Relationships between Family Socioeconomic Status and Mathematics Achievement in OECD and Non-OECD Countries

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This article examines the relationships between family socioeconomic status (SES) and mathematics achievement across countries while taking into account (*a*) the country's development status and (*b*) the types of resources (physical versus human) available at home. The 2012 round of the Programme for International Student Assessment (PISA) data were analyzed using the necessary condition analysis (NCA) procedures. The study found that only the human resource aspects of family SES, that is, parental education and parental occupational status, were statistically significant necessary conditions for mathematics achievement across more developed, OECD countries. By contrast, none of the 10 SES variables showed statistically significant, necessary conditions for mathematics achievement across less developed, non-OECD countries. Therefore, the necessary conditions for countries' mathematics achievement differ depending on their developmental status and by different measures of family SES. Some practical implications are discussed along with limitations and directions for future studies.

Family socioeconomic status (SES) has long been considered one of the strongest enablers of academic achievement. Many empirical, including meta-analytic, studies (e.g., Sirin 2005) have identified a moderately strong, family SES-achievement association. Furthermore, a similar, moderate effect size of SES was found in most, if not all, countries in the international data based on the Organization for Economic Cooperation and Development (OECD)'s Programme for International Student Assessment (PISA) across the years 2003, 2006, 2009, and 2012 (Lee et al. 2019). Past studies on the topic suggest that the effect of family background on academic success tends to be consistent and strong enough that reversing its effect may be hard to accomplish by interventions implemented outside of the home.

Another dimension of the SES-achievement relationship, and one that is often neglected, is the country's overall development status (e.g., Chiu and

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Khoo 2005). In recent years, large-scale international assessment programs—such as PISA or the International Association for the Evaluation of Educational Achievement's (IEA) Third International Mathematics and Science Study (TIMSS)—have expanded their programs by inviting and including middle- and low-income countries. The availability of the international data that include less developed countries provides an unprecedented opportunity to examine the SES-achievement relationship in a new light. Knowledge and insight to be gained may contribute to informed decisions about optimal approaches to address educational inequality due to SES across a wider range of countries. Most previous studies on the effects of family SES have been based on data from developed countries, and such results cannot be assumed to be applicable universally across countries at different levels of development (Lockheed et al. 2015; Lee 2020). It is worth noting that previous large-scale cross-national studies were based on data from about 40 countries, including only a few or no low-income countries, and that the most recent of these studies was based on PISA 2000 data involving 41 countries (Chiu 2010). The present investigation analyzed a total of 60 countries, using the PISA 2012 data set.

The research reported in this article was guided by four broad findings identified in prior research. First, families with more resources and higher SES can provide better educational opportunities for their children, and children tend to show better academic performance (Sirin 2005; Lee et al. 2019). Second, families in high-income countries on average have more resources in general—that is, they have more human, financial, or social capital—compared to families in middle- or low-income or developing countries. Thus, absolute levels of family SES are generally higher in high-income countries. Third, although some middle- or low-income countries (such as Vietnam) perform above the predicted level given their country's economic development status (OECD 2019), high-income countries generally perform better in large-scale international assessments than middle- or low-income countries (Chiu and Khoo 2005; Lee 2020). Finally, the way that physical/financial and cultural benefits are gained and utilized to provide social and motivational support for children's education can differ between richer and poorer countries (Heyneman and Loxley 1983; Schiller et al. 2002).

The purposes of the present study are threefold. First, we examine relative effects of family SES on academic achievement across developed (OECD) versus less developed (non-OECD) countries. Second, we focus on two broad categories of SES resources, namely, physical resources and human resources available in the family, as a way to explain potentially differential effects of family SES across countries with differing levels of development. Third, we explore the SES-achievement relationship with a relatively new analytic framework called necessary condition analysis (NCA; Dul 2016) to test whether family SES is, in fact, a *necessary* condition for academic achievement. In comparison to the traditional correlation-based analysis, the NCA analytic framework imposes a more restricted requirement for a relationship to hold in order to allow necessity interpretations. Most previous studies of the SES-achievement relationship were based on traditional types of statistical analysis (i.e., extension of correlation or covariance), which have an inherent limitation whereby necessity inferences cannot be made, even for statistically significant relationships (see the Method section below).

In the following section, we introduce five theoretical hypotheses that contributed to the substantive backgrounds of the present study. These hypotheses explicate the roles that *country development* may play as an important moderator of the SES-achievement relationship.

Theoretical Hypotheses about the SES-Achievement Relationship in High-Income and Middle-/Low-Income Countries

First, what is known as the *family resource provider hypothesis* suggests that families in high-income countries have more physical/financial resources on average compared to families in middle- or low-income countries and that high-SES families in high-income countries provide better learning opportunities to their children compared to high-SES families in middle- or low-income countries. Hence, high-income countries manifest stronger family SES effects on students' academic achievement (Chiu et al. 2007; Chiu 2010). This hypothesis aligns with the argument demonstrated in the landmark study by Heyneman and Loxley (1983), who placed the level of economic development of countries at the center of research on the SES-achievement relationship (now known as the Heyneman-Loxley effect). The authors reported that the family effect on science achievement of primary school students was weaker in middle- to low-income countries compared to that in high-income countries. Specifically, family SES accounted for 18 percent of science achievement in low-income countries, 23 percent in middle-income countries, and 35 percent in high-income countries (Heyneman and Loxley 1983). The correlation between a country's wealth measure and the proportion of science achievement variance explained by family SES was $r = .41$ ($p < .001$), indicating that the wealthier a country was, the larger the variance that was explained by family SES. Overall, it was concluded that "for whatever reason, the learning advantages or disadvantages of the home, established prior to entering school, are significantly more powerful determinants of achievement in high-income countries" (Heyneman and Loxley 1983, 1176).

More recent studies have given support to the Heyneman-Loxley effect. For instance, Chiu et al. (2007) reported that as much as 60 percent of between-country variances in the PISA 2000 science achievement scores could be explained by countries' gross domestic product (GDP) per capita (transformed to a log score) alone. In another study by Chiu and Khoo (2005), GDP per capita accounted for 54 percent of the variance in PISA 2000 mathematics achievement scores across countries. A recent analysis by Lee and Stankov (2018) also showed that the country-level correlation between home possessions and mathematics achievement in TIMSS 2011 data was as high as $r = .77$, and between home possessions and mathematics achievement in PISA 2003 data was $r = .76$. These relatively strong between-country-level correlations suggest that academic achievement was higher in countries where the country's family SES was higher.

The second hypothesis is referred to as the *complementary intangibles hypothesis*.[1] Intangible resources are hard to measure precisely. They include parental involvement in child-rearing, quality of conversation at home, cultural resources or communication about books and social events, and attitudes toward academic achievement. Intangible resources at home also strengthen the value of tangible (physical and financial) resources (Chiu and Khoo 2005)—for example, caregivers reading with children and purchasing more books to encourage further reading, or parents learning about their children's aptitudes and then supplying relevant materials accordingly.

The intangible resources available in the community go beyond education per se and include broader system-wide infrastructure such as housing, health systems, safety standards, residential mobility, building conditions/regulations, employment rate, poverty rate, job security, individuals' health and nutrition status, child-rearing practices, participation in voluntary activities, public communications, and adult engagement in life-long learning and cultural events, to name a few (Neisser et al. 1996; Heyneman and Lee 2016). Higher quality of intangible resources is often associated with higher SES families in high-income countries (Chiu and Khoo 2005), which points to a stronger effect of family background on academic achievement in more developed countries.

Third, the *public resources substitution hypothesis* (Montagnes 2001), which is rooted within the classic modernization theory (Parsons 1970), postulates that a minimum level of public resources and institutional infrastructure within the country to support youth learning tends to be more available and accessible in more economically developed countries (Blossfeld and Shavit 1993; Schiller et al. 2002). Thus, the benefits from public resources (such as libraries, museums, books and other educational materials) can enhance young people's learning opportunities outside their home environment and, perhaps to some extent, serve as a substitute for the role of families in providing educational resources to the younger generations. Thus, this hypothesis points to a weakened family background effect on academic achievement in more developed countries.

