$
$$H_1 : \gamma_{101} \neq 0 \qquad \ldots(18)$$

Results.

The data support the hypothesis of the varying relationship between family SES and academic achievement among countries with difference national income levels (see model 2 in Table A6). More specifically, estimates are in agreement with the *complementary intangibles* theory. The estimate of the interaction of student SES and national income is positive and statistically significant (γ_{101}=3.93; p<0.01), indicating that the average student SES coefficient across countries (γ_{100} = 20.08) is greater in higher income countries than in lower income countries.

Hypothesis 9: The hypothesis of varying school SES effects by national income

Hypothesis.

The hypothesis holds that *variation across countries in the relationship of school SES and achievement is conditioned by the national income levels of countries*.

In response to the Coleman report (Coleman et al., 1966) that attributed a very limited role to schools in the United States once family SES was taken into consideration, researchers attempted to evaluate whether similar findings held in other countries. In the 1980s, Heyneman and Loxley (1982, 1983) found evidence that the contribution of student variables and school variables to academic achievement was greater in higher income countries and lower income countries, respectively. This came to be known as the *HL-effect* (also Heyneman, 2004). Recent

research provides inconsistent findings and possible explanations for the HL-effect (Baker et al., 2002; Chudgar & Luschei, 2009; Hanushek, 1995; Hanushek & Luque, 2002; Llie & Lietz, 2010; Riddell, 1989).

Here, we do not test the HL-effect, but only whether the role of school SES is greater in lower income countries. The role of other school variables related to school quality and teacher practices is neglected. Evaluating the HL-effect requires developing a full level 1 and level 2 model.

Model.

Level 1 equation is (1) and the level 2 equations for the intercept and student SES slope are similar to (11) and (3). Level three equations for the intercept and student SES slope are (16) and (17) and for the school SES slope is:

$$\beta_{01k} = \gamma_{010} + \gamma_{011}\ln(GNI) + u_{01k} \quad \ldots(19)$$

Level 1 and level 2 covariates are group-mean centered and level 3 covariates are grand centered. It is expected that the interaction of school SES and national income will be statistically different from zero. The critical test is:

$$\begin{aligned} H_0 &: \gamma_{011} = 0 \\ H_1 &: \gamma_{011} \neq 0 \end{aligned} \quad \ldots(20)$$

Results.

The results provide weak evidence for a varying relationship between school SES and academic achievement among higher income and lower income countries (see model 3 in Table A6). The estimate of the interaction between national income and school SES is negative (γ_{011}=-4.54) but statistically significant at the 10 percent level, only. If we are willing to accept this

confidence level, then the relationship between the school SES and academic achievement increases for lower income countries, suggesting greater school SES segregation in lower income countries.

Hypothesis 10: The hypothesis of the welfare states

Hypothesis.

The hypothesis maintains that *segregation of schools in terms of SES varies for the country's welfare state regime.*

The theory of welfare states anticipates different roles for schools depending on the country's welfare regime. Gøsta Esping-Andersen (1990) distinguished between three types of welfare states (i.e., liberal, corporatist-statist, and social democratic) and proposed a method for classifying states according to this typology. Traditional examples of liberal, corporatist-statist, and social democratic states are United States, Germany, and Sweden, respectively. Subsequent empirical work finds, however, limited support or equivocal evidence for this typology (Scruggs & Allan, 2006).

Here, we use income inequality to distinguish among welfare regimes. The degree of social inequality in a society somewhat reflects key aspects of welfare states, such as the organization of the labor market, access to public services, and pension systems (Fernández & Blanco, 2004). Countries with greater inequalities often exhibit relatively low overall performance in international evaluations of student achievement and their schools are more segregated in terms of SES.

But the level of income inequality cannot be interpreted independently. Kuznets postulated a curvilinear relationship between economic inequality and national income. Inequality tends to be greater during the early stage of development, when economic growth is

driven by investment in physical capital, and then decreases when economies are more mature and rely increasingly on human capital. Thus, countries with equivalent levels of income inequality may have very different levels of social welfare. Amartya Sen (1974) proposed a social welfare indicator that adjusts income inequality for national income. The indicator is equal to the GDP per capita adjusted by the Gini coefficient [i.e., GDP per capita * (1-Gini)]. Our model uses a similar measure to evaluate the relationship between social welfare and school segregation.

Model.

