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Skills inequalities in 21 countries: PIAAC results for prime-age adults

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Abstract

Only few previous studies have explored cross-national variation in the relationship between educational certificates and competences. In this paper, we investigate the certificate-competence relationship, operationalized as skills gaps by level of educational attainment. More importantly, we scrutinize how two aspects of educational stratification processes, vertical stratification and occupation-specificity, affects skills gaps. Using data on 25-54 year olds from the 2011/12 round of the *Programme for the International Assessment of Adult Competencies* (PIAAC), we find that more occupation-specific education systems produce smaller differences in basic general skills between adults with low and intermediate levels of education. Higher levels of vertical stratification, by contrast, result in larger low-intermediate skills gaps. None of the two stratification aspects can however explain variations in the skills gaps between intermediate and high educated adults. We conclude by discussing the implications of our findings for labor market research.

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Contents

1. Introduction

Scholars agree that the relationship between educational degrees and competences or skills may vary across countries. Yet previous research has devoted surprisingly little attention to the sources of this cross-national variability. To our knowledge, only one quantitative study has attempted to explain country differences in the relationship between certificates and skills among adults: Using data on 19 countries from the *International Adult Literacy Survey* (IALS, conducted between 1994-1998 by the OECD), Park and Kyei (2011) examined literacy differentials by level of formal qualification (less than upper secondary education, upper secondary or non-tertiary post-secondary education, and college/tertiary education). They found substantial cross-national variation in literacy gaps between less and intermediate educated adults and, to a lesser extent, also between adults with intermediate and high levels of formal qualification (cf. Park and Kyei 2011:894-5). The main country-level explanatory variable examined by Park and Kyei was within-country heterogeneity of school quality, measured as between-school inequality of various resources (e.g., instructional resources, class size, or teacher experience). They showed that greater between-school resource inequality is associated with larger low-intermediate literacy gaps. Resource inequality, however, did not explain differences in intermediate-high literacy gaps.

Quite strikingly, Park and Kyei (2011) did not consider differences in educational stratification processes as an explanatory factor. They argued that "[b]ecause we are interested in literacy gaps between adults who did not graduate from high school (or may never have attended high school) and adults with high school degrees or higher, tracking is much less relevant for our study, even for countries with tracking systems (unless the tracking occurs at an early age). Moreover, studies that focus on tracking effects cannot address differences in other important aspects of educational systems among countries with the same type of tracking system." (Park and Kyei 2011:882) They decided to therefore "look at institutional factors that are likely to be more universally relevant", namely between-school inequality in basic school resources (Park and Kyei 2011:882).

In this study, we reconsider the potential role of educational stratification for explaining skills gaps by educational attainment. We focus on two distinct types of stratification: vertical stratification by student performance in lower secondary education (e.g., via achievement-related tracking) and horizontal stratification in terms of the primary content of educational programs in upper secondary education (occupational/vocational vs. general). There are at least two reasons why we should not rule out *a priori* that these two types of stratification condition the relationship between formal certificates and competences. First of all, there is substantial variability in the extent of stratification. Taking the example of vertical stratification, it is clear that countries do not simply track or not: Tracked education systems differ with respect to things such as the number of tracks or the age when tracking occurs (Bol and Van de Werfhorst 2013). Further, as we discuss below, even non-tracked education systems may differ in terms of how strongly high- and low-performing students cluster in the same schools and classrooms (e.g., because of differences in residential segregation). Second, and relatedly, there are strong reasons to expect that educational stratification influences the relationship between formal qualifications and competences: Educational stratification processes channel individuals into different learning environments (socialization) and/or different programs that lead to different levels of formal qualification (allocation) (cf. Allmendinger 1989:236; Kerckhoff 1995:326; Meyer 1977). Higher degrees of educational stratification may thus affect the relationship between competences and educational degrees via (competence-based) selection into different (more or less favorable) learning environments or formal educational programs (Gamoran 1986; Hallinan 1992).

More concretely, we extend the study by Park and Kyei (2011) in three ways. First, we investigate the impact of educational stratification processes on skills gaps by educational attainment, distinguishing between vertical (i.e., performance-related) stratification of lower secondary education and horizontal stratification, that is, occupation-specificity of upper secondary education. We also compare the importance of these dimensions of educational stratification to that of between-school inequality in instructional resources in lower secondary education, the focal variable of Park and Kyei (2011). Second, we use new data from the first round of the *Programme for the International Assessment of Adult Competencies* (PIAAC)—conducted in 2011/12 by the OECD. This data set contains information on educational certificates and generic basic competences (literacy and numeracy) of the adult population for more than 20 countries. Not only are the competence measures in PIAAC of much higher quality than in IALS (see Section 3). PIAAC also embraces a broader country sample, especially by including "achievement-oriented" East Asian countries (Korea and Japan). Third, even though our empirical contribution is restricted to (institutional sources of) cross-country variation in skills gaps, we do discuss some important implications of our findings for the interpretation of certificate and skills effects in labor market regressions.

The paper is structured as follows. We start with theoretical considerations about country variation in skills gaps by educational certificates (Section 2). In Section 3, we describe the PIAAC data and the methods used in our analyses. We present our empirical analysis in Section 4. Section 5 concludes by summarizing our findings and discussing their implications for studies of competence and certificate effects on labor market outcomes.

2. Country variation in skills gaps by educational degrees

We investigate country differences in two "skills gaps" as indications of the relationship between competences and educational degrees: The "lower skills gap" is defined as the (adjusted) difference in mean basic cognitive competences between adults with low (less than upper secondary) and intermediate (upper secondary or non-tertiary post-secondary) levels of educational attainment. The "upper skills gap" is defined as the difference between adults with intermediate and high (tertiary) levels of education.

Our basic assumption is that educational stratification processes sort individuals into different learning environments and thereby define opportunities to acquire educational degrees *and* (different types of) competences or skills. Correspondingly, one would expect that in more stratified systems formal certificates tend to be more closely related to (specific types of) skills. Plausible mechanisms through which more stratified systems strengthen the link between formal qualifications and skills include selection on the basis of pre-existing differences in competences (allocation), reinforcement of pre-existing differences due to the allocation of better-performing students to more favorable learning environments (socialization), and/or greater between-program (and hence between-student) differences in the types of skills that are emphasized (socialization and allocation).

Before we elaborate on these issues, we need to say a few words about the types of skills measured in PIAAC. In all countries, respondents were assessed with respect of two types of "key information-processing skills" (OECD 2013:3): literacy (reading and text comprehension) and numeracy (applied numeric and mathematical skills).[1] These skills are undoubtedly important, but it is important to be clear about what they are and what not. The literacy and numeracy skills assessed in PIAAC are probably best described as basic (as opposed to advanced) and general (as opposed to specific). The focus in the literacy domain was on the comprehension of (short) pieces of text (such as instructions or newspaper articles) that citizens of economically advanced societies might encounter in everyday life, inside and outside of work. It was not on understanding (or writing) research articles or other long and complex documents. In the numeracy domain, the focus similarly was on everyday tasks involving numerical operations such as correctly interpreting bar charts that might appear in newspaper articles or government brochures. It was not on solving problems that require knowledge of inferential statistics or calculus.

Even though it is likely that the skills measured in PIAAC are to some extent correlated with more advanced competences, the latter were not directly tested (see Section 3). As we discuss below, this may limit our ability to ascertain compe-

1 A third domain, "problem solving in technology rich environments", is unfortunately only available for a subset of countries and only for respondents who took the assessment on a computer (OECD 2013).

tence differentials in the upper part of the educational distribution, where we would expect to see differences primarily with respect to advanced skills. In addition, the skills assessed in PIAAC are general (or transferable) in the sense that they are likely to be useful in a large variety of work- and non-work settings. Occupation-specific skills (e.g., knowing the functioning of a car engine or certain programming languages), which are useful only in a much smaller set of specific occupations (and therefore emphasized by the respective training programs), were not measured. In the following discussion of how educational stratification conditions the link between formal qualification and skills, we will primarily focus on the relationship between qualifications and basic general skills as they are measured in PIAAC—because this is the relationship that we can ascertain empirically. Nevertheless, the (unobserved) types of skill (advanced and occupation-specific) also play a crucial part in our argument.

Returning to educational stratification processes, we begin with *vertical stratification*, by which we mean sorting by performance (ability) into different educational environments. A well-known form of vertical stratification is external differentiation via (ability) tracking. A broad definition of vertical stratification in terms of "performance-segregated learning environments" directs attention to vertical stratification occurring through processes other than explicit tracking. Explicit tracking (or "external differentiation") in lower secondary education certainly is an important source of vertical stratification, but it is not the only one possible. Residential segregation by family background—in combination with residence-based allocation to schools—might result in high levels of vertical stratification even in a system where children are not explicitly sorted into different academic tracks (cf. Kerckhoff 1995:327). The US is a good example: It has a comprehensive school system with little external differentiation, but due to (socioeconomic) residential segregation nevertheless an intermediate degree of vertical stratification—in the sense that there is considerable between-school variation in average student performance, that is, high and low-performing students tend to cluster in different schools. In the US-American case, a decentralized funding system may further raise the consequences of this clustering for skills acquisition: Because they tend to be located in less affluent neighborhoods, schools with lower-performing students will typically have fewer resources (Park and Kyei 2011:883). Other countries that differ noticeably in the degrees of school-level segregation by student performance ("performance sorting") and "external differentiation" are Italy, Japan, and the UK (cf. Appendix Table A2).

A first reason for expecting vertical stratification—school-level segregation by performance—to be associated with differences in skills gaps is that segregated learning environments may reinforce preexisting differences in competences: Literature on the so-called reflected-glory (or assimilation) effect suggests that lower-performing students' motivation and learning processes benefit from classmates with higher levels of proficiency (e.g., Cialdini and Richardson 1980; Snyder, Lassegard, and Ford 1986). In more stratified systems, low-ability students are deprived of such positive stimulation—when it comes to imparting basic cognitive competences in literacy and numeracy. This reflected-glory effect might be reinforced by larger differences in the aspiration levels of curricula and teacher's expectations and aspirations in more vertically stratified systems.