Fourth, the *rising meritocracy hypothesis*, which also sprung out of classic modernization theory (Parsons 1970), is related to the meritocratic modernization

[1] Schiller et al. (2002); Chiu and Khoo (2005); Chiu et al. (2007); Chiu (2010).

process that occurred in many developed countries in the last century. The meritocratic value has mobilized societal members including young students to envision that their personal success is reachable through education, effort, and hard work (Montagnes 2001; Schiller et al. 2002). Such social attitudes and conditions give motivation to academically capable young people to work hard, achieve academically, and gain social and economic benefits, regardless of their family socioeconomic background (Schiller et al. 2002). Thus, this hypothesis assumes that the effect of family SES background on academic performance is weakened as the country becomes more modernized (Montagnes 2001).

The fifth and final hypothesis is derived from the *deprivation of public resources* assumption (cf. Schiller et al. 2002). It states that in a less economically developed country where basic physical resources tend to be scarce among those at the lower end of the SES spectrum, a stronger influence of family SES on academic achievement may be expected. In contrast, economic resources to establish social and institutional infrastructures that can provide a basic level of national services to support youth's education are more prevalent in developed countries (Blossfeld and Shavit 1993). The sheer lack of physical resources, infrastructure, and educational opportunities in the *public space* in less developed countries perpetuates the within-family power to exert stronger influences on youth learning. Although developed countries face the issue of within-country inequality in educational outcomes due to family SES, disadvantaged populations living in the less developed world suffer the most from a relative lack of the *basic* level of public resources needed for academic achievement (Schiller et al. 2002). Thus, the public resources deprivation hypothesis points to a stronger SES effect on academic achievement in less developed countries.

Overall, while the five theoretical hypotheses presented above emphasize the critical role that the country's developmental status and family SES may play in youth learning opportunities, there have been mixed views. It remains unclear whether and how family SES and academic achievement relationships vary depending on the country's developmental status.

SES Measures and Academic Achievement

Another potentially critical factor that needs to be considered in the SES-achievement relationship in the context of country development are different foci in SES measures. The explanatory power of family SES variables can vary depending on specific aspects of the SES measures used (O'Connell 2019), while there has been a relative lack of attention on how differently the importance of SES variables may be exhibited across country's contexts. As pointed out by Williamson (1985), when a country develops economically, reliance on physical capital decreases while reliance on human and cultural capital increases. However, the relative paucity of physical resources, and yet greater reliance on them, in less developed countries can allow physical resources or wealth of family to play a greater role in education-related decisions; for instance, decisions about school enrollment or assisting and providing extra help with schoolwork. Indeed, researchers studying developing countries have long argued that greater access to tangible (physical) assets (such as family income), rather than intangible assets (such as parental education), is critical in families' decisions to send their children to secondary school (Lathapipat 2013; Lounkaew 2013). Thus, one argument is that the less developed a country is, the more important physical resources are for academic achievement.

Human resources at home, on the other hand, tend to develop and amass more effectively in richer countries, which can assist the establishment of the social and cultural capital conducive to academic achievement. Human resources at home, in particular, are typically created and enhanced by parents' educational attainment and occupational status. Countries with greater schooling among parents are more likely to have a critical mass to help children to achieve in school and to provide social and cultural resources to enrich learning (Ho 2000; Schiller et al. 2002). For instance, parents with a higher level of educational attainment tend to be more active in volunteering within school communities and parent-teacher associations and in forming good relationships with teachers and other parents in the school (Cheung 2009). Such human and social capitals often serve as enablers of further educational opportunities and sources of motivation for the children raised in these contexts.

Taken together, these studies allow the following hypotheses to be drawn: (*a*) physical resources may play a stronger role in academic achievement across less developed countries, while (*b*) human resources may play a greater role in academic achievement across developed countries. The present study employed both types of SES indices to gauge the relative effects of physical and human resources on academic achievement across developed and less developed countries.

The Present Study

The present study examines the extent to which family SES of a country is a *necessary* condition for its academic performance while taking into account: (1) the country's overall (economic, social, political) development (OECD versus non-OECD countries), and (2) different types of family resources (physical versus human resources). Following from this, four hypotheses were created for the current study: the first two hypotheses (hypotheses 1a and 1b) focus on whether the association is stronger or weaker in more or less developed countries and the latter two hypotheses (hypotheses 2a and 2b) aim to examine whether the association differs depending on physical versus human resource availability.

Hypothesis 1a. The *family resource provider hypothesis* and the Heymenman-Loxley effect (Heyneman and Loxley 1983) both point to a stronger effect of family SES in developed countries due to the greater availability of educational resources and better educational opportunities and infrastructure in the country, hence, higher academic achievement.

Hypothesis 1b. The *public resources substitution hypothesis*, the *public resources deprivation hypothesis*, and the *rising meritocracy hypothesis*, on the other hand, suggest a stronger family SES-achievement relationship across less developed countries.

Hypothesis 2a. The *complementary intangibles hypothesis* emphasizes the intangible aspects of family SES rather than physical and tangible resources. It suggests that the effect of human resources–related SES on academic achievement may be stronger in more developed countries.

Hypothesis 2b. Both the *public resources substitution hypothesis* and the *public resources deprivation hypothesis* point to the stronger need for physical and tangible resources in less developed countries, suggesting that the effect of physical resources–related SES on academic achievement may be stronger in less developed countries.

Method

Data/Participants

The data for this study were drawn from the PISA 2012 round.[2] The participants were 15-year-old students who were attending school across 37 OECD (more developed) and 23 non-OECD (less developed) countries/educational systems at the time of the PISA test administration. Country development can be operationalized in many ways, such as through economic production measures (e.g., gross domestic product or gross national income) or the United

[2] In the international research communities of PISA, the 2012 data set is not considered as outdated because PISA is conducted every three years and each assessment has the rotated, focal academic domains to measure. There are three academic domains in PISA: mathematics, science, and reading. Therefore, the same academic domain PISA cycle is nine years. The cycle of mathematics was 2003 and 2012, and the next cycle will be in 2022. The apparent time gap between the assessment year and research publication is not uncommon in the studies based on large-scale data. For instance, Chiu (2010) used PISA 2000 data for his 2010 publication. Lee et al. (2019) also demonstrated almost identical correlations between SES and achievement in the 2003, 2006, 2009, and 2012 PISA cycles, demonstrating the stability and replicability of results based on large-scale data over the 10-year period.

Nation's human development index (HDI). In this study, OECD membership was used as a proxy index for countries' overall development status, which broadly incorporates a country's standing in terms of its economic, social, and geopolitical power in the world.[3] The main variable of this study is *country's developmental status*, that is, developed versus less developed countries; accordingly, country (aggregated from individual-level data) was used as the unit of data analysis.

Variables/Measures

Mathematics achievement.—Mathematics performance is used as a proxy for academic achievement. The PISA mathematics scale was set to have a mean of 500 and a standard deviation of 100 across OECD countries in the original PISA 2000 metric (see OECD 2014). The internal consistency reliability of mathematics items was $\alpha = 0.82$ in PISA 2012 (OECD 2014, 230). All five mathematics scores available in PISA 2012 were used, following the PISA recommended analysis framework, and then aggregated into a country's mathematics score (see table A3 for descriptive statistics).

In PISA tests, the scores of the three academic domains (reading, mathematics, and science) tend to be highly correlated with each other ($r = .90$ between mathematics and science; $r = .86$ between mathematics and reading; and $r = .88$ between reading and science across all participant countries; OECD 2014, 230). Test scores' correlations with family SES also tend to be consistent across the three domains (e.g., $r = .38$, .40, and .40 for reading, mathematics, and science achievement in PISA 2012; Lee et al. 2019, 316).