Level 1 equation is (1) and the level 2 equations for the intercept and student SES slope are similar to (11) and (3). Level three equations are (17) for the student SES slope and (21) and (22) for the intercept and school SES slope.

$$\beta_{00k} = \gamma_{000} + \gamma_{001} GNI(1 - Gini) + u_{00k} \quad ..(21)$$

$$\beta_{01k} = \gamma_{010} + \gamma_{011} GNI(1 - Gini) + u_{01k} \quad \ldots(22)$$

It is expected that schools will be more segregated by SES when the degree of social welfare is lower. The critical test is:

$$\begin{aligned} H_0 &: \gamma_{011} \geq 0 \\ H_1 &: \gamma_{011} < 0 \end{aligned} \quad \ldots(23)$$

Results.

The hypothesis is supported by the data (see model 4 in Table A6). The estimate of the interaction of school SES and the social welfare indicator is negative and highly significant (γ_{011}=-0.68; p<0.01). Thus, the school SES coefficient is greater in countries where the social

welfare index is lower. Notably, the results of this hypothesis and the previous render support for greater school SES segregation by the country's social welfare than by the national income level.

Summary and discussion

Willms (2002, 2003, 2006) introduced the socioeconomic gradients framework to study inequalities in social outcomes related to family SES. The framework has been applied in several national and international assessment studies of student achievement, including PISA. The findings have provided a detailed characterization of achievement inequalities related to family SES with regard to aspects such as the strength and functional form of the relationship of family SES and academic achievement, how the relationship varies between schools and countries, how the relationship is mediated and moderated by other family characteristics, the extent to which the goals of equity and quality of education are simultaneously attainable, among others. With that, policy research has gained a greater understanding of how inequalities are shaped and can be altered.

Studies managed by the IEA, such as PIRLS, TIMSS, and ICCS have not benefited from the study of socioeconomic gradients. Neither they provide a standard measure of family SES nor do they give a detailed account of inequalities in outcomes related to family SES. Using the example of PIRLS 2006, this paper another prepared by the first author (Caro, 2010a) propose an analytical method for studying socioeconomic gradients and a measure of SES. These methodological papers seek to contribute to the study of socioeconomic inequalities in IEA studies and other national and international assessment studies of student achievement.

The analytical approach proposed in this paper was illustrated through the evaluation of ten key hypotheses for sociological theory. The theoretical background, statistical model, and critical test was presented for each hypothesis and then the hypothesis was evaluated with HLM.

The application of the proposed approach is straightforward and can be easily generalized to other regions, countries, and international studies. Countries with lowest, highest, and medium income levels in PIRLS 2006 were selected for two-level analysis. The analytical method performed well at examining socioeconomic gradients in countries with varied economic characteristics. All PIRLS 2006 participating countries or communities for which data were available were included for three-level analysis. Findings and related methodological considerations are discussed next.

Findings and methodological considerations

A gradient relationship between family SES and reading performance was found in the five selected countries selected for two-level analysis. Achievement inequalities within classes related to family SES are greatest in Hungary and smallest in Indonesia. Inequalities within classes do not convey the full extent of achievement disparities related to SES, though. In fact, when we look between-schools, Indonesia exhibits the greatest achievement disparities related to school SES. Then the within-class gradient reflects that differences among students related to family SES are lower in Indonesia than in Norway, Luxemburg, Hungary, and Moldova. But differences between schools ought to be considered for having a comprehensive picture of SES inequalities.

Gradient lines may cross for two different countries. In those cases one country yields greater achievement levels for students of higher SES families and the other for students of low SES families. Such pattern is found in Norway and Moldova. Particularly, higher SES students seem to perform better in Norway, but lower SES students perform better in Moldova. This results from greater achievement inequalities within classes in Norway and lower in Moldova.

Apparently, socioeconomic gradients within classes are linear in all five countries or

achievement inequalities related to family SES do not widen or narrow for increasing levels of SES. Similar findings have been reported for PISA participating countries (OECD, 2003, 2004, 2007). Also, the influence of family SES appears to remain invariant for the level of parent-child communication. Based on social capital theory, a greater influence of family SES was expected for more frequent communication. Communication is seen as a critical gateway for the transmission of human capital and is expected to play a more important role when parents have attained higher levels of education or SES. Evidence for an interaction effect of parent-child communication and family SES has been found in PISA 2006 (Caro, 2010b). The results here likely indicate that the influence of parent-child interactions on achievement varies with the age of students and tends to be more effective as students become adolescents than in the early school years.