A second mechanism through which vertical stratification might affect skills gaps by educational attainment is selection. In countries with tracked systems, low-performing students likely face greater difficulties in gaining access to programs leading to higher educational degrees. Thus, at one and the same educational level, there should be smaller within-group heterogeneity with respect to preexisting differences in performance or ability. In particular, higher degrees of vertical stratification in lower secondary education might raise the probability that individuals with low initial levels of basic competences do not transition to or complete upper secondary education, thus ending up in the group with low formal qualifications. Conversely, in more inclusive systems, more of these individuals would presumably be found among the intermediate educated, lowering the mean competence level of this group—and thus the gap in basic competences between the individuals with low and intermediate levels of formal qualifications. By the same token, that is, because of selection processes that exclude low-performing students from gaining access to programs at the upper secondary level, one might expect skills gaps between intermediate and higher educated adults to be small(er) in countries with higher degrees of vertical stratification.

To sum up, if selection processes based on ability and/or reflected-glory-type processes are important, then higher degrees of vertical stratification lead to a situation where initial cognitive competences influence access to more favorable educational environments, that is, to a mutually reinforcing process of competence-based selection into less or more favorable learning environments. Given the expected negative consequences of vertical stratification for low-performing students, it is plausible to assume that vertical stratification primarily affects the relationship between certificates and competences in the lower part of a country's educational distribution. Differences in basic cognitive competences between less and intermediate educated individuals should be most strongly influenced by selection and different learning opportunities: Low-performing students end up in less stimulating learning environments in terms of enhancing their basic cognitive competences.

As for country-level variation in skills gaps, we therefore hypothesize that the gap in basic competences between less and intermediate educated adults rises with a country's level of vertical stratification in lower secondary education (*hypothesis 1a*). In contrast, according to the reflected-glory effect, individuals with intermediate and high educational degrees should be exposed to more stimulating schools or school tracks—and thus to learning environments that are more similar with respect to preserving and enhancing *basic* (as opposed to advanced) general competences. For the gap between intermediate and higher educated adults, we would therefore expect to find no effect of vertical stratification. If anything, we would expect to see smaller skills gaps in countries with higher degrees of vertical stratification of lower secondary education, because of a selection effect (i.e., individuals with low competences are more effectively excluded from entering educational programs that lead to intermediate formal qualifications) (*hypothesis 1b*).

These hypotheses and especially hypothesis 1a are based on the assumption that reflected-glory type processes predominate. There also exists a literature on the so-called big-fish-little-pond effect (Marsh 1987), which argues opposite to the reflected-glory effect. According to this explanation, the self-concept, motivation, and ultimately performance level of lower-ability students are negatively affected by peers with higher levels of proficiency. An implication of this effect is that low-ability students would be better off in terms of motivation and learning in more stratified school systems. In addition, teachers might be better able to tailor their teaching to the needs of students if the latter are more homogeneous. These arguments would suggest that hypothesis 1a will be falsified: The gap in basic competences between less and intermediate educated adults should decrease with a country's level of vertical stratification in lower secondary education. In terms of hypothesis 1b, only the selection effect would than apply, that is we would find lower skills gaps in more stratified countries.

The second dimension of educational stratification that likely affects skills gaps is horizontal: *the degree of occupation specificity of upper secondary education*. This feature is related to the question of what is learned in different tracks (at the same educational level): whether a country's system of upper secondary education puts greater emphasis on general or occupational/vocational skills. In more occupation-specific education systems, curricula and attention are directed more towards vocational than general skills (cf. Hanushek, Woessmann, and Zhang 2011; OECD 2010:59-60; OECD 2013:200-2; Shavit and Müller 2000).

We cannot directly explore the relationship between general competences, occupation-specific skills, and educational certificates with PIAAC (because occupation-specific skills were not measured). But it is plausible to assume that greater emphasis on occupation-specific skills in (upper) secondary education draws some resources (e.g., teaching and learning time) away from the acquisition of general cognitive skills. Thus, more of the learning time of intermediate-educated adults is devoted to acquiring occupation-specific skills rather than basic competences in countries with greater occupation-specificity. This is particularly true for countries with apprenticeship systems, like Germany or Austria: "In many apprenticeships, there is a rather small element of numeracy and literacy skills as part of the (typically) one or one and a half days a week part-time school element in the dual system." (OECD 2010:60)

In addition, occupation-specific upper secondary education systems are a constitutive part of occupational labor markets (Marsden 1990; Hall and Soskice 2011)—meaning that in these countries adults with vocational upper secondary education have rather good labor market opportunities in terms of occupying skilled position, while in general upper secondary education systems school leavers need to continue and finish tertiary education as a "safety net" to avoid unskilled jobs (Shavit and Müller 2000). Hence, in the latter countries, more adults attend college or university education than in occupational labor markets. This is evident in a rather high correlation between degree of occupation-specificity of upper secondary education system (Appendix Table A2) and the proportion of tertiary educated adults (Appendix Table A1) of -0.65. This suggests that entry into tertiary education is more selective with respect to preexisting differences in performance or ability in occupation-specific countries—and less selective in general-education countries.

Given these two mechanisms—learning time devoted to general competences in upper secondary education and selection into tertiary education—, occupation-specificity in upper secondary education might again differently affect the size of the lower and the upper skills gap. For the skills gap (in basic general competences) between less and intermediate-educated adults, we expect to find smaller gaps in countries with higher degrees of occupation-specificity of upper secondary education—because the intermediate group devoted a substantial portion of their learning time in upper secondary education to acquiring occupational rather than general skills (*hypothesis 2a*). As for the upper skills gap—that is, the gap between intermediate and higher educated adults—, we would expect it to be larger in countries with higher degrees of occupational specificity (*hypothesis 2b*). Again, this is partly because the intermediate group in more occupation-specific countries more heavily invested in occupation-specific skills. Yet it is also because of country differences in the selectivity of attending higher education: In occupation-specific countries, where vocational training programs at the upper secondary level provide a good alternative, those who decide to attend higher education should be a more selective, academically inclined group than in general systems.

One might suggest that we more directly test our assumption about the impact of attending a vocational program in upper secondary education, namely by comparing skills gaps between adults with vocational and general upper secondary education. This is, however, not a convincing approach. The PIAAC data provide only information on the *highest* educational degree completed. Hence those with general (as opposed to vocational) upper secondary education do not comprise all individuals who ever attended general programs at the upper secondary level: They rather are a selective group that did not continue with tertiary education. In this paper, we therefore rely on our indirect hypotheses and take their verification/falsification as a signal (proxy) of "theoretical constructs that provide hypothetical links between observable events," although they cannot can be (directly) observed (Hedström and Swedberg 1996:290).

The two institutional characteristics of education systems—vertical stratification and horizontal stratification in terms of occupation-specificity—co-exist in different combinations and in some countries their effects may cancel each other out. We expect the lower skills gaps to be smaller in more occupation-specific and to be larger in more stratifying education systems—and vice versa for the upper skills gap. Some well-known examples combine both a high degree of occupation-specificity and of vertical stratification (like Austria or Germany), or both a low degree of occupation-specificity and of vertical stratification (like Canada). If this relationship (i.e., of a positive relationship between occupational specificity and vertical stratification) holds more generally (which, as we show in Section 3, it does), then the expected effects of occupational specificity and vertical stratification should be stronger when both characteristics are included simultaneously in the regression.

3. Data and Methods

Data and sample

For our empirical analysis, we use data from the first round of the *Programme for the International Assessment of Adult Competencies* (OECD 2013). Data collection took place in 2011/2012 in a total of 24 countries. All samples are probability samples of the 16 to 65 year old population, with a minimum sample size of 5,000 and a total sample size of approximately 160,000 cases. Our analysis is based on the public use files that are available on the OECD's PIAAC webpage.[2]

We include 21 of the 24 participating countries. We exclude Cyprus because of a very high share of "literacy-related non-respondents" of 17.1 percent (for more details, see below), Russia because of concerns about data quality, and Australia because it does not provide a public use file. "Belgium" is included but PIAAC was only conducted in the region of Flanders.

PIAAC provides internationally comparable information on educational certificates based on the 2011 revision of the International Standard Classification of Education (ISCED). We distinguish between low (ISCED 0-2), intermediate (ISCED 3-4) and high (ISCED 5-6) education—roughly equivalent to having completed less than upper secondary, upper secondary or (non-tertiary) post-secondary, and tertiary education, respectively.

The unique feature of PIAAC is that it provides high-quality data on *basic* cognitive competences or "key information-processing skills" (OECD 2013). All countries mandatorily administered test items to assess respondents' reading and text comprehension skills (*literacy*) and practical mathematical skills (*numeracy*). A third skill domain, *problem solving in technology-rich environments*, was optional and is therefore not available for all countries. Literacy and numeracy scores are very highly correlated. For example, the country-level correlation between the low-intermediate numeracy and literacy gaps (adjusted for key individual-level characteristics, see below) is 0.95 in our sample. Results for literacy and numeracy gaps therefore tend to be very similar and we only present results for numeracy gaps in the paper.

The PIAAC data are of much higher quality than the first large-scale international survey of adult competences, the *International Adult Literacy Survey* (IALS), which was conducted in the mid-1990s. First, the quality of competence measurements has advanced considerably since the mid-1990s, partly due to the advances spawned by the *Programme for International Student Assessment* (PISA). Second, in IALS information on educational certificates was incorrect for four countries (Czech Republic, Germany, Poland, and the UK). These misclassifications can be remediated based on information available in the IALS data (for details see Gesthuizen, Solga, and Künster 2011). Unfortunately, the erroneous education var-

2 We use the updated public use files that were released on November 7, 2013, approximately one month after the initial release (http://www.oecd.org/site/piaac/publicdataandanalysis.htm).

iables also lead to problems with the IALS competence scores that cannot be fixed: To limit respondent burden, IALS—like other large-scale assessments such as PISA, TIMSS, and also PIAAC—administered only a relatively small number of test items to each interviewee. These items on their own are insufficient for constructing accurate competence scores. Respondents were therefore assigned a set of (multiply imputed) "plausible values" on the basis of test performance *and* background characteristics. These background variables comprise various education measures and in the case of IALS presumably included the erroneous qualifications variable (detailed information on the imputation procedure are no longer available, but see Kirsch, 2001:31, for further useful information).