SES measures.—Ten SES variables are employed in this study. They were based on student responses to the PISA student questionnaire. Four variables are related to *physical* resources of the home environment: home possessions (HOMEPOS), educational resources at home (HERES), household wealth (WEALTH), and cultural possessions at home (CULTPOS). The remaining six variables pertain to *human* resources at home: father's education (FISCED), mother's education (MISCED), parental education (HISCED, which takes the higher of the two FISCED and MISCED scores), father's occupational status

[3] The OECD versus non-OECD division is not a perfect categorization of nation's economic development alone. There is huge variation across countries within each grouping of OECD and non-OECD. The gross national income (GNI) per capita of Chile, Greece, Mexico, and Turkey is substantially lower than the rest of OECD countries. Liechtenstein, Qatar, and United Arab Emirates are very developed countries economically. Exclusion of Chile, Greece, Mexico, and Turkey increases the average GNI per capital of OECD countries to US$41,372. Exclusion of Liechtenstein, Qatar, and United Arab Emirates decreases the average GNI per capital of non-OECD countries to US$6,487. However, the human development index (HDI) of Chile and Greece are in the middle range across all countries examined in this article. Mexico and Turkey can be seen as having strong geopolitical influences in the region. Considering the overall development of a country, evidenced in the HDI scores as well as each component score of the HDI (life expectancy, education, economic), OECD countries on average have a development standing that is stronger than the non-OECD countries. See table A1 for the HDI numbers.

(BFMJ2), mother's occupational status (BMMJ1), and parental occupational status (HISEI, which takes the higher value of BFMJ2 or BMMJ1).

The HOMEPOS, HEDRES, WEALTH, and CULTPOS scales were created by the item response theory (IRT) scaling method, with a mean of 0 and standard deviation of 1 across OECD countries (OECD 2014). The parental occupation data (HISEI, BFMJ2, and BMMJ1) were coded and then mapped onto the International Socioeconomic Index of Occupational Status (ISEI; Ganzeboom 2010). The parental education data (HISCED, FISCED, and MISCED) were based on raw scores between 0 (no formal education at all) and 6 (university education). Although the data on educational levels were collected using categories, the student responses were aggregated as the country mean-level scores. This process converted them to continuous variables for the NCA (see table A2 for the measurement details and table A3 for descriptive statistics of the SES variables).

Necessary Condition Analysis (NCA)

In this study, the *X*-*Y* (family SES-achievement) relationship was analyzed using NCA (Dul 2016). As mentioned above, much of the quantitative research in social sciences has been conducted using traditional statistics based on correlation or covariance structure (e.g., correlation, regression, structural equation modeling), which does not allow any *necessity inferences.* A typical predictive framework of such traditional approaches allows inferences such as "if *X* increases, *Y* is likely to increase," "*X* is associated with an increase in *Y* on average," or "a higher value of *Y* may exist in the presence of a higher value of *X*." On the other hand, NCA is built with a necessary condition interpretative framework that allows inferences such as: "*X* is necessary for *Y* to happen," "*X* is a must-have for *Y* to happen," "*X* is essential for *Y*," or "we cannot expect to have *Y* without *X*." Dul (2016, 10) points out that "without the necessary condition, there is guaranteed failure, which cannot be compensated by other determinants of the outcome."

The main outcome of NCA is expressed by a ceiling line. The most commonly used methods to obtain a ceiling line are the ceiling envelopment–free disposal hull (CE-FDH) and ceiling regression–free disposal hull (CR-FDH), which are akin to a regression line in regression analysis (see detailed information in Dul 2016). A ceiling line is obtained as the piecewise linear function that does not decrease (i.e., *Y* values increase with higher values of *X*) and is drawn between the almost completely empty (without observations) and nonempty (with observations) zones in a Cartesian coordinate system.

For illustrative purposes, let's take the example of figure 1*A*, which shows the relationships between mathematics achievement and home educational resources. The thick straight line is based on the NCA CR-FDH method and the thick dotted line is obtained from the ordinary least squares (OLS)-based regression (i.e., for a bivariate relationship, representing correlation).

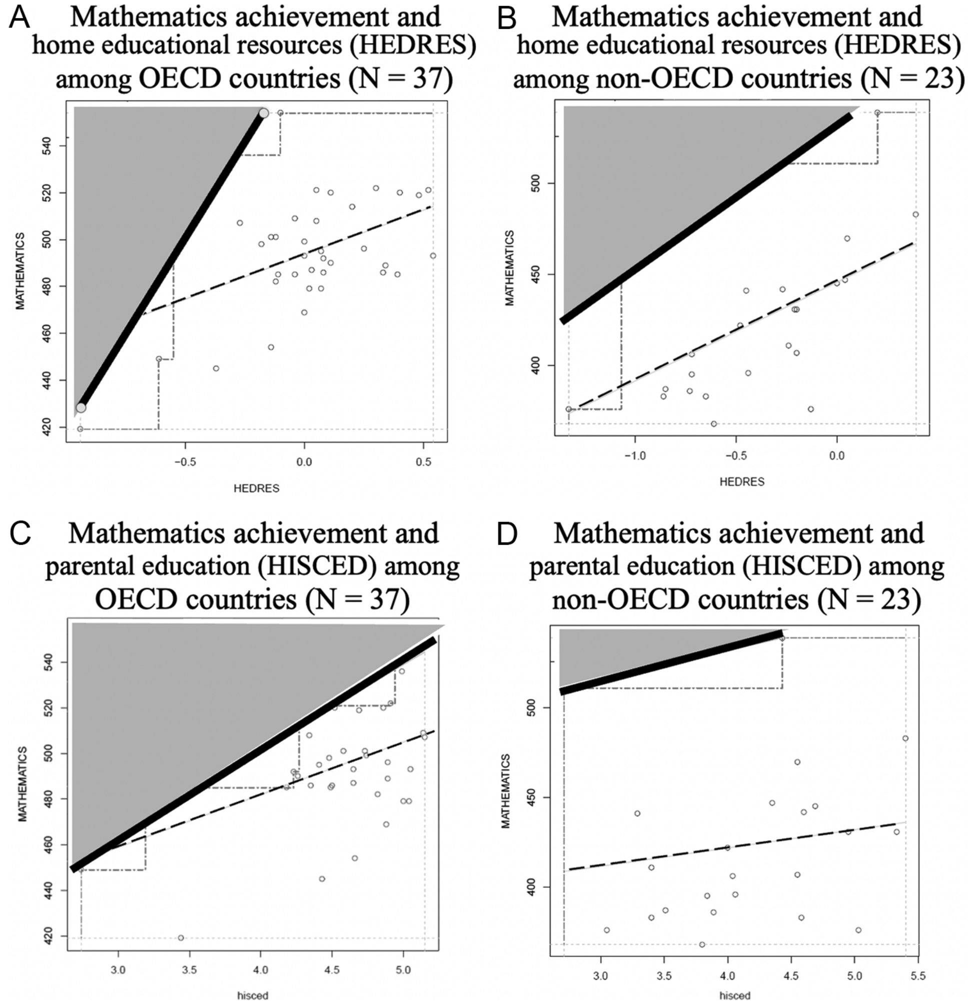

FIGURE 1.—Necessary condition analysis (NCA) plots for home educational resources (HEDRES), parental education level (HISCED), and mathematics achievement in OECD and non-OECD countries based on PISA 2012 data. NOTE.—The thick straight lines are based on the NCA CR-FDH ceiling method; the thin dotted (step) lines are based on the NCA CE-FDH ceiling method; and the thick dotted lines are obtained from the ordinary least squares (OLS)-based regression. A color version of this figure is available online.

As can be seen, the NCA-based line is drawn by connecting the ceiling points whereas the correlation/regression-based line is drawn by cutting through the data points in the middle. Thus, the data points in *X* for a given *Y* exist above and below the correlation/regression line and thus, on a particular predicted point of *Y*, variation of *X* is possible. On the other hand, the NCA method includes (virtually) all possible *X* points below the ceiling line and excludes (virtually) all possible *X* points above the ceiling line, for a given *Y*. Thus, the ceiling line represents a necessary condition of *Y* "must happen" for all values of *X*; the NCA framework places stronger constraints on the explanatory variables' relationship to the outcome variable, which makes NCA appropriate to model a "necessary" condition.