We found evidence that family cultural capital mediates family SES influences on academic achievement. The mediating role of cultural capital ranges from 41 percent in Luxemburg to 3 percent in Indonesia and is driven mostly by the static form of this construct, while the dynamic or relational component plays a less apparent role. Weak evidence for the contribution of the dynamic cultural capital is found in Luxemburg and Moldova, only. Tramonte and Willms (2010) found greater effects of dynamic cultural capital. But PISA 2000 includes more pertinent data to distinguish among the two forms of cultural capital.

Students are subject to three levels of cumulative disadvantage related to SES: the family, school, and country socioeconomic context. First, they are more likely to perform worse in school if coming from a low SES family. Secondly, they perform even worse when they are located in a low SES school, or the school context potentially strengthens inequalities among high and low SES students. And third, irrespective of their family SES and school SES, their

achievement levels are lower if they live in a lower income country. Previous studies referred to a second level of disadvantage or *double jeopardy* for low SES students due to the school context (e.g., Willms, 2003, 2006). Here, we find evidence for a third level of disadvantage. Students are in *triple jeopardy* if coming from a low SES family, attending a low SES school, and living in a low income country.

The three-level analyses also offer evidence for a stronger association of family SES and academic achievement in higher income countries and a stronger association of school SES and school achievement in lower income countries. Consistently, estimates of two-level analyses suggest that family SES influences are greater in Luxemburg and Norway (highest income) than in Indonesia and Moldova (lowest income) and school contextual influences are greater in Indonesia than in Luxemburg and Norway. Note that these results do not confirm the HL-effect nor they provide evidence for the contrary.

A greater association with school variables in lower income countries may only indicate that schools are more segregated in terms of SES and not that schools have a greater role in these countries. And the weaker association with family variables in lower income countries could also reflect the achievement variance decomposition among students and classes, namely, that the lower achievement variability within classes in lower income countries limits the extent to which family and student variables capture achievement inequalities.

Limitations and further research

The analyses presented here are not without limitations and estimates should not be easily generalized. One is the cross-sectional nature of the data. Regression estimates reflect associations and not effects. Only with longitudinal data or an experimental design can relatively strong arguments in terms of causality be made. Here, the study design permits a detailed

characterization of socioeconomic gradients but does not allow establishing the order of causality. And yet, the analytical approach introduced here can be applied to longitudinal data of student achievement to examine trajectories of SES inequalities as students get older or over historical time periods, for example.

Researchers may also investigate other topics using this analytical method such as the mediating role of parenting styles, family social capital, and the country's collectivist/individualist values in the relationship between family SES and academic achievement, the trade-off between quality and equity in educational outcomes, the consistency of SES inequalities across subject areas, the public/private school gap related to school SES, among others. Many hypotheses can be postulated based on theory, then evaluated for the available data, and results interpreted in light of theory. Also, regional studies can draw on this approach to study specific aspects of SES inequalities relevant for the context. Currently, available data from international assessment studies of student achievement enable researchers to comprehensively study SES inequalities in specific geographical/economic regions.

Cultural capital data in PIRLS 2006 represents another limitation. Not only the frequency parents go to the bookstore/library with children poorly measures dynamic cultural capital, but the use of number of books as an indicator of static cultural capital is also limited. This variable may well capture achievement differences related to socioeconomic background not included in the SES indicator. Whenever possible, analyses should use more appropriate data for reflecting complex constructs like cultural capital.

Still another limitation for the evaluation of the *triple jeopardy* hypothesis lies in the measurement and validity of SES among countries. The family SES indicator does not include data on family income and its comparability between countries is limited by cross-cultural

characteristics (Caro, 2010a). Instead, the country's national income per capita adjusted for living standards used in this hypothesis provides a comparable measure of income across countries. Possibly, it also captures socioeconomic differences among students not reflected by SES.

A final limitation is missing data. Multiple imputation techniques were employed to counteract for this source of bias. But ten countries are excluded from the analysis for having more than 25 percent missing data in SES. The final sample of three-level analyses includes 30 countries and 5 Canadian provinces. Remaining countries do not cover all the original range of national income nor do they cover the world range of national income, limiting the generalizability of three-level hypotheses.