Our sample is restricted to respondents who were 25 to 54 years old in 2011, that is, to birth cohorts 1957 to 1987. These respondents had mostly left education in 2011 and went to secondary school between the 1960s and early 2000s—thus after post-war educational expansion in most countries. We exclude respondents who obtained their highest degree in a foreign country because their degrees and competences cannot be considered as results of the education system of their current country of residence.

Some respondents sampled by PIAAC were not administered the full interview because of insufficient proficiency in the interview language (the most common reason), reading or writing difficulties, or learning or mental disabilities. For these so-called "literacy-related non-respondents" (LRNR) only information on gender and age is available. Excluding them from the analysis could bias our results, because their share differs considerably across countries. In our sample, the proportion of LRNR ranges from zero percent to 3.8 percent in the US and 4.8 percent in Belgium (see Appendix Table A1). Most LRNR likely have low levels of basic competences and formal education. Even though country differences in the proportion of LRNR may seem small, this group can be quite large in relation to the group of less educated adults (ISCED 0-2). Excluding them could thus be quite consequential when, as in this paper, less educated adults (or their difference to intermediate educated adults) are of particular interest. Our analysis therefore includes LRNR (in contrast to the study of Park and Kyei 2011, because this is not possible with the IALS data). For doing so, we had to assign LRNR respondents values on all variables other than gender and age. We proceeded as follows. First we assigned a (very low) numeracy score of 85 to LRNR. This is the value used by the OECD (2013:69) in robustness checks that explore the impact of including LRNR on country differences in average competence scores. Using these assumed competence scores and information on age and gender, we then obtained 10 imputations of all other variables relevant to our analysis, including highest educational degree (see below). Including LRNR substantially raises the share of the less-educated group in some countries, for example, from about 10.2 to 13.0 percent in the US and from 11.5 to 15.1 percent in Belgium.

Overall, the PIAAC data for the 21 countries in our analysis include a total of 88,818 observations who meet our age restriction. We exclude 3,538 cases who obtained their highest degree in a foreign country and another 30 cases for whom this information is missing although they do not belong to the group of literacy-related non-respondents. We exclude another 168 cases that are not LRNR, but have missing information on at least one of the variables included in the analysis. Our final sample comprises 83,999 "regular" respondents with complete information and 1,079 literacy related non-respondents.[3]

Methods and variables

Our data have a two-level structure: We study respondents who are nested within countries. We analyze these data using a two-step procedure. In a first step, we estimate the two numeracy gaps for each of the 21 countries in our sample, controlling for key individual characteristics (see below). In a second step, we then regress the estimated numeracy gaps on our focal variables—different measures of vertical stratification and occupation-specificity—and additional country-level control variables (see below). These country-level regressions are estimated using weighted least squares (WLS). WLS is used to increase efficiency by incorporating information on the uncertainty of the numeracy gap estimates (as contained in the standard errors of the estimated numeracy gaps; for further details on this two-step approach, see Lewis and Linzer 2005). We report heteroscedasticity-consistent standard errors to safeguard against any remaining heteroscedasticity. As a sensitivity analysis, we also carried out the two-step procedure with ordinary least squares at the country level and the results were very similar (results are available on request).

This two-step approach is an alternative to simultaneous estimation via (restricted) maximum likelihood, often referred to as hierarchical or multilevel modeling. We opted for the two-step approach because it does not impose strong assumptions on the distribution of the country-level error terms and allows the effects of control variables to vary across countries (Achen 2005). Our approach also facilitates inspection of country-specific estimates and thus the detection of substantively interesting cases and/or outliers, which are readily overlooked with simultaneous estimation and important to consider especially in country comparisons consisting of less than 30 or even 50 cases (Bryan and Jenkins 2013).[4] Descriptive information for all individual and country level variables is displayed in Appendix Tables A1 and A2.

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3 Consistent with our analysis of non-LRNR, we exclude LRNR from the analysis of a given imputation if the variable "foreign degree" takes the value "true" for that imputation. The set of LRNR cases included in the analysis thus differs slightly across imputations. Four LRNR are excluded completely because they were imputed as having a foreign degree in all 10 imputations.

4 There is a shortage of systematic comparisons between these different approaches in country-comparative settings. It is clear on analytic grounds that simultaneous estimation will be more efficient than the two-step approach when the data come reasonably close to meeting the stronger assumptions of the former approach (e.g., normality of cluster-level error terms)—but it is not clear how close "reasonably close" is. The efficiency gains are probably modest when the number of individual observations per cluster is relatively large so that cluster-specific parameter estimates are relatively precise (Lewis and Linzer 2005). This is the case in our application, as it is in most applications where the higher-level units are countries (as opposed to, for instance, schools or classrooms). Recent studies using the two-step method are Gebel and Giesecke (2011) and Heisig (2011).

Our *individual-level regressions* adjust mean numeracy differences between educational groups (our two skills gaps) for differences in the following variables: age (5-year groups), gender, being below age 30 and in formal education (to account for country differences in the typical age of completing vocational and tertiary education), and foreign-birth/foreign-language status (to control for country variation in the migrant population) (see Appendix Table A1). The latter variable has four categories indicating whether a respondent was born in the country where she took the test and/or whether her primary language was that of the test language or another language. We exclude adults with high levels of education from the estimation of the lower skills gap and adults with low levels of education from the estimation of the upper skills gap. The effects of these compositional variables are thus allowed to differ across the educational distribution.

As noted above, to limit respondent burden, PIAAC administered only a relatively small number of test items to each individual. Individual competence scores are therefore quite uncertain. To account for this uncertainty, PIAAC provides 10 so-called plausible values rather than a unique competence score for each respondent, much like multiple imputation uses multiple imputations to account for imputation uncertainty. PIAAC also provides jackknife replicate weights (80 for most countries) to adjust variance estimates for the different complex survey designs of participating countries. We also took these weights into account, meaning that the estimated numeracy gaps and associated standard errors are based on up to 800 regressions per country (80 jackknife weights—or the number of available weights—times 10 plausible values). All estimations were carried out in Stata 13.

We now describe the *macro-level variables* used in the country-level regressions. For *vertical stratification* in secondary education, the prevailing practice is to focus on *external differentiation* via tracking (i.e., the existence of different school types). Bol and Van de Werfhorst's (2013) *Educational Systems Data Set* (version 4) provides an *index of external differentiation* that is based on the age of first selection into different tracks (with lower ages corresponding to greater external differentiation), the number of tracks available at age 15, and the length of tracked education as a proportion of the total duration of primary and secondary education. We will also use this variable in the present study.

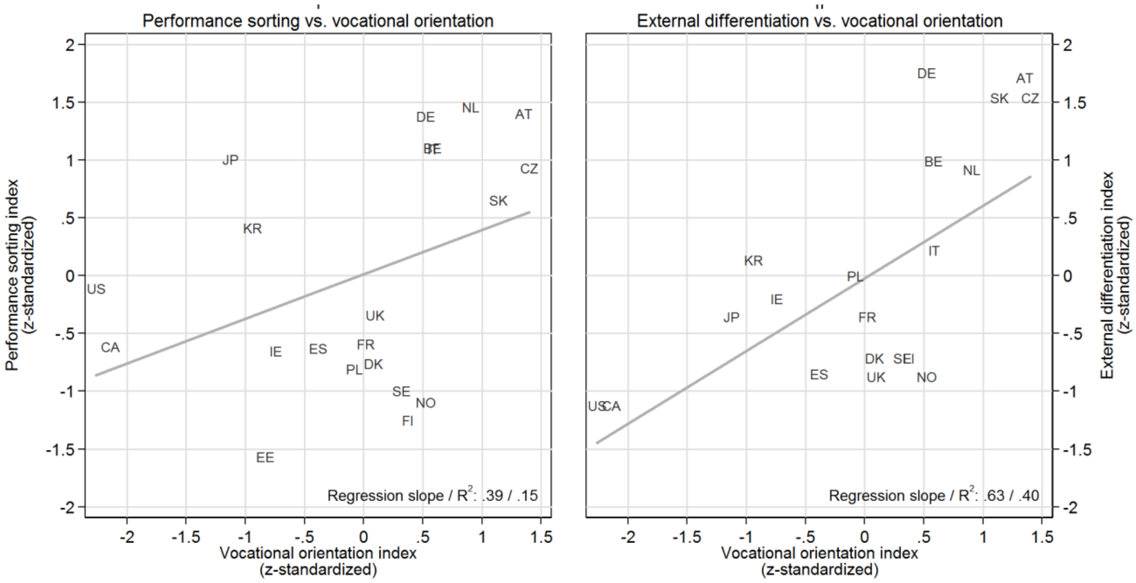
What this measure may fail to capture, however, is that segregation according to student performance may occur through processes other than explicit tracking, for instance, because of residential segregation. To capture such processes, we need a measure that is sensitive to school-level differences in (average) student performance within the same track. Such a measure is given by the proportion of total variance in student performance that is attributable to between-school differences, which the OECD regularly publishes in its PISA reports. More recent publications often report its inverse (i.e., 1 minus the proportion of overall performance variance), which the OECD also refers to as the "index of vertical inclusion." In these cases we simply inverted the measure again so that higher values consistently correspond to higher levels of vertical stratification. In order to reduce measurement error, we averaged all available estimates from the 2000, 2003, 2006, and 2009 PISA studies (i.e., we averaged estimates for different years and for different domains such as reading, mathematics, and science) (OECD 2004, 2005, 2007, 2011). We call this indicator of vertical stratification *performance sorting index*.