Due to differences in analytic paradigms and effect size calculations, NCA and traditional methods can produce different results; thus "correlation and necessity can be completely independent: there can be necessity without correlation and correlation without necessity" (Karwowski et al. 2017, 113). It is now recognized that "traditional analysis (correlation, regression, "average line through the middle") and necessary conditions analysis (ceiling line) are fundamentally different and equally valid for their own purposes" (Dul 2016, 36). It is recommended that due to the complementary nature between NCA and traditional analyses, the data be "analyzed using traditional variants of the general linear model (e.g., correlation or regression)" as part of the methodological sequence of NCA (Dul 2016, 12). Following this recommendation, most NCA application papers present their results using both NCA and traditional methods, which we have also done in this article.

Although NCA is a relatively new method (Dul 2016), over 70 publications of NCA applications have appeared across diverse fields including medicine, economics, business, organizational psychology, cognitive psychology, information system, tourism, environmental studies, history, and transportation.[4] Recently, education researchers have started to embrace this method. For example, Tynan et al. (2020) reported that class attendance, prior achievement, growth mindset, and intelligence are moderately strong necessary conditions, while grit, conscientiousness, and self-esteem are weak necessary conditions for undergraduate students' grade point average. Another example from cognitive psychology demonstrated that there are only minimal chances of being creative among individuals whose intelligence, as measured 40 years ago, was low (Karwowski et al. 2017). As mentioned above, NCA and correlation-based statistics can produce different outcomes, as was the case in Karwowski et al. (2017), where statistically significant NCA effects were found between creativity and intelligence but their bivariate correlation was nearly zero.

Another important feature of NCA is what is known as a *bottleneck* outcome (presented in table 2), which identifies a value of *X* that is minimally necessary for *Y* to occur (Dul 2016). Thus, a bottleneck is a point in the necessary (critical) point of *X* that would deter an outcome *Y* from occurring. Effect size (d) of NCA is calculated as the area above the ceiling line (i.e., where observations are not found) divided by the scope, which is the total area where observations are possible given the minimum and maximum values of *X* and *Y*. Effect size is expressed as a value between 0 and 1, with a larger effect size being associated with a stronger constraint of *X* on *Y*. An effect size (d) between 0 and 0.1 is considered a small effect, between 0.1 and 0.3 a medium

[4] Papers are compiled on the NCA website, https://www.erim.eur.nl/necessary-condition-analysis/publications/substantive-publications/.

effect, between 0.3 and 0.5 a large effect, and a value greater than 0.5 is considered a very large effect (Dul 2016).

NCA effect sizes are also evaluated via the conventional statistical significance tests (Dul et al. 2020). Dul (2016) recommends that three conditions should be considered simultaneously to reach a necessary condition conclusion: theoretical support, statistical significance (p-values smaller than .05), and practical significance (meaningful effect size, e.g., $d > .10$). Thus, in the present study, statistical test results are taken to demonstrate "statistical significance," while the actual effect sizes (in an absolute sense) are interpreted as having practical significance. NCA was conducted using the NCA package 3.0.1 in the R program.

Results

OECD Countries: NCA Effect Sizes

The first two columns in table 1 present NCA results across the OECD countries. Overall, similar results were obtained by the two (CE- and CR-based)

TABLE 1
NECESSARY CONDITION ANALYSIS (NCA) EFFECT SIZES OF SOCIOECONOMIC STATUS ON MATHEMATICS ACHIEVEMENT IN OECD AND NON-OECD COUNTRIES

	OECD Countries/Educational Systems (N = 37)			Non-OECD Countries/Educational Systems (N = 23)		
SES Variable	NCA-CE	NCA-CR	r	NCA-CE	NCA-CR	r
Physical resources:						
1. Educational resources at home (HEDRES)	.30	.25	.45**	.27	.26	.51*
2. Home possessions (HOMEPOS)	.37*	.23	.44**	.26	.29	.40
3. Household wealth (WEALTH)	.29	.15	.34*	.21	.26	.27
4. Cultural possessions at home (CULTPOS)	.09	.05	.06	.25	.20	.29
Human resources:						
5. Parental education (HISCED)	.44**	.40**	.46**	.11	.05	.17
6. Father's education (FISCED)	.40**	.36**	.52**	.10	.05	.21
7. Mother's education (MISCED)	.47*	.37*	.44**	.09	.04	.22
8. Parental occupational status (HISEI)	.37*	.31*	.40*	.14	.07	.11
9. Father's occupational status (BFMJ2)	.29*	.24*	.40*	.13	.06	.04
10. Mother's occupational status (BMMJ1)	.16	.13	.12	.09	.05	−.13

NOTE.—NCA-CR = necessary condition analysis based on ceiling regression; NCA-CE = necessary condition analysis based on ceiling envelopment. OECD countries/educational systems (N = 37) are Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Republic of Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom (excluding Scotland), United Kingdom (Scotland), and United States of America; non-OECD countries/educational systems (N = 23) are Albania, Argentina, Brazil, Bulgaria, Colombia, Costa Rica, Croatia, Indonesia, Kazakhstan, Jordan, Liechtenstein, Malaysia, Montenegro, Peru, Qatar, Romania, Russian Federation, Serbia, Vietnam, Thailand, United Arab Emirates, Tunisia, and Uruguay; the five East Asian educational systems that were excluded from the non-OECD country analysis (N = 23) are China (Shanghai), Chinese Taipei, Hong Kong–China, Macao-China, and Singapore.

* $p < .05$.

** $p < .01$.

NCA methods, and thus only the CR-based results are described in this section. The first and perhaps most interesting finding is that all four physical resource variables (educational resources at home, home possessions, household wealth, and cultural possessions) failed to reach statistical significance as a necessary condition for mathematics achievement. This means that physical resources at home were not a necessary condition for higher mathematics achievement across OECD countries.

On the other hand, five out of six human resource–related SES variables (parental education, father's education, mother's education, parental occupational status, and father's occupational status) turned out to be necessary conditions for higher mathematics achievement across OECD countries. The effect sizes of these five variables were all in the medium range according to the NCA framework (Dul 2016), and statistically significant at a conventional level ($p < .05$), ranging from father's occupational status ($d = .24$; $p = .02$) at the lowest to parental education level ($d = .40$; $p = .009$) at the highest.

Within the human resource variables, parental educational attainment ($d = .36$ to .40) showed slightly stronger effect sizes than parental occupation status ($d = .13$ to .31), highlighting the greater importance of parental education as a necessary condition for countries' mathematics achievement across OECD countries. Further, the result relating to the NCA effects of father's and mother's occupational status is noteworthy: father's occupational status ($d = .24$; $p = .02$) was statistically significant while mother's occupational status was not ($d = .13$; $p = .28$). In fact, mother's occupational status was the only human resource–related variable that did not turn out to be a statistically significant, necessary condition for countries' mathematics achievement. This means that a country with higher mother's occupational status does not necessarily produce higher mathematics performance across OECD countries.

The third column of table 1 shows country-level raw correlations between each of the SES variables and mathematics achievement across OECD countries. The unique features of the NCA-based results are evident in light of the results obtained from the more traditional statistical method (correlation). As can be seen, eight out of the 10 SES variables, with the exceptions of mother's occupational status ($r = .12$) and cultural possessions ($r = .06$), showed statistically significant, moderately strong correlations with mathematics achievement, ranging between $r = .34$ (household wealth) and .52 (father's education). Of particular relevance to the current study is the finding of no considerable difference in the effect sizes between the physical and human resource variables with respect to mathematics achievement. Specifically, the correlations shown by educational resources at home ($r = .45$) and home possessions ($r = .44$) were similar to the correlations of parental education ($r = .46$), mother's education ($r = .44$), parental occupational status ($r = .40$), and father's occupational status ($r = .40$). In contrast, as described above, the NCA results showed that overall, the human resource–related variables were, but physical resource–related variables were not, statistically significant necessary conditions for mathematics achievement across OECD countries.