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Appendix A

Table A1. Hypothesis tests of the relationship between reading performance and family SES: Two level model estimates for Luxemburg (unstandardized regression coefficients)

Fixed effects	(0) Null	(1) SES gradient	(2) SES curvilinearity	(3) Interaction	(4) Mediator	(5) School SES
Intercept	557.52 ***	557.53 ***	558.95 ***	556.59 ***	557.53 ***	557.51 ***
Student level						
Student SES		23.16 ***	23.60 ***	20.95 ***	13.59 ***	23.21 ***
Student SES^2			-1.95 *			
Books					13.72 ***	
Library					2.30 *	
Talk				0.24		
Student SES X Talk				0.61		
Class level						
School SES						49.93 ***
Rural						
Random effects (σ^2)	(0) Null	(1) SES gradient	(2) SES curvilinearity	(3) Interaction	(4) Mediator	(5) School SES
Student level residual	3620.33	3188.91	3199.17	3203.28	2968.03	3203.71
Class level						
Intercept	784.79 ***	813.77 ***	816.02 ***	816.05 ***	828.36 ***	452.09 ***
Student SES		18.59				

* p<0.1, **p<0.05,*** p<0.01

Table A2. Hypothesis tests of the relationship between reading performance and family SES: Two level model estimates for Norway (unstandardized regression coefficients)

Fixed effects	(0) Null	(1) SES gradient	(2) SES curvilinearity	(3) Interaction	(4) Mediator	(5) School SES	(6) Rural	(7) Rural/SES
Intercept	496.40 ***	496.31 ***	496.19 ***	519.20 ***	496.29 ***	496.16 ***	497.78 ***	496.32 ***
Student level								
Student SES		20.72 ***	20.74 ***	25.51 ***	17.00 ***	20.66 ***	20.70 ***	20.66 ***
Student SES^2			0.20					
Books					7.28 ***			
Library					-2.25			
Talk				-7.04				
SES X Talk				-1.38				
Class level								
School SES						40.11 ***		39.35 ***
Rural							-12.42 **	-1.3677
Random effects (σ^2)	(0) Null	(1) SES gradient	(2) SES curvilinearity	(3) Interaction	(4) Mediator	(5) School SES	(6) Rural	(7) Rural/SES
Student level residual	3801.49	3502.76	3503.66	3516.15	3451.02	3498.86	3501.97	3498.27
Class level								
Intercept	629.20 ***	657.14 ***	657.58 ***	585.19 ***	662.14 ***	488.46 ***	628.22 ***	491.51 ***
Student SES		51.94 **	51.67 **	49.43 **	51.27 **	51.25 **	51.70 **	52.37 **

* p<0.1, **p<0.05,*** p<0.01

Table A3. Hypothesis tests of the relationship between reading performance and family SES: Two level model estimates for Hungary (unstandardized regression coefficients)

Fixed effects	(0) Null	(1) SES gradient	(2) SES curvilinearity	(3) Interaction	(4) Mediator	(5) School SES	(6) Rural	(7) Rural/SES
Intercept	546.08 ***	545.99 ***	545.93 ***	545.88 ***	545.98 ***	552.85 ***	549.04 ***	552.75 ***
Student level								
Student SES		24.76 ***	24.42 ***	24.32 ***	19.98 ***	24.45 ***	24.45 ***	24.45 ***
Student SES^2			0.12					
Books					7.79 ***			
Library					-1.34			
Talk				1.20				
Student SES X Talk				2.17				
Class level								
School SES						52.22 ***		52.89 ***
Rural							-28.84 ***	1.84
Random effects (σ^2)	(0) Null	(1) SES gradient	(2) SES curvilinearity	(3) Interaction	(4) Mediator	(5) School SES	(6) Rural	(7) Rural/SES
Student level residual	3526.15	3132.07	3137.59	3136.88	3084.34	3143.16	3137.34	3143.02
Class level								
Intercept	1519.52 ***	1544.10 ***	1544.45 ***	1544.18 ***	1548.28 ***	506.56 ***	1358.53 ***	509.74 ***
Student SES		9.15						

* p<0.1, **p<0.05,*** p<0.01

Table A4. Hypothesis tests of the relationship between reading performance and family SES: Two level model estimates for Indonesia (unstandardized regression coefficients)