We use two different measures of horizontal stratification in terms of *occupation-specificity*. Previous research (e.g., Bol and Van de Werfhorst 2011; Van de Werfhorst 2011) has often used the proportion of students in upper secondary education who are in a vocational program (tracks). We also use this "vocational orientation index" (again obtained from version 4 of the *Educational Systems Data Set* by Bol and Van de Werfhorst, 2013). We cannot compute this index from the PIAAC data, because information on vocational education is subject to high proportions of missing data in Belgium, Denmark, Italy, Sweden, the United Kingdom, and the United States.

There also exists a large literature that captures occupation-specificity using a fourfold typology of *systems of upper secondary education*: apprenticeship systems, mixed systems, school-based vocational systems, and general systems (cf. European Centre for the Development of Vocational Training 2013; Müller 1994; OECD 2000). The first three types can be characterized as occupation-specific, but differ in the strength of employer involvement in the development of curricula, time for firm-based training, and the standardization of vocational certificates. The degree of occupation-specificity is generally supposed to be largest in apprenticeship countries and smallest in countries with general upper secondary education systems. This classification suggests a different order of countries than the share of students in vocational tracks (see Table A2 in the Appendix). For example, the Czech Republic and the Netherlands have higher shares of vocational education enrolment than Germany or Denmark. Based on the vocational orientation index, the Czech Republic and the Netherlands—two countries with mixed systems—would thus be considered as being more occupation-specific than the apprenticeship countries Germany or Denmark. We will use both indicators of occupation-specificity in our analysis as robustness check.

Figure 1 displays the two measurements of vertical stratification and their relationship to the vocational orientation index. Two points are noteworthy. First, while both measures of vertical stratification are positively related to vocational orientation index, the relationship is stronger for external differentiation (Subgraph II) than for performance sorting (Subgraph I). This reflects the obvious fact that external differentiation grasps tracking in lower and upper secondary education and that some tracking is a necessary condition for having vocational tracks in upper secondary education. Second, the positive relationship between the two indicators of vertical stratification and the vocational orientation index suggests that in many countries, the two institutional characteristics partly cancel each other out when it comes to the size of the *low-intermediate skills gaps*. This supports the idea that evidence for hypotheses 1a and 2a should be stronger when including indicators of both characteristics simultaneously in the country-level regression.

Figure 1. Country–level association between measures of vertical stratification (performance sorting and external differentiation) and vocational orientation



Notes:
AT Austria; BE Belgium; CA Canada; CZ Czech Republic; DE Germany; DK Denmark; EE Estonia; ES Spain; FI Finland; FR France; IE Ireland; IT Italy; JP Japan; KR Korea; NL Netherlands; NO Norway; PL Poland; SE Sweden; SK Slovak Republic; UK United Kingdom; US United States.
Performance sorting index is missing for France and external differentiation index is missing for Estonia. In these cases, average imputed values across 10 imputations are displayed.

Sources: OECD (2004, 2005, 2007, 2011), Bol and van de Werfhorst (2013), authors' calculations.

Country-level control variables

We also present specifications that include a set of country-level control variables. As discussed above, Park and Kyei (2011) found that greater *between-school inequality of instructional resources* is associated with greater literacy gaps between less and intermediate educated adults. We will also include this factor in our country-level regressions. The underlying measurement of school's instructional capacity is based on information collected through the Grade 8 school principal questionnaires of the *Trends in International Mathematics and Science Study* (TIMSS). School principals indicated to what extent (4-point scale) their school's capacity to provide instruction was affected by shortages or inadequacies in 17 different domains. Following Park and Kyei (2011), we averaged principals' responses to these 17 items to obtain a measure of school resources and then computed the school-level Theil index to capture inequality. We constructed this measure for the 1995, 1999, 2003, and 2007 TIMSS and averaged all available values for a given country in order to reduce measurement error. Further information on the TIMSS studies is available on at http://timssandpirls.bc.edu/. Column 10 in Appendix Table A2 reports the values of the Theil index for our country sample. The Pearson correlation between our measure and the corresponding measure reported by Park and Kyei (2011) is 0.84 for the 13 countries that are included in both studies.

We include two further control variables that were constructed from the PIAAC data. One is the proportion of 25-to-54-year-olds who were born in a foreign country and/or whose primary language is not that of the PIAAC test. As noted above, we control for foreign-birth/foreign-language status at the individual level. We additionally include the population share of adults to account for the possibility that countries with larger foreign-born/foreign-language populations may have higher levels of "ethnic" segregation at the school level (which would presumably result in larger skills gaps).

Finally, skills gaps among adults with different levels of education might partly arise from different participation rates in further training after leaving full-time education. Post-schooling opportunities may renew or enhance adult generic skills. Park and Kyei (2011:898) found that skills gaps are smaller in countries that provide more equal further education opportunities for adults with different school attainment (Park and Kyei 2011:898). We therefore control for the percentage point difference in continuing education and training participation among 25-to-54-year-olds. For obvious reasons, the difference is calculated between adults with ISCED 3-4 vs. 0-2 in the models of the lower and between ISCED 5-6 vs. 3-4 in the models of the upper skills gap.

Missing values

In a few cases, information on country-level variables is missing. The data set by Bol and Van de Werfhorst (2013) does not provide an external differentiation score for Estonia. The performance sorting measure is missing for France and the measure of school-level resource inequality for France and Poland. Finally, the point difference in further training could not be estimated for Austria, because the variable on participation in further training is not included in the Austrian PIAAC public use file. We used multiple imputation at the country level (10 imputations using predictive mean matching) to predict these missing values.

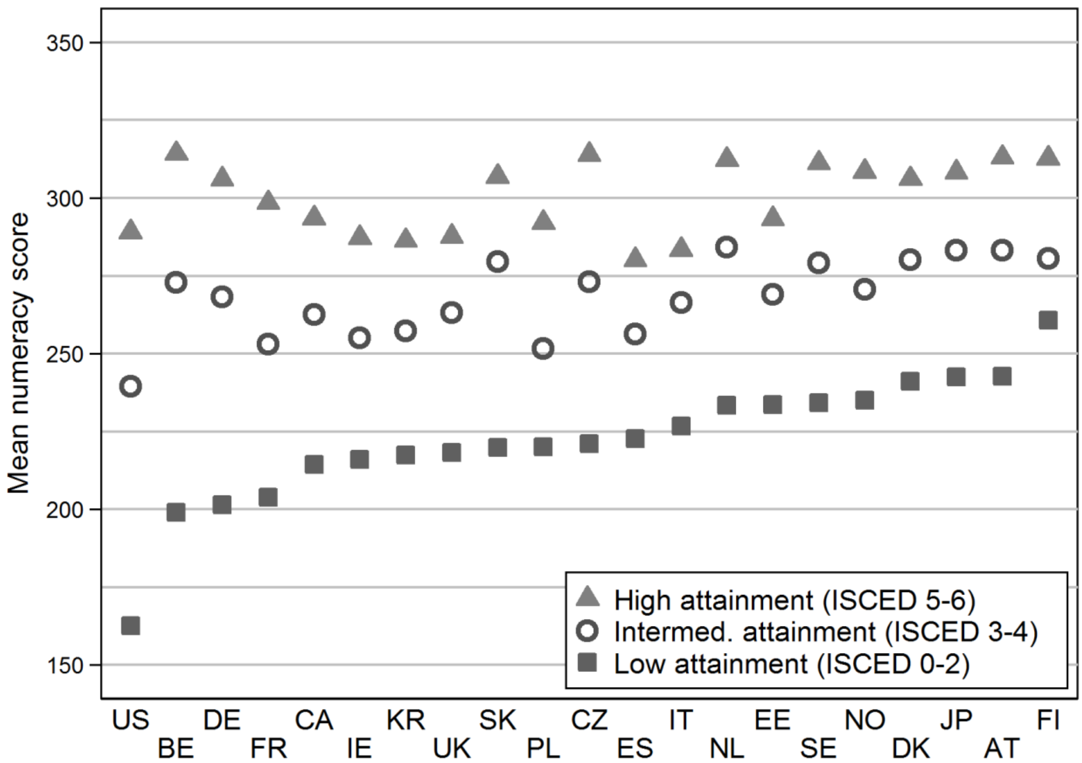
4. Findings

We start with descriptive findings on country variation in the mean numeracy proficiency of educational groups and then continue by testing our hypotheses for the lower and the upper skills gaps, respectively.

Country variation in mean numeracy by educational degree

Figure 2 depicts the mean numeracy levels achieved by adults with different levels of educational attainment (see also Appendix Table A2). In all countries, the mean numeracy score is lower for less educated adults than for those with intermediate levels of education, who in turn have lower means than those with college education. Thus, unsurprisingly, in all countries we find a positive relationship between basic cognitive competences and certificates. Moreover, country variation in the mean numeracy level of all educational groups is quite substantial. It is largest for less educated adults (ISCED 0–2), followed by the country differences of intermediate (ISCED 3–4) and then higher (ISCED 5–6) educated adults.

Figure 2. Mean numeracy levels by educational attainment



Countries are ordered by numeracy means of ISCED 0–2. For country abbreviations see Figure 1.

Source: PIAAC 2012, authors' calculations.

The mean competence level of less-educated adults is lowest in the US (162.6) and highest in Finland (260.8). This difference corresponds to almost two competence levels: The PIAAC framework distinguishes among six competence levels (below level 1 to level 5)—with the intermediate levels 2-4 each spanning a range of 50 points (OECD 2013:76). Another benchmark for putting these differences in perspective is the standard deviation of numeracy scores for the full PIAAC sample (i.e., adults aged 16 to 65 from all participating countries), which is 51.3 points (OECD 2013:266).