OECD Countries: Bottleneck Analysis

The NCA bottleneck results (based on the CR-FEH line) are presented in table 2. The numbers under each of the SES variable columns show the minimum level of the SES variables (in a percentage range) as a necessary

TABLE 2
NECESSARY CONDITION BOTTLENECK RESULTS OF TEN SES VARIABLES (IN PERCENTAGE RANGE) FOR MATHEMATICS ACHIEVEMENT

	OECD Countries/Educational Systems (N = 37)									
	Socioeconomic Status Variable									
Math Achievement	1	2	8	5	7	3	9	6	10	4
419 (0%)	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
433 (10%)	3	1	NN	NN	NN	NN	NN	NN	NN	NN
446 (20%)	9	6	4	NN	NN	NN	NN	NN	NN	NN
460 (30%)	14	12	10	4	11	4	NN	NN	NN	NN
473 (40%)	20	18	19	20	23	9	6	NN	NN	NN
487 (50%)	25	23	29	35	34	14	17	20	5	NN
500 (60%)	31	29	38	50	46	18	29	42	13	NN
514 (70%)	36	34	48	65	57	23	41	63	21	NN
527 (80%)	42	40	57	80	69	28	52	85	29	NN
540 (90%)	47	46	66	96	80	33	64	100	37	17
554 (100%)	53	51	76	100	92	38	75	100	45	68
	Non-OECD Countries/Educational Systems (N = 23) Excluding Five East Asian Educational Systems									
	Socioeconomic Status Variable									
	4	2	3	1	8	9	5	6	7	10
368 (0%)	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
385 (10%)	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
402 (20%)	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
419 (30%)	5	NN	NN	NN	NN	NN	NN	NN	NN	NN
436 (40%)	12	3	1	6	NN	NN	NN	NN	NN	NN
454 (50%)	19	18	15	19	NN	NN	NN	NN	NN	NN
470 (60%)	26	33	29	31	NN	NN	NN	NN	NN	NN
487 (70%)	32	48	43	44	NN	NN	NN	NN	NN	NN
505 (80%)	39	63	58	56	NN	NN	NN	NN	NN	NN
521 (90%)	46	78	72	69	33	30	25	24	20	22
540 (100%)	53	93	86	81	86	77	64	61	52	58

NOTE.—1: Educational resources at home (HEDRES); 2: Home possessions (HOMEPOS); 3: Household wealth (WEALTH); 4: Cultural possessions (CULTPOS) 5: Parental education (HISCED); 6: Father's education (FISCED); 7: Mother's education (MISCED); 8: Parental occupational status (HISEI); 9: Father's occupational status (BFMJ2); 10: Mother's occupational status (BMMJ1); NN = not necessary. The following categories were used for the three variables of educational levels (HISCED, FISCED, MISCED): 0 = none; 1 = ISCED 1 (primary education); 2 = ISCED 2 (lower secondary education); 3 = ISCED 3B, C (upper secondary education); 4 = ISCED 3A, ISCED 4 (nontertiary postsecondary or upper secondary); 5 = ISCED 5B (*non-university* tertiary education); 6 = ISCED 5A, 6 (university level tertiary education or advanced research programs). The educational levels and the variable percentile scores correspond in the following manner: 4.34 (24%), 4.65 (51%), 4.89 (76%), and 5.15 (100%) for HISCED; 3.94 (24%), 4.10 (51%), 4.42 (76%), and 4.71 (100%) for FISCED; and 3.88 (24%), 4.24 (51%), 4.56 (76%), and 4.88 (100%) for MISCED among the OECD countries; and 3.51 (26%), 4.06 (52%), 4.58 (74%), and 5.40 (100%) for HISCED; 3.24 (26%), 3.66 (52%), 4.21 (74%), and 5.11 (100%) for FISCED; and 2.94 (26%), 3.63 (52%), 4.17 (74%), and 5.21 (100%) for MISCED among the non-OECD countries.

condition for the mathematics scores listed in the first column. For illustrative purposes, the NCA bottleneck results for every tenth percentage of mathematics achievement between the minimum (419) and maximum (554) scores of OECD countries are presented in the top part of table 2. The letters "NN" (not necessary) indicate that an SES variable is not a necessary condition for a given level of mathematics performance (please also refer to statements and numbers in the notes for table 2 describing how percentage ranges of education variables correspond to parents'/father's/mother's educational levels).

The bottleneck results indicate that in order to reach a 100 percent or 90 percent range of mathematics performance, all 10 SES variables were necessary conditions (none are indicated as "NN"), although there was a wide range of percentage requirements for the bottleneck conditions across different SES variables. Specifically, for an OECD country to have the highest country-level mathematics achievement (a score of 554), the country needs to be at a 100 percent range of parental education (variable 5) and father's education (variable 6). Mother's education (variable 7) was also an important necessary condition, requiring 92 percent, and the percentage requirements were somewhat lower at 76 percent for parental occupational status (variable 8) and 75 percent for father's occupational status (variable 9). These five variables were all education- and occupation-related SES indicators, which showed the strongest effect sizes for mathematics achievement across OECD countries (see table 1). It is important to note the much lower percentage requirements for the physical resource variables (e.g., 53 percent for variable 1, educational resources at home), indicating that human resources (education and occupation) were much more important than physical resources for OECD countries' achievement.

For a 50 percent range of mathematics performance (a score of 487), the strongest bottleneck conditions were 35 percent for variable 5, parental education, 34 percent for variable 7, mother's education, and 29 percent for variable 8, parental occupational status. Physical resources were weaker constraints, requiring a lower percentage range, for example, 25 percent for educational resources at home (variable 1) and 23 percent for home possessions (variable 2) across OECD countries.

Overall, the bottleneck results showed that human resources (education- and occupation-related SES variables) were necessary conditions and much more stringent requirements than physical resources were for an OECD country to perform at a higher level. However, the distinct benefits of human resources became blurry at about the 40 percent performance range. Subsequently, only physical resources were necessary conditions for the mathematics performance range of 20 percent and lower. Thus, it can be concluded that human resources were important for an OECD country's high levels of performance and that they became less important for low levels of performance in mathematics.

Non-OECD Countries: NCA Effect Sizes

The right-hand side of table 1 presents the effect sizes of the SES variables as necessary conditions for mathematics achievement across non-OECD countries. To our surprise, none of the 10 SES variables examined in this study turned out to be a statistically significant, necessary condition for countries' mathematics achievement (based on either CE or CR methods). When statistical significance was set aside and only practical significance (i.e., an absolute value of effect size greater than .20) was considered, all four physical resource variables had a medium effect size: home possessions ($d = .29$), educational resources at home ($d = .26$), household wealth ($d = .26$), and cultural possessions ($d = .20$).

All of the six human resource–related variables (those regarding educational and occupational status), on the other hand, showed effect sizes hovering around zero, ranging from $d = .04$ for mother's education to $d = .07$ for parental occupational status, indicating that human resources at home had neither statistical nor practical significance for mathematics achievement. Thus, the NCA results showed a sharp contrast between OECD and non-OECD countries in terms of the relative importance of physical versus human resources for mathematics performance.

The last column of table 1 presents country-level correlations between each of the SES variables and mathematics achievement across non-OECD countries. Only one SES variable, educational resources at home ($r = .51, p < .05$), showed a statistically significant association with mathematics achievement. Further, the correlations were stronger for the physical resources variables (ranging from $r = .29$ to .51) than for the human resource variables (ranging from $r = -.13$ to .22), across non-OECD countries. Overall, stronger effect sizes were found for physical resources (compared to human resources) across non-OECD countries. This overall conclusion was consistent between both correlational and NCA analyses, but the NCA findings demonstrated a clearer pattern in favor of the necessity of physical resources for increased mathematics performance across non-OECD countries.

Non-OECD Countries: Bottleneck Analysis

The lower portion of table 2 presents the bottleneck results for non-OECD countries. The SES variables did not become bottleneck conditions for most of the score ranges in mathematics (indicated with "NN"). Only four variables related to physical resources (educational resources at home, home possessions, household wealth, and cultural possessions) were needed from the 40 percent (a score of at least 436) performance range. The lack of relevance of parental educational attainment and occupational status (variables 5–10) as necessary conditions for countries' achievement throughout most of the performance range (i.e., up to 80 percent) is a surprising result.