Fixed effects	(0) Null	(1) SES gradient	(2) SES curvilinearity	(3) Interaction	(4) Mediator	(5) School SES	(6) Rural	(7) Rural/SES
Intercept	403.37 ***	403.37 ***	402.48 ***	401.99 ***	403.37 ***	406.88 ***	405.36 ***	407.01 ***
Student level								
Student SES		11.96 ***	11.14 ***	12.32	11.56 ***	11.93 ***	11.95 ***	11.93 ***
Student SES^2			1.97					
Books					2.55 **			
Library					-2.26			
Talk				0.31				
Student SES X Talk				-0.09				
Class level								
School SES						55.42 ***		53.01 ***
Rural							-39.93 ***	-5.79
Random effects (σ^2)	(0) Null	(1) SES gradient	(2) SES curvilinearity	(3) Interaction	(4) Mediator	(5) School SES	(6) Rural	(7) Rural/SES
Student level residual	3799.37	3717.36	3716.69	3718.22	3711.58	3718.06	3718.18	3718.08
Class level								
Intercept	2472.28 ***	2476.74 ***	2461.43 ***	2482.27 ***	2477.03 ***	1662.52 ***	2205.85 ***	1668.23 ***
Student SES		20.99 **	20.21 **	20.66 **	21.04 **	22.34 **	21.01 **	22.45 **

* p<0.1, **p<0.05,*** p<0.01

Table A5. Hypothesis tests of the relationship between reading performance and family SES: Two level model estimates for Moldova (unstandardized regression coefficients)

Fixed effects	(0) Null	(1) SES gradient	(2) SES curvilinearity	(3) Interaction	(4) Mediator	(5) School SES	(6) Rural	(7) Rural/SES
Intercept	499.34 ***	499.32 ***	499.15 ***	478.71 ***	499.31 ***	501.79 ***	501.15 ***	502.06 ***
Student level								
Student SES		14.20 ***	14.18 ***	8.21	11.68 ***	14.12 ***	14.15 ***	14.11 ***
Student SES^2			0.27					
Books					4.54 ***			
Library					2.61 *			
Talk				5.30 ***				
Student SES X Talk				1.31				
Class level								
School SES						25.56 ***		22.97 ***
Rural							-20.46 ***	-5.88
Random effects (σ^2)	(0) Null	(1) SES gradient	(2) SES curvilinearity	(3) Interaction	(4) Mediator	(5) School SES	(6) Rural	(7) Rural/SES
Student level residual	3566.34	3403.94	3404.19	3375.53	3378.64	3405.22	3403.86	3405.99
Class level								
Intercept	1203.79 ***	1213.69 ***	1213.32 ***	1296.68 ***	1215.21 ***	999.01 ***	1128.49 ***	1001.24 ***
Student SES		38.81 ***	39.82 ***	43.27 ***	40.50 ***	39.48 ***	39.80 ***	38.12 ***

* p<0.1, **p<0.05,*** p<0.01

Table A6. Hypothesis tests of the relationship between reading performance and family SES: Three level model estimates (unstandardized regression coefficients)

Fixed effects	(0) Null	(1) Triple jeopardy	(2) Student SES by income	(3) Heyneman-Loxely	(4) Welfare regimes
Intercept	458.00 ***	524.31 ***	518.26 ***	533.33 ***	509.41 ***
Student level					
Student SES		16.27 ***	20.08 ***	19.97 ***	16.35 ***
Class level					
School SES		36.23 ***		47.76 ***	45.34 ***
Country level					
GNI per capita(1-Gini)					4.95 ***
Ln(GNI per capita)		27.38 ***	66.35 ***	37.30 ***	
Cross-level interactions					
Student SES X Ln(GNI per capita)			3.93 ***	3.98 ***	
School SES X Ln(GNI per capita)				-4.54 *	
School SES X [GNI per capita X (1- Gini)]					-0.68 ***

Random effects (σ^2)	(0) Null	(1) Triple jeopardy	(2) Student SES by income	(3) Heyneman-Loxely	(4) Welfare regimes
Student level residual	4017.32	3864.56	3836.13	3838.46	3838.08
Class level					
Intercept	2258.05 ***	848.65 ***	2272.89 ***	1420.22 ***	1420.23 ***
Student SES		108.19 *	16.94 **	15.81 **	16.65 **
Country level					
Intercept	5754.03 ***	980.50 ***	2050.03 ***	982.70 ***	3034.22 ***
Student SES		46.30 ***	28.29 ***	28.14 ***	41.59 ***
School SES		160.48 ***		95.29 ***	88.85 ***

* p<0.1, **p<0.05,*** p<0.01