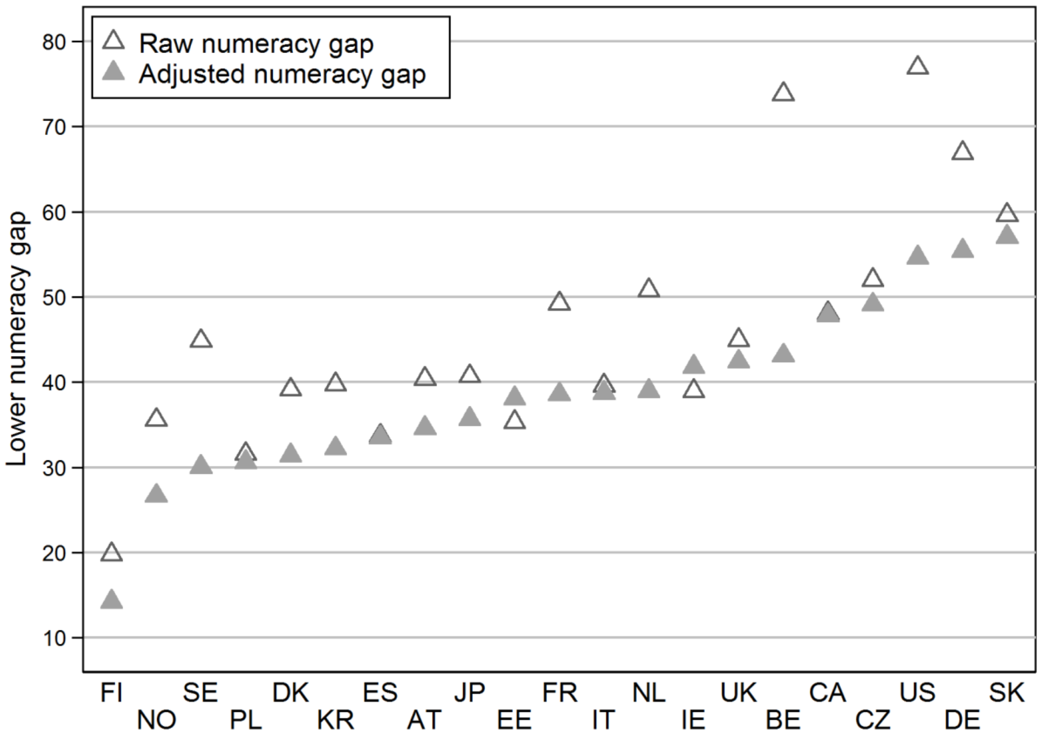
Country variation in the mean numeracy levels of intermediate educated adults (ISCED 3-4) ranges from 239.5 points in the US to 284.2 points in the Netherlands. This still amounts to about 45 points. Country differences in the average score of higher educated adults (ISCED 5-6) are again smaller, but remain quite substantial—ranging from 280.2 in Spain to 314.3 in Belgium (about 34 points).

To what extent these differences "translate" into country differences in skills gaps, and whether educational stratification processes influence the size of these gaps, will be investigated in the following.

Low-intermediate numeracy gaps

Figure 3 shows the results of our first step, that is, of the individual-level regressions of the low-intermediate numeracy gap for each of the 21 countries.

Figure 3. Numeracy gap between adults with ISCED 3–4 vs. ISCED 0–2



Countries are ordered according to the size of the adjusted lower skills gap. For country abbreviations see Figure 1.

Source: PIAAC 2012, authors' calculations.

The figure displays the raw (unadjusted) and adjusted numeracy gaps between adults with low and intermediate levels of education (ISCED 0-2 vs. 3-4). Adjusted numeracy gaps are controlled for age, gender, an indicator for being below age 30 and (still) in formal education, and foreign-birth/foreign language status.

The unadjusted lower numeracy gap varies from only 19.8 points in Finland to 76.9 points in the United States, a range of about 57 points. The adjusted lower numeracy gap reaches a low of 14.2 points in Finland and a high of 57.0 points in the Slovak Republic, a range of 42.8 points. This is still substantial, yet noticeably smaller than for the raw gap, implying that compositional differences in the above mentioned individual characteristics account for a good portion of country variation in the lower skills gap.

In order to test hypotheses 1a and 2a, we now turn to the second step: the country-level regressions of adjusted numeracy gaps. We provide two tables: Table 1 presents results without further country-level controls and Table 2 presents results with the controls included. We start with the results without controls, which are displayed in Table 1. All continuous predictors (i.e., all except the typology of upper secondary education systems) are standardized to have a mean of zero and standard deviation of one, so the point estimates can be interpreted as the expected increase in the lower numeracy gap for a standard deviation increase in the respective predictor.

Models M1 – M4 show that without including indicators of both dimensions of stratification simultaneously in the regression, only the performance sorting index as one of the two indicators of vertical stratification is significant—and, as expected, higher levels of performance sorting are associated with a larger lower skills gap (model M1). The external differentiation index also has a sizable effect in the expected direction, but is less precisely estimated. Coefficient estimates for the two measures of occupational specificity generally have the expected sign, but are relatively small and far from reaching statistical significance (the sole exception is the difference between general system and vocational schools system countries in model M4).

Yet, given that occupation-specificity and vertical stratification are positively correlated (see Figure 1 in Section 3) and presumably have opposite effects on the lower skills gap, the expected effects might begin to show or become reinforced once we include measures of both dimensions in the regression. Models M5 to M8 in Table 1 confirm this expectation. These models include indicators of both institutional characteristics simultaneously, but differ in the combination of indicators included.

The models reveal that when controlling for occupation-specificity (regardless of which of the two indicators is used), both the performance sorting and the external differentiation index are significant and go in the expected direction: The lower numeracy gap is larger in countries with higher sorting education systems and the effect sizes are substantial: According to the estimates displayed in model M5 (and M6), a standard deviation increase in performance sorting is associated with a 6.2 (or 4.8) point increase in the lower numeracy gap, when occupation-specificity is controlled via the vocational orientation index (or via the typology of upper secondary education systems). The corresponding estimates for a standard deviation increase in the external differentiation index are 8.4 (or 5.4) points (M7 and M8). These results support hypothesis 1a.

Table 1. Country–level WLS regression of numeracy gap between adults with ISCED 3–4 vs. ISCED 0–2, without control variables

	M1	M2	M3	M4	M5	M6	M7	M8	M9
Vertical stratification									
Performance sorting index	4.8*				6.2*	4.8+			
	(2.26)				(2.41)	(2.35)			
External differentiation index		4.0					8.4*	5.4+	
		(2.78)					(2.91)	(2.90)	
Horizontal stratification: Occu–pation–specificity									
Vocational orientation index			–1.2		–3.6		–6.7*		
			(2.85)		(2.86)		(3.10)		
System of upper secondary education (Ref.: General system)									
Apprenticeship system				–0.9		–5.2		–9.3	
				(9.97)		(8.89)		(8.27)	
Mixed system				0.7		–1.5		–6.0	
				(7.04)		(6.99)		(6.98)	
Vocational schools system				–6.6		–6.1		–8.6	
				(5.65)		(5.67)		(6.57)	
Between–school resources inequality (Theil index)									1.6
									(2.32)
Constant	38.8**	38.7**	38.7**	40.9**	38.8**	41.9**	38.8**	44.4**	38.6**
	(2.10)	(2.22)	(2.40)	(3.93)	(2.10)	(4.83)	(2.00)	(5.27)	(2.33)
Observations	21	21	21	21	21	21	21	21	21
R^2	0.23	0.16	0.00	0.01	0.34	0.30	0.41	0.28	0.02

Notes: Weighted Least Squares (WLS) estimates following Lewis and Linzer (2005). Heteroskedasticity-consistent (HC3) standard errors in parentheses (cf. Lewis and Linzer 2005).
Dependent variable: country's adjusted lower numeracy gap, obtained from individual-level regressions (controlled for age, gender, being in formal education and under 30, and foreign birth/foreign language status).
All continuous variables standardized (mean of zero and standard deviation of 1). For details on variables see Appendix Table A2.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Source: PIAAC 2012, authors' calculations.

Turning to occupation-specificity, we only find a significant effect in model M7 in Table 1—that is only for the vocational orientation index and only in combination with the external differentiation index. The effect of vocational orientation is negative, as expected: The more upper secondary education emphasizes occupation-specific skills, the smaller is the low-intermediate numeracy gap. This result confirms our hypothesis 2a. There is less support for the second measurement of occupation-specificity "types of upper secondary education systems," at least if conventional standards of statistical significance are applied. The indicators for the different systems are insignificant in all specifications. The directions of the effects are mostly as expected, suggesting that the low-intermediate numeracy gap is larger in countries with a general system (the reference category) than in countries with an apprenticeship system or vocational schools. The effect of “mixed systems” is “wrongly” (i.e., positively) signed in some specification, but tends to be very small.

Before we move on to the regression results including our control variables, model M9 displays estimation results for the Theil index on between-school differences in instructional resources. In contrast to the findings of Park and Kyei (2011), the effect size is small (1.7) and not statistically significant (standard error 2.32). The picture does not change substantially if we more closely follow Park and Kyei and look at literacy (rather than numeracy) gaps or and/restrict the analysis to the age range 25-34 (Park and Kyei’s study was restricted to ages 26-35, which we cannot replicate exactly because the PIAAC data only provide five-year age groups; these results are available upon request). Thus, with an improved measurement of basic competences (in PIAAC) and a different country sample, their finding cannot be replicated.

Table 2 summarizes the same basic specifications as Table 1, but this time with additional country-level control variables (between-school inequality, difference in adult training participation, share of foreign-born and/or foreign-language status). These models yield quite similar results. Both measures of vertical stratification are significant in models M5 and M7, but no longer attain statistical significance in models M6 and M8 (where occupation-specificity is captured via the typology). However, the effect sizes in models M6 and M8 are similar to those in Table 1: The loss of statistical significance is attributable to a loss of precision (larger standard errors) rather than smaller effect sizes (the latter in fact increase). In models M5 and M7 (where occupation-specificity is captured via the vocational orientation index), the effects of the stratification measures are (even) more robust to the inclusion of additional controls. Taken together, these results provide strong support for hypothesis 1a.