Even at the 90 percent performance range, physical resources appeared to be more important than human resources for mathematics achievement across non-OECD countries. The percentage requirement was still quite low for the human resource variables, at 20 percent (variable 7, mother's education), 22 percent (variable 10, mother's occupation), 24 percent (variable 6, father's education), 25 percent (variable 5, parental education), 30 percent (variable 9, father's occupation), and 33 percent (variable 8, parental occupation). These percentages are in contrast to the much higher percentage requirements for physical resources: 78 percent (variable 2, home possessions), 72 percent (variable 3, household wealth), and 69 percent (variable 1, educational resources at home). Overall, the bottleneck analysis across non-OECD countries shows that physical resources do matter more than human resources for better mathematics performance in a non-OECD country.

NCA Plots: Summary Findings for OECD and Non-OECD Countries

The main conclusions from the NCA are summarized using the visual representations of NCA plots. For illustrative purposes, figure 1 presents NCA plots for home educational resources (i.e., physical resources) for OECD countries (fig. 1*A*) and for non-OECD countries (fig. 1*B*), and parental educational attainment (i.e., human resources) for OECD countries (fig. 1*C*) and for non-OECD countries (fig. 1*D*). The thick straight lines are based on the CR-FDH ceiling method, the thin dotted (step) lines are based on the CE-FDH ceiling method, and the thick dotted lines are obtained from the ordinary least squares (OLS)-based regression. The "empty zone" with no data is the area above the ceiling line, which is highlighted in gray.

When the NCA plots of figure 1*A* and figure 1*B* are compared, the areas of the empty zones of home educational resources (HEDRES) marked by the NCA ceiling lines do not appear to differ substantially between OECD and non-OECD countries. This suggests that the home educational resource variable (HEDRES) played a similar role in countries' mathematics achievement between these two groups of countries. On the other hand, the empty zones for parental education (HISCED) were larger (i.e., were a more stringent requirement) for OECD countries (fig. 1*C*) and smaller (i.e., being a less stringent requirement) for non-OECD countries (fig. 1*D*). These two plots indicate that relatively good performance is not possible when parental educational attainment is low for an OECD country, which is not the case for a non-OECD country.

Discussion

Key Findings

The present study investigated the relative advantage of physical and human resources representing family SES for mathematics performance across the (generally) richer, more powerful, and more developed OECD countries versus the (generally) poorer, less powerful, and less developed non-OECD countries. Indeed, our analysis showed the differential effects of family SES on countries' mathematics achievement depending on the types of family SES and also by countries' developmental status. This conclusion lends support to the long-standing concern expressed in the international educational assessment community that "what applies to OECD countries does not apply equally to all countries" (Bloem 2013, 18). Specifically, the human resources at home (i.e., educational attainment or occupational status) were statistically significant and practically meaningful for countries' mathematics performance only across OECD countries. On the other hand, the relationship between family human resources and mathematics achievement was not statistically significant with near zero effect size across non-OECD countries. This result suggests that investment in human resources is likely to produce a good return for countries' mathematics performance for developed countries, while a similar conclusion does not hold for less developed, non-OECD countries.

Revisiting the Theoretical Hypotheses

The main findings of the present study were evaluated in the context of the theoretical hypotheses presented in the introduction (see table 3). First, there was partial support for the *family resource provider hypothesis* (see Chiu et al. 2007; Chiu 2010) because the hypothesized relationship (a stronger SES-achievement effect in more developed countries) was found only on the human resources variables. The hypothesis did not consider distinct types of SES, and in a nutshell, it was not supported when only physical resources were considered (see tables 1 and 3).

The *complementary intangibles hypothesis* (Chiu et al. 2007; Chiu 2010), however, was fully supported by this study's findings in that the effect of human resources was stronger in more developed countries. Intangible resources within a family are primarily created and influenced by parental education and occupational status.[5] As this hypothesis suggests, human resource aspects of family SES showed the necessary condition effects only in the richer OECD countries.

The *public resources substitution* and *public resources deprivation* hypotheses (Blossfeld and Shavit 1993; Schiller et al. 2002), which posited a stronger SES-achievement relationship in less developed countries, were not supported by the NCA results because the effects of physical resources were more or less similar between OECD and non-OECD countries. This finding aligns with Chiu (2010), who concluded that the effects of physical resources at home (more books and cultural possessions) on academic achievement were similar between poor and rich countries in PISA 2000 data.

[5] Fuller and Clarke (1994); Chiu et al. (2007); Chiu (2010).

TABLE 3
THEORETICAL HYPOTHESES AND EMPIRICAL SUPPORT FROM NECESSARY CONDITION ANALYSIS (NCA) OF THE PRESENT STUDY

Theoretical Hypothesis	Hypothesis	Prediction	The Present Study: Empirical Support: Overall	Physical Resources	Human Resources
Family resource provider hypothesis (Chiu et al. 2007; Chiu 2010) and Heyneman-Loxley effect (Heyneman and Loxley 1983)	Stronger effect in developed countries	No distinction made between physical and human resources	Partially supported	Not supported: Similar effect sizes between OECD and non-OECD countries	Supported
Complementary intangibles hypothesis (Chiu et al. 2007; Chiu 2010)	Stronger effect in developed countries	Human resources	Fully supported	N/A	Supported
Public resources substitution and Public resources deprivation hypotheses (Blossfeld and Shavit 1993; Schiller et al. 2002)	Stronger effect in less developed countries	Physical resources	Not supported	Not supported: Similar effect sizes between OECD and non-OECD countries	N/A
Rising meritocracy hypothesis (Montagnes 2001; Schiller et al. 2002)	Stronger effect in less developed countries	No distinction made between physical and human resources	Not supported	Not supported: Similar effect sizes between OECD and non-OECD countries	Not supported: Stronger effect sizes in OECD countries

Finally, the present study gives empirical support to the Heyneman-Loxley effect, that is, overall, a lower SES effect in less developed countries. However, Heyneman and Loxley's (1983) study was based on only 29 countries, while the present study is based on 60 countries. The SES measure of Heyneman and Loxley (1983) is an SES composite variable consisting of mother's education, father's education, father's occupation, the number of books in the home, and some other measures of consumption such as possession of a record player, while no distinction was made for physical versus human resources in the family SES measure. Thus, the present study offers a more fine-grained analysis of the impact of SES by decomposing its sources to physical versus human resources at home.

Relative Importance of Physical Resources in Non-OECD Countries

The family SES variables related to physical resources—home possessions, home educational resources, household wealth, and cultural possessions—failed to produce statistically significant necessary conditions in both OECD and non-OECD countries. Thus, physical aspects of SES are only "nice to haves" on average (based on the correlational results) but not must-haves (based on the NCA results). However, the NCA results also suggested that the relative importance of physical resources, compared to that of human resources, was stronger across less developed, non-OECD countries. Medium NCA effect sizes (greater than .20) were found for all four physical resource variables, in contrast to nearly zero NCA effect sizes from all six human resource SES variables.

Past research on physical resources and academic achievement with respect to country development has largely focused on physical facilities and resources of schools, rather than those of families. For example, Hanushek (1995) reported that the quality of a school's physical facilities was the only factor that was systematically related to academic achievement in developing countries. In Fuller and Clark (1994), basic physical resources at school (e.g., facilities and electricity) tended to show larger effect sizes in poorer environments. Other scholars who specialize in education issues of developing countries have emphasized the importance of tangible, physical resources at home for students to gain access to schooling beyond primary school (Lathapipat 2013; Lounkaew 2013).

Human Resources Are Not Necessary in Non-OECD Countries

The present study's finding that parental education and occupation variables show virtually zero necessary condition effects across non-OECD countries was unexpected and thus warrants more in-depth discussion. A few scenarios can be drawn from past studies to contextualize this result. First, the *complementary intangibles hypothesis* (Chiu et al. 2007; Chiu 2010) suggests that quality of parental support for their child's education often represent intangible resources within the family and broader community including the overall economic and educational development and achievement of the population. For instance, even if a parent is highly educated within a given country, their influence on a child's education may be weakened by the relative lack of economic, social, and educational infrastructure and resources within the country (Heyneman and Lee 2016). Therefore, parental human resources may have attenuated influence on children's achievement if system-wide intangible resources (e.g., teacher development opportunities or school quality) have not been sufficiently developed within the country.

Another scenario is related to the PISA target population, which is 15-year-old students. School children in middle- and low-income countries tend to be select groups whose parents value education and send their children to secondary school instead of choosing or allowing their child to engage in paid or unpaid work (Lathapipat 2013). In other words, not all young people of that age are enrolled in school in middle- or low- income countries whereas virtually all youth of that age are enrolled in school in high-income countries.

Thus, our result suggesting little effect of human resources on the country's achievement among less developed countries might be due to the PISA student participants having parents with relatively similar values and mindsets.

Third, the lack of the necessary condition relationship between family human resources and countries' achievement across less developed countries may be related to the challenges of measuring educational attainment and occupational status. In the current large-scale assessments, only quantity (but not quality) of parental educational attainment is measured, yet "nobody believes that all the schools within a country or across countries are the same in terms of knowledge imparted and quality in general" (Hanushek and Luque 2003, 482). Quality of education refers to the "knowledge base and analytical skills that are the focal point of schools" (Hanushek and Luque 2003, 482), which is critically important for understanding economic growth across countries. The same issue is evident in the parental occupation measure in PISA, which treats the same occupation as "equal" across different countries. Yet the power of physical and human resources to create educational opportunities can vary widely within the same profession between richer and poorer countries.

One of the OECD's recent international projects (titled "Higher Education Policy") is to benchmark cross-national qualities of higher education systems. However, the development of a conceptual framework for understanding quality in the higher education context is still in its infancy, with only four countries (Belgium, Estonia, the Netherlands, and Norway) being involved in the project thus far (OECD 2017). The country-level "education quality" index may be incorporated into the PISA individual-level SES index scores. As long as cross-country variation in educational quality is not taken into consideration, the parental educational and occupational indicators will continue to be imprecise proxies across the countries with differing levels of economic and educational development.

The last, but perhaps most fundamental, issue may be attributable to the long history of the SES concept being developed primarily by researchers from more developed, Western countries. The OECD's recent project ("PISA for Development," known as PISA-D) embodies an international effort to incorporate education-related concepts including family SES, to be examined and assessed in a way that is better aligned with the social and economic contexts of low- and middle-income countries (OECD 2018b).

Limitations of This Study

Several limitations of this research should be mentioned. First, the current study used the existing PISA data and was therefore based on the SES conceptual framework adopted by PISA. Further, variables that are not measured in the current PISA data framework were excluded from the current study (e.g., direct modeling of public resources). Second, the data on family SES variables were obtained from students' self-reports and therefore may be biased or simply not reported correctly. Information about family wealth may be supplemented by other data sources, such as national-level census data or residential postal code information. Third, NCA effect sizes are known to be influenced by outliers because they are calculated by the ceiling line (i.e., including maximally possible scores). Accordingly, the deletion of outliers should be based on theoretical or conceptual grounds (Dul 2016). In the present study, outliers were not removed because the country-level aggregated scores were not treated as “outliers.”

Fourth, we used countries as the unit of analysis because the country’s development was the main variable in this study. Analysis using different units of analysis (such as individual level) may produce somewhat incongruent results (see Lee et al. 2019). Fifth, the present study employed the OECD/non-OECD division to separate more and less developed countries. The dichotomous grouping of OECD and non-OECD is practical and comprehensive in that OECD membership represents not only the countries’ economic status but also their geopolitical influence in the world. However, we also acknowledge that this approach may not represent the most ideal indicator of country development. Further, within-country family SES variations exist in both OECD and non-OECD countries, but these variations were not a focus of the present study.

Sixth, the analysis of this study focused on bivariate relationships between SES variables and mathematics achievement at the country level. Other national-level, social, educational, and economic conditions that may be potentially related to both SES and student achievement (and thus can act as either mediators or moderators that may imply causality) were excluded. Seventh, we would also like to emphasize that NCA results do not contain any causality implications. The results of the current study were presented with effect sizes, that is, correlation and effect size (d) within the NCA framework. These effect sizes do not imply the pre- and post-intervention effects often seen in an experimental study design.

Finally, although the data set contained 60 countries and is therefore among the largest of its kind to date in terms of global coverage of student achievement data, many low-income or severely underdeveloped countries as well as countries in the Latin American and African regions were underrepresented in the PISA data. Although PISA’s SES concepts evolve to accommodate economic conditions of lower- and middle-lower income countries, theory regarding the SES-achievement relationship has been developed primarily in English-speaking countries (e.g., the United States or United Kingdom) and thus the findings of this study may reflect this bias. This point warrants more theoretical development of the localized SES concept in less developed countries. Future studies may further examine the present study’s findings by using the data from the PISA for Development (PISA-D) project, which included more countries from South Asia, Latin America, and Africa.

Practical Implications and Conclusion

The present study provides insights of importance to the international educational communities about ways to help reduce inequality in educational achievement across countries with different levels of development. Identifying necessary conditions implies that interventions that do not take these variables into account are likely to produce very small or null effects. Therefore, system-level initiatives and support programs may need to be adjusted accordingly and countries may consider specific types of family resources that are more appropriate for their developmental status.

Developed Countries

The only necessary condition that was significant for obtaining higher mathematics performance across OECD countries was the availability of human resources *residing within the family*. This finding points to the importance of parents and caregivers (i.e., adults) having better education and higher occupational status. Thus, interventions to improve the necessary human resources may focus on strengthening and widening educational opportunities of the people across all ages and with differing levels of family background. Specific policies may include national-level strategies to allow multiple pathways to entering educational institutions (higher education, vocational schools, or universities), better and easier access to such opportunities for low-SES students and families, and more flexibility in allowing those who may wish to engage in or return to learning at a later age. This way, a critical mass of educational development may be reached and expanded within the nation.

Less Developed Countries

In contrast to developed countries, SES variables reflecting human resources showed no statistically significant necessary condition results within the sample of less developed countries. In addition, physical resources were shown to be more important than human resources for non-OECD countries' performance in mathematics. Given this finding, the international education interventions may involve direct investment of physical resources to the respective nation. As mentioned above, past research in developing countries has been heavily focused on school resources, and less so on family resources. Direct assistance with physical and material resources *residing at home* (e.g., books, computers, a place to study and discuss) may add more value to the international efforts to reduce inequality across countries, especially given that not all young children in low- and middle-income countries attend schools.

International Educational Communities

Educational equity has been declared to be one of the global aims of educational policy (OECD 2018a; UNESCO 2018). In spite of this general agreement, the educational equity outcome has not come to fruition (OECD

2019). The international community has called for more concerted commitment from national and international leaders if we are to see any tangible positive equity outcome (OECD 2018a; UNESCO 2018). The good news is that some countries have shown more successful outcomes in terms of SES-related educational disadvantage. Specifically, low-SES students in some Asian countries (e.g., Singapore, Hong Kong, Korea, and Japan) tend to perform better than their counterpart low-SES students in other countries. Some European countries, which are considered to be egalitarian societies (e.g., Finland, Ireland, Iceland, Latvia, Norway, and Sweden), have shown an inverted disadvantage—that is, their high-SES students had below average achievement outcome compared to their peers in other countries (Rowley et al. 2020). These variations across countries suggest that better educational equity outcomes are possible especially when macro-level country factors including economic development, geographic location, and social and cultural backgrounds variables (Stankov 2017; Rowley et al. 2020) are simultaneously considered. As many scholars have noted (e.g., Rowley et al. 2020), it is important that national and international leaders take note that equity-promoting policies speak not only to democratic and humanitarian values but may also facilitate economic development and aspirations of both richer and poorer nations (OECD 2018a). While educational policies will largely remain within the scope of each country's orientation (Stankov 2017), global leadership that emphasizes educational equality can be driven by the international community's continual call for the importance of providing equal opportunities for children of all socioeconomic backgrounds.