The vocational orientation index is again only significant in model M7 in Table 2. Coefficient estimates for the typology of upper secondary education systems most clearly show the pattern predicted by hypothesis 2a when the external differentiation index and the additional country-level control variables are included in the regression (model M8 in Table 2): The smallest skills gap can be found in countries with apprenticeship systems, followed by countries with mixed and vocational school systems, while countries with general secondary education systems have, on average, the largest low-intermediate skills gap. On the whole, the empirical evidence for hypothesis 2a is thus somewhat less conclusive than for hypothesis 1a. Overall, however, the results do lend reasonable support to the idea that greater occupation-specificity of upper secondary education is associated with smaller differences in (PIAAC) skills between adults with low and intermediate formal qualifications. As for the role of between-school resource inequality (captured by the Theil index), we still find no clear evidence for a positive association with the lower skills gap.

Table 2. Country–level WLS regression of numeracy gap between adults with ISCED 3–4 vs. ISCED 0–2, including control variables

	M1	M2	M3	M4	M5	M6	M7	M8	M9
Vertical stratification									
Performance sorting index	5.1				5.5^{+}	5.7			
	(3.17)				(2.93)	(3.87)			
External differentiation index		5.0					8.3*	7.2	
		(3.43)					(3.35)	(4.68)	
Horizontal stratification: Occupation–specificity									
Vocational orientation index			–2.2		–3.0		–5.7*		
			(2.29)		(2.10)		(2.36)		
System of upper secondary education (Ref.: General system)									
Apprenticeship system				–3.4		–6.0		–11.5	
				(9.24)		(7.07)		(8.32)	
Mixed system				–0.1		1.5		–4.3	
				(8.29)		(7.03)		(7.47)	
Vocational schools system				–3.5		–0.5		–3.7	
				(7.23)		(6.02)		(7.53)	
Control variables									
Between-school resources	2.5	2.6	0.0	0.7	1.3	3.2	1.3	3.0	1.0
inequality (Theil index)	(2.43)	(2.50)	(2.53)	(3.32)	(2.50)	(3.24)	(2.07)	(3.18)	(2.17)
% point difference in adult	4.1	4.0	6.9*	6.2^{+}	4.6	4.2	3.8	3.7	6.3*
training participation (ISCED 3-4 vs. 0-2)	(2.78)	(2.68)	(2.39)	(3.00)	(2.91)	(3.10)	(2.49)	(3.54)	(2.25)
Share of adults (25-54) with	2.0	2.5	–0.1	0.3	1.6	1.9	3.0	2.9	0.4
foreign birth and/or foreign language	(3.02)	(3.00)	(2.99)	(3.36)	(3.36)	(3.40)	(3.04)	(4.01)	(2.65)
Constant	38.6**	38.6**	38.7**	40.3**	38.7**	39.3**	38.7**	42.5**	38.6**
	(2.03)	(2.03)	(2.17)	(5.07)	(2.06)	(4.05)	(1.80)	(6.26)	(2.10)
Observations	21	21	21	21	21	21	21	21	21
R^2	0.57	0.53	0.43	0.43	0.63	0.62	0.70	0.62	0.40

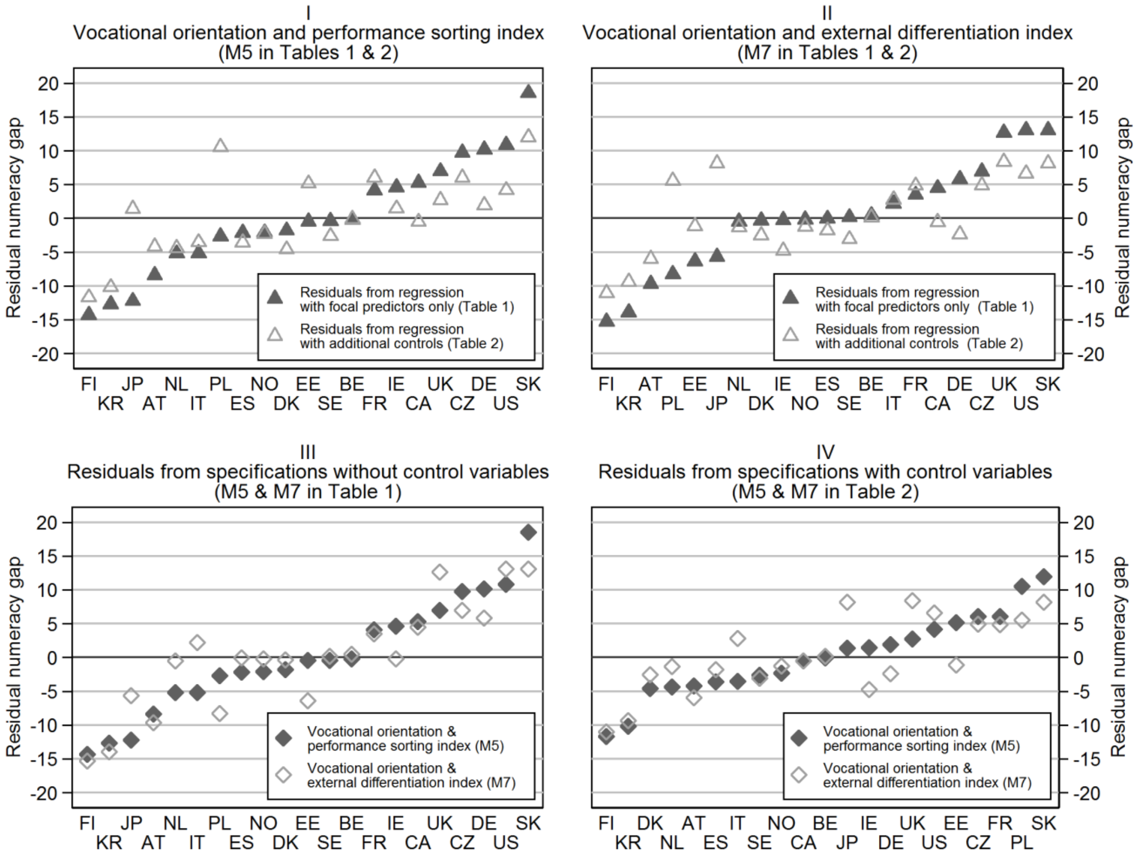
Notes: see Table 1
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Source: PIAAC 2012, authors' calculations.

A look at the explained variance Table 1 (models M5 – M8), suggests that the included stratification characteristics together account for a quite high proportion (between 28 and 41 percent) of the country variation in lower skills gaps. Moreover, the two indicators of vertical stratification do almost equally well explain country variation in the low-intermediate skills gap and neither is clearly preferable to the other.

Finally, we follow the suggestion of Bryan and Jenkins (2013) to look for substantively interesting outliers, especially in country comparisons consisting of less than 30 cases: Figure 4 plots the residual numeracy gap for each country based on models M5 and M7 in Tables 1 and 2.[5] Subgraph I plots the residuals from the regressions with the vocational orientation index and the performance sorting index (models M5 in Tables 1 and 2). Subgraph II plots the residuals from the regressions with the vocational orientation index and the external differentiation indices (models M7 in Tables 1 and 2). Filled triangles represent estimates without additional controls (Table 1) and hollow triangles depict estimates with additional country-level controls (Table 2).

Figure 4. Residuals from country-level regressions of numeracy gap between adults with ISCED 3–4 vs. 0–2 on measures of vertical stratification, vocational orientation, and control variables



Notes. Calculations based on Tables 1 to 2. For country abbreviations see Figure 1.

Source: PIAAC 2012, authors' calculations.

A first result apparent from Figure 4 (Subgraphs I and II) is that accounting for country differences in occupation-specificity and vertical stratification (performance sorting or external differentiation index) substantially reduces cross-national variation in the (adjusted) lower numeracy gap. Whereas adjusted lower

5 More precisely, the figure displays the average residual numeracy gap across the ten imputed country data sets (see Section 3).

numeracy gaps span a range of 42.8 points (cf. the discussion of Figure 3 above), the residuals from the country-level regressions without additional controls (filled triangles) span ranges of 32.8 points (vocational orientation and performance sorting indices, Subgraph I) and 28.4 points (vocational orientation and external differentiation indices, Subgraph II).