Appendix

TABLE A1
The UNDP Human Development Index (HDI)

	HDI (2018)	Life Expectancy at Birth (2018)	Expected Years of Schooling (2018)	Mean Years of Schooling (2018)	GNI per Capita (2018)	HDI Rank (2017)
OECD Countries:						
Australia	.938	83.3	22.1	12.7	44,097	5
Austria	.914	81.4	16.3	12.6	46,231	20
Belgium	.919	81.5	19.7	11.8	43,821	17
Canada	.922	82.3	16.1	13.3	43,602	13
Chile	.847	80.0	16.5	10.4	21,972	42
Czech Republic	.857	77.4	14.5	12.6	30,672	37
Denmark	.930	80.8	19.1	12.6	48,836	11
Estonia	.882	78.6	16.1	13.0	30,379	30
Finland	.925	81.7	19.3	12.4	41,779	12
France	.891	82.5	15.5	11.4	40,511	26
Germany	.939	81.2	17.1	14.1	46,946	4
Greece	.872	82.1	17.3	10.5	24,909	31
Hungary	.845	76.7	15.1	11.9	27,144	44
Iceland	.938	82.9	19.2	12.5	47,566	7
Ireland	.942	82.1	18.8	12.5	55,660	3

TABLE A1 (*Continued*)

Israel	.906	82.8	16.0	13.0	33,650	22
Italy	.883	83.4	16.2	10.2	36,141	29
Japan	.915	84.5	15.2	12.8	40,799	19
Korea	.906	82.8	16.4	12.2	36,757	22
Latvia	.854	75.2	16.0	12.8	26,301	39
Lithuania	.869	75.7	16.5	13.0	29,775	34
Luxembourg	.909	82.1	14.2	12.2	65,543	21
Mexico	.767	75.0	14.3	8.6	17,628	76
Netherlands	.933	82.1	18.0	12.2	50,013	10
New Zealand	.921	82.1	18.8	12.7	35,108	14
Norway	.954	82.3	18.1	12.6	68,059	1
Poland	.872	78.5	16.4	12.3	27,626	33
Portugal	.850	81.9	16.3	9.2	27,935	40
Scotland	.920	81.2	17.4	13.0	39,507	15
Slovak Republic	.857	77.4	14.5	12.6	30,672	37
Slovenia	.902	81.2	17.4	12.3	32,143	24
Spain	.893	83.4	17.9	9.8	35,041	25
Sweden	.937	82.7	18.8	12.4	47,955	7
Switzerland	.946	83.6	16.2	13.4	59,375	2
Turkey	.806	77.4	16.4	7.7	24,905	59
United Kingdom (excluding Scotland)	.920	81.2	17.4	13.0	39,507	15
United States	.920	78.9	16.3	13.4	56,140	15
Average	.897	80.8	17.0	12.0	39,316	23
Non-OECD Countries:						
Albania	.791	78.5	15.2	10.1	12,300	69
Argentina	.830	76.5	17.6	10.6	17,611	48
Brazil	.761	75.7	15.4	7.8	14,068	78
Bulgaria	.816	74.9	14.8	11.8	19,646	51
Colombia	.761	77.1	14.6	8.3	12,896	78
Costa Rica	.794	80.1	15.4	8.7	14,790	68
Croatia	.837	78.3	15.0	11.4	23,061	46
Indonesia	.707	71.5	12.9	8.0	11,256	111
Jordan	.723	74.4	11.9	10.5	8,268	99
Kazakhstan	.817	73.2	15.3	11.8	22,168	51
Liechtenstein	.917	80.5	14.7	12.5	99,732	18
Malaysia	.804	76.0	13.5	10.2	27,227	61
Montenegro	.816	76.8	15.0	11.4	17,511	51
Peru	.759	76.5	13.8	9.2	12,323	85
Qatar	.848	80.1	12.2	9.7	110,489	40
Romania	.816	75.9	14.3	11.0	23,906	51
Russia	.824	72.4	15.5	12.0	25,036	49
Serbia	.799	75.8	14.8	11.2	15,218	65
Thailand	.765	76.9	14.7	7.7	16,129	77
Tunisia	.739	76.5	15.1	7.2	10,677	91
United Arab Emirates	.866	77.8	13.6	11.0	66,912	35
Uruguay	.808	77.8	16.3	8.7	19,435	58
Vietnam	.693	75.3	12.7	8.2	6,220	118
Average	.795	76.5	14.5	9.9	26,386	65

SOURCE.—http://hdr.undp.org/en/data, accessed January 01, 2020.

NOTE.—GNI = gross national income. Czech Republic data were substituted by Slovak Republic data; Scotland data were substituted by the data from the UK, excluding Scotland.

TABLE A2

Family SES Variables in PISA 2012

Variable Name in PISA	Description (Response Categories versus Scale)
Educational resources at home (HEDRES)	Single scale (IRT-based) constructed based on the students' responses (yes/no) on seven items: a desk to study, a quiet place to study, a computer that students can use for schoolwork, educational software, books to help with schoolwork, technical reference books, and a dictionary.
Home possessions (HOMEPOS)	Semicomposite scale (IRT-based) derived from three possession-related scales: cultural possession (CULTPOS), home educational resources (HEDRES), and household wealth (WEALTH)
Household wealth (WEALTH)	Single scale (IRT-based) constructed based on students' responses (yes/no) on the items of whether they had: a room of their own, a link to the Internet, a dishwasher, and a (DVD or some other types of) player, plus three country-specific wealth-related items.
Cultural possessions at home (CULTPOS)	Single scale (IRT-based) constructed based on students' responses (yes/no) on the following three items: classic literature, books of poetry, and works of art.
Parental education (HISCED)	Scores created as the higher value of educational level of either parent (between MISCED and FISCED)
Father's education (FISCED)	Scores based on the response categories of: none (0), primary education (1), lower secondary (2), vocational/pre-vocational upper secondary (3), general upper secondary and/or nontertiary postsecondary (4), vocational tertiary (5), and theoretically oriented tertiary and post-graduate (6)
Mother's education (MISCED)	Constructed in the same way as FISCED.
Parental occupational status (HISEI)	Scores created as the higher value of educational level of either parent (between BFMJ2 and BMMJ1) or the only available parental occupational status score (ISEI)
Father's occupational status (BFMJ2)	Father's occupation data were collected through open-ended questions. The responses were coded according to the four-digit International Standard Classification of Occupations (ISCO) codes developed by the International Labour Organization (ILO 2007), which were then mapped into the International Socioeconomic Index of Occupational Status (ISEI, Ganzeboom 2010).
Mother's occupational status (BMMJ1)	Constructed in the same way as BFMJ2.

TABLE A3

Descriptive Statistics of the Country-Level Family SES Variables in PISA 2012

	OECD Countries/Educational Systems (N = 37)				Non-OECD Countries/Educational Systems (N = 23)			
SES Variable	Min	Max	Mean	SD	Min	Max	Mean	SD
HEDRES	−.94	.54	.02	.31	−1.33	.39	−.41	.42
HOMEPOS	−1.36	.69	.00	.40	−2.12	.48	−.79	.67
WEALTH	−1.54	.69	−.01	.48	−2.41	.84	−.90	.80
CULTPOS	−.48	.63	.00	.24	−.53	.52	−.02	.33
HISCED	2.74	5.15	4.53	.51	2.71	5.40	4.15	.72
FISCED	2.56	4.71	4.09	.49	2.44	5.11	3.77	.76
MISCED	1.79	4.88	4.16	.62	2.17	5.21	3.65	.82
HISEI	35.14	58.99	50.96	5.12	26.59	64.82	45.85	9.64
BFMJ2	33.90	52.21	43.74	4.05	23.78	61.70	40.61	8.86
BMMJ1	37.36	55.31	45.59	4.16	22.08	65.21	43.44	10.65
MATHEMATHICS	419	554	494	26	368	539	423	45

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