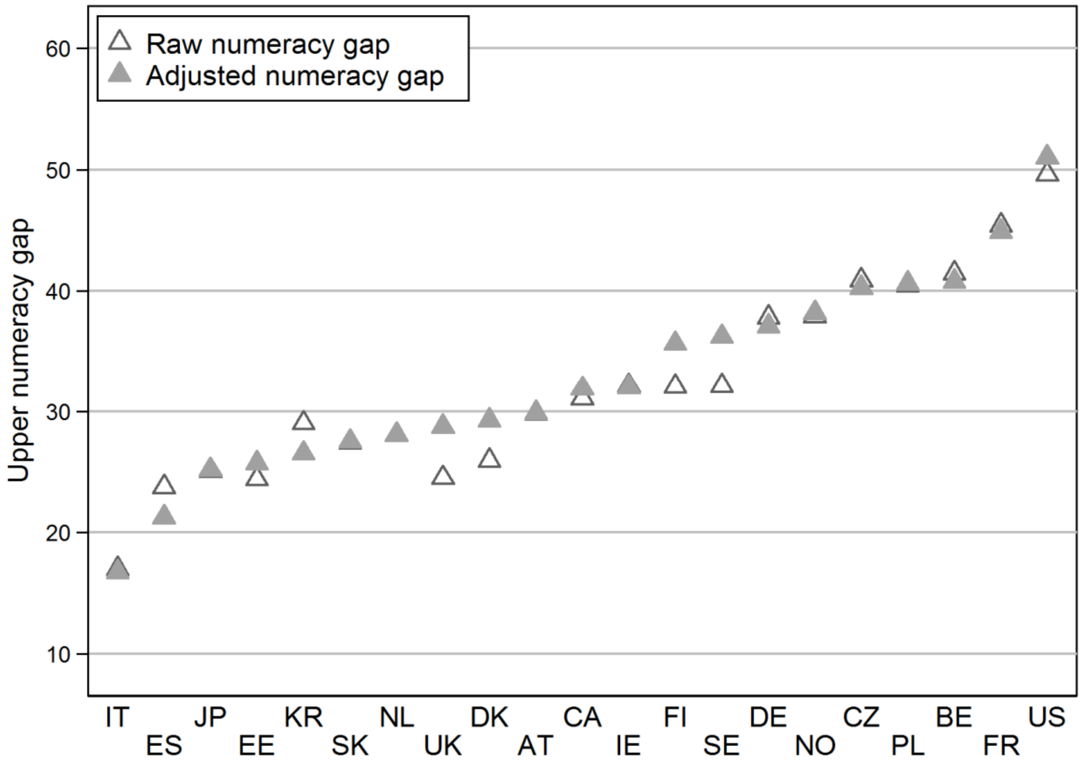
Adding the country-level control variables further reduces the country variation (hollow triangles), to 23.7 points (Subgraph I) and 19.4 points (Subgraph II). A look at Table 2 suggests that this is primarily due to the control variable "percentage point difference in training participation between adults with low and intermediate levels of education", because this is the control variable that has the largest effect. Like Park and Kyei (2011:898), we find that lower numeracy gaps tend to be smaller in countries that show less inequality in opportunities between less and intermediate educated adults to receive adult education and training.

Second, looking at outliers (hollow triangles including the controls), we see that for the performance sorting index, quite large residuals (more than 5 points) can be found for Finland and Korea in negative direction and Poland, France, the Czech and Slovak Republic in positive direction. For the external differentiation index, substantial outliners are also Finland, Korea, Poland, and the Slovak Republic, and differently, Austria, Japan, the UK, and the US. The latter three countries are interesting, because these are countries which show a much lower degree of vertical stratification in terms of external differentiation than of performance sorting. For the majority of country cases the two indicators of vertical stratification seem to perform similarly well, however.

Intermediate-high numeracy gaps

We now turn to the upper numeracy gap. Figure 5 plots the (unadjusted and adjusted) gap between adults with high (ISCED 5-6) and intermediate (ISCED 3-4) levels of education. Overall, we find somewhat smaller numeracy gaps than for the lower part of the educational distribution. In contrast to the lower numeracy gap, Figure 5 shows that compositional differences between adults with intermediate and high formal qualifications tend to explain only a small part of the of the upper numeracy gap and therefore also do not account for much of the country differences. The raw and adjusted numeracy gaps are very similar in all countries. The adjusted numeracy gap is smallest in Italy (16.8 points) and highest in the US (51.0 points), implying a range of 34.2 points.

Figure 5. Numeracy gap between adults with ISCED 5–6 vs. ISCED 3–4



Countries are ordered according to the size of the adjusted upper skills gap. For country abbreviations see Figure 1.

Source: PIAAC 2012, authors' calculations.

The results for the impact of educational stratification processes on the intermediate-high skills gaps can be briefly summarized. They are displayed in Table 3 (without control variables) and Table 4 (including the control variables). None of the indicators of occupation-specificity and vertical stratification reaches statistical significance in any specification. Moreover, the effect sizes are much smaller than for the low-intermediate skills gaps. The only substantial difference, although not significant, can be found for the comparison of apprenticeship systems versus general education systems (models M6 and M8 in Table 4). As expected, the upper skills gap tends to be larger in apprenticeship systems (where the intermediate group invests heavily in occupation-specific skills and where the tertiary educated presumably are a more selective, academically inclined group). Overall, however, hypothesis 2b, which predicted this pattern to hold more generally, is not confirmed. We also expected vertical stratification to be unrelated to the upper skills gap or even slightly negatively related to the upper skills gap (hypothesis 1b). The coefficient estimates on both measures of vertical stratification (performance sorting and external differentiation index) are indeed not significant and tend to very small (and negative). This result supports our hypothesis.

Table 3. Country–level WLS regression of numeracy gap between adults with ISCED 5–6 vs. 3–4, without control variables

	M1	M2	M3	M4	M5	M6	M7	M8	M9
Vertical stratification									
Performance sorting index	−1.8				−1.7	−1.7			
	(1.59)				(1.88)	(2.41)			
External differentiation index		−0.5					−0.0	−0.6	
		(1.81)					(2.05)	(2.48)	
Horizontal stratification: Occu–pation–specificity									
Vocational orientation index			−0.8		−0.2		−0.8		
			(2.78)		(3.29)		(3.39)		
System of upper secondary education (Ref.: General system)									
Apprenticeship system				0.8		2.2		1.8	
				(5.54)		(7.02)		(6.76)	
Mixed system				0.5		1.2		1.2	
				(5.69)		(5.82)		(5.90)	
Vocational schools system				3.6		3.3		3.9	
				(5.98)		(6.31)		(5.75)	
Between–school resources inequality (Theil index)									−1.9
									(1.50)
Constant	32.7**	32.7**	32.7**	31.3**	32.7**	31.0**	32.7**	30.9**	32.7**
	(1.84)	(1.90)	(1.98)	(4.63)	(2.04)	(4.62)	(2.04)	(4.38)	(1.82)
Observations	21	21	21	21	21	21	21	21	21
R^2	0.05	0.00	0.00	0.00	0.05	0.08	0.01	0.04	0.06

Notes: Weighted Least Squares (WLS) estimates following Lewis and Linzer (2005). Heteroskedasticity-consistent (HC3) standard errors in parentheses (cf. Lewis and Linzer 2005).
Dependent variable: country's adjusted upper numeracy gap, obtained from individual-level regressions (controlled for age, gender, being in formal education and under 30, and foreign birth/foreign language status).
All continuous variables standardized (mean of zero and standard deviation of 1). For details on variables see Appendix Table A2.All continuous variables standardized (mean of zero and standard deviation of 1).
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Source: PIAAC 2012, authors' calculations.

Although the variation in the (adjusted) intermediate-high numeracy gap is quite substantial (see Figure 5), differences in vertical and horizontal stratification do not contribute much to their explanation. This confirms our argument that it is important, first, to separately investigate the lower and upper parts of the educational distribution and, second, to keep in mind that PIAAC is measuring *basic* cognitive competences.

Moreover, as indicated in Table 4, inequality in adult education opportunities (% point difference in adult training participation between ISCED 5-6 vs. 3-4) is much less important for the upper than for the lower skills gaps. A plausible interpretation of these results is that adults with at least upper secondary education have mostly acquired the basic cognitive competences measured in PIAAC during schooling whereas training opportunities do provide a second chance of learning for less educated adults.

Table 4. Country–level WLS regression of numeracy gap between adults with ISCED 5–6 vs. 3–4, including control variables

	M1	M2	M3	M4	M5	M6	M7	M8	M9
Vertical stratification									
Performance sorting index	−2.5				−2.3	−3.5			
	(1.80)				(2.00)	(3.12)			
External differentiation index		−1.4					−0.9	−3.0	
		(1.90)					(2.67)	(3.79)	
Horizontal stratification: Occupation–specificity									
Vocational orientation index			−1.3		−0.8		−0.7		
			(2.70)		(2.87)		(3.53)		
System of upper secondary education (Ref.: General system)									
Apprenticeship system				2.9		5.5		7.9	
				(6.37)		(6.26)		(8.73)	
Mixed system				−1.5		−2.0		1.2	
				(6.46)		(7.14)		(7.71)	
Vocational schools system				1.0		−1.5		0.9	
				(7.03)		(8.04)		(6.79)	
Control variables									
Between-school resources inequality (Theil index)	−4.2*	−4.0+	−3.9	−3.8	−4.5+	−5.6	−4.1	−5.1	−3.5
	(1.92)	(2.11)	(2.77)	(2.80)	(2.55)	(3.31)	(2.67)	(3.27)	(2.00)
% point difference in adult training participation (ISCED 5-6 vs. 3-4)	2.5	2.7	2.2	2.7	2.3	3.2	2.4	3.7	2.5
	(2.42)	(2.65)	(2.74)	(2.87)	(2.39)	(2.87)	(3.18)	(3.74)	(2.62)
Share of adults (25-54) with foreign birth and/or foreign language	3.1	3.3	3.3	3.8	3.0	3.5	3.3	3.6	3.6
	(2.49)	(2.31)	(2.50)	(2.75)	(2.56)	(2.64)	(2.55)	(2.62)	(2.37)
Constant	32.7**	32.7**	32.7**	32.3**	32.7**	32.9**	32.7**	31.0**	32.7**
	(1.83)	(1.91)	(2.02)	(4.63)	(1.99)	(5.02)	(2.08)	(4.50)	(1.88)
Observations	21	21	21	21	21	21	21	21	21
R^2	0.30	0.24	0.24	0.25	0.31	0.37	0.25	0.31	0.22

Notes: See Table 3.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Source: PIAAC 2012, authors' calculations.

Finally, model M9 in Table 3 displays again that between-school inequality in instructional resources (Park and Kyei's Theil index) is not significant (the same results are found for literacy). It does seem to be somewhat more strongly related to the upper skills gap in the specifications in Table 4 (which include the other country-level controls and different combinations of the measures of vertical stratification and occupational specificity): Here, the estimates do suggest that the upper skills gap is *lower* in countries with higher levels of between-school resource inequality in lower secondary education. In two specifications (models M2 and M5) this effect is significant at the ten percent level and model M1 it even reaches significance at the 5 percent level. Nonetheless, this finding contradicts the results by Park and Kyei (2011), whose results suggest that there is no clear or perhaps a small positive relationship between school-level resource inequality and the upper skills gap. Further research is needed to reconcile these divergent findings.

5. Conclusions

The main goal of our paper was to investigate the importance of educational stratification processes for the relationship between certificates and competences, operationalized as skills gaps by educational attainment. We have chosen to display the results for numeracy, but the results for literacy are very similar (available upon request). We explored the impact of two aspects of educational stratification: vertical stratification of lower secondary education (sorting by performance/ability) and occupation-specificity of upper secondary education.

Our two-step approach of accounting for country differences in skills gaps by compositional differences (individual-level regressions, first step) and institutional differences (country-level regressions, second step) revealed interesting differences for the lower and upper part of the educational distribution for each of the two steps.

First, whereas a high portion of the country variation in the low-intermediate skills gap could be explained by compositional differences with respect to age, gender, migration/language background, and participation in education (under age 30), this was not the case for country variation in the intermediate-high skills gap.

Moreover concerning the impact of educational stratification processes, the results for country variation in the lower skills gaps (between less and intermediate educated adults) confirm our hypotheses: Higher levels of vertical stratification increase the lower skills gap (hypothesis 1a) and greater horizontal stratification in terms of occupation-specificity of upper secondary education reduces it (hypothesis 2a). As for the role of vertical stratification (hypothesis 1a), we could not determine to what extent it is due to differences in learning opportunities and to selection on the basis of pre-existing competence/ability. Nevertheless, our results would seem to support the reflected-glory story—which posits a positive effect of more inclusive education systems for low-achieving students—rather than the big-fish-little-pond effect, which assumes a positive effect of ability-sorted educational environments (see Section 2). The confirmation of hypothesis 2a is consistent with the idea that occupation-specific systems devote greater resources to the enhancement of occupation-specific skills (especially in upper secondary education). Adults who have completed such programs therefore score lower on the kinds of non-occupational general skills assessed in PIAAC. As predicted, we also found that the effects of our different indicators of vertical and horizontal stratification on the low-intermediate numeracy gap became stronger when both aspects of stratification were included in the regression. Both vertical and horizontal stratification are at work, but their effects partly cancel each other out because they tend to be positively correlated, yet influence the lower skills gap in opposite directions.

As for the intermediate-high (upper) skills gap, we found some support for hypothesis 1b, which expected no (or, if at all, a negative) impact of vertical stratification on the upper skills gap. Hypothesis 2b predicted a larger upper skills gap in countries with occupation-specific upper secondary education due to higher selection into tertiary education. It was not confirmed. Nevertheless, specifications including further country-level control variables (Table 4) yielded a sizeable effect for apprenticeship systems compared to other types of upper secondary education system, even though it did not reach conventional significance levels. Given that there are only three apprenticeship countries in the sample (which of course limits statistical power), this may be seen as some indication that more occupation-specific and especially in apprenticeship systems are characterized by stronger selectivity of tertiary education attendance, which presumably drives up skills differentials between adults with upper secondary and tertiary education.

In sum, our main result is that the lower skills gap can be explained quite well by compositional differences and by differences in educational stratification processes. Thus, in contrast to the argument by Park and Kyei (2011, see Section 1), stratification processes do account for a substantial part of the variation in the low-intermediate skills gap. As in the study of Park and Kyei (2011), we also found that participation in adult education or, more precisely, the trainings gap between less and intermediate educated adults is related to the lower skills gap.

Park and Kyei's (2011) result that between-school resource inequality is a major predictor of the lower skills gap received much less support, however. One possible explanation for these divergent findings might be differences in sample restrictions or the type of skills studied. Yet, as mentioned already in Section 3, our results do not change substantially when we mimic Park and Kyei's study more closely by including only the age group 25-34 and/or focusing on literacy rather than numeracy gaps. Another explanation could be differences in data quality. For example, Park and Kyei (2011) found Germany to have a very small lower skills gap in IALS, whereas in PIAAC the gap in Germany is among the largest (cf. Figure 3). We cannot rule out the possibility that these results reflect a genuine trend. However, problems with the IALS data for Germany (and a few other countries) that have only recently become obvious (cf. Section 3) render the validity of the IALS-based estimate dubious and we are inclined to take the PIAAC-based one more seriously. On a more substantive level, it may also be important to recognize that school-level resource inequality is an ambiguous predictor. In particular, resource inequality should be most likely to enhance between-student inequalities if schools with above-average students also tend to have above-average resources. Conversely, if extra resources are targeted at disadvantaged schools or neighborhoods with low-performing students, resource inequality might well have equalizing effects. In other words: the level of school-level resource inequality per se may be less important than how it is related to school-level student composition. Future research should attempt to develop measures that are capable of differentiating between these scenarios—something we could not do in this paper where the main focus was on educational stratification.

As for the upper skills gap between intermediate and tertiary educated adults, none of the indicators of educational stratification had a clear effect and neither had the other country-level (control) variables. At best, we got some hints that stronger selection into tertiary education in countries with apprenticeship systems plays a role. We clearly need further studies that develop and test new ideas how education systems shape differences in basic cognitive competences between adults with intermediate and higher degrees of formal qualification.

Labor market implications

As a last point, we would like to discuss the relevance of our findings for broader discussions about the interpretation of labor market returns to competences and educational certificates. Given the easy availability of competence data from PIAAC, new empirical analyses of the impact of (basic) competences and educational certificates on labor market outcomes can be expected to mushroom during the next few years. But how should we interpret the effects of skills and certificates that will be revealed in these analyses?

A long-standing debate that our analysis speaks to is whether and to what extent the well-documented positive relationship between educational attainment and labor market outcomes such as wages reflects *productivity differentials* or *rents*. According to the productivity explanation (emphasized by human capital or signaling theory; Becker 1964; Spence 1973), individuals with higher levels of education have better labor market outcomes because they have more job-relevant skills than workers with lower levels of education. By contrast, the rent story argues that educational certificates at least partly serve as devices that artificially restrict access to jobs, thereby ensuring that the holders of credentials achieve better labor market outcomes than they would if access were unrestricted (Collins 1979; Sørensen 2000). These different ideas about education have stimulated a sizable literature that seeks to identify the productivity and rent components of the effect of education on labor market outcomes (cf. Barone and Van de Werfhorst 2011; Bowles and Gintis 2000, 2002). In 2011, the journal *Research in Social Stratification and Mobility* (Bills and Brown 2011) dedicated an entire special issue to this question.

Confronted with a regression that uses PIAAC to simultaneously estimate the impact of educational certificates and skills on a labor market outcome, the most straightforward response would perhaps be to interpret the net skills effect (controlled for certificates) as reflecting productivity differentials and the net certificate effects (controlled for skills) as reflecting rents. This would only be appropriate, however, if the meaning of skills (as measured in PIAAC) and of *certificates* did not vary across countries. Yet our results for the *lower* skills gap suggest that this is the case (see also Bills 2003: 439).

The clear negative relationship between occupation-specificity of upper secondary education and the lower skills gap (hypothesis 2a) is indirect evidence that the intermediate group in more occupation-specific countries invests in occupation-specific rather than in the basic general skills that were measured in PIAAC. This suggests that controlling for measured skills does not effectively remove skills differentials between workers (with respect to occupation-specific skills), particularly in occupation-specific systems. In addition to rent effects, the net effects of educational certificates would thus capture differentials with respect to occupation-specific skills—especially in countries where upper secondary education emphasizes these kinds of skills. Other things being equal, we would therefore expect to find larger net certificate effects on labor market outcomes in more occupation-specific countries, as Van de Werfhorst (2011) already did on the basis of the IALS data. Our results corroborate his interpretation that this pattern partly reflects skills/productivity differentials (rather than only better opportunities for generating rents via occupational licensing in more occupation-specific countries).

The finding that the lower skills gap rises with the level of vertical stratification in lower secondary education (hypothesis 1a) may also have implications for the labor market effects of educational credentials. In particular, this finding suggests that having completed (at least) an intermediate-level educational program is a better predictor of an individual's actual level of skills in countries with higher levels of vertical stratification. Theories of job-market signaling (Spence 1973) and statistical discrimination (Aigner and Cain 1977) suggest that this may enhance certificate effects even net of actual individual-level skills: These theories argue that worker's actual levels of skills or productivity are difficult to ascertain and that prospective employer will rely on formal educational credentials as a low-cost way of screening applicants. They should be especially likely to do so if the credentials are highly informative with respect to the applicant's actual level of skills, which our findings suggest is the case in vertically stratifying countries. This should amplify labor market effects of formal credentials even after controlling for actual individual skills or ability.

Future research should use PIAAC and similar data sets to empirically investigate this possibility. Research along those lines should examine the lower and the upper part of the educational distribution separately, as we found the impact of vertical and horizontal stratification to be quite different for the lower and the upper skills gap. Researchers thus need to carefully consider not only that the relationship between competences and certificates differs across countries, but also that the processes generating this relationship differ between the upper and the lower parts of the educational distribution.

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Appendix Table A1: Distributions of the variables used in the individual-country regressions

	Country codes (ISO)	% LRNR 1	Mean lite-racy score 2	Mean numeracy score 3	% with low education ISCED 0-2 4	% with inter-mediate education ISCED 3-4 5	% with higher education ISCED 5-6 6	% male 7	Mean age 8	% NB, NL 9	% NB, FL 10	% NB, FL 11	% FB, FL 12	% 25-to-29-year-olds in formal education 13	N 14
Austria	AT	0.6	276.3	283.3	14.5	65.6	20.0	49.9	40.4	92.4	2.0	2.1	3.4	20.8	2883
Belgium	BE	4.8	272.9	279.0	15.1	43.1	41.9	51.2	40.6	87.2	3.1	2.3	7.4	12.8	3245
Canada	CA	0.0	282.9	274.4	9.5	37.6	52.9	50.6	39.9	80.3	6.0	5.2	8.4	21.2	13627
Czech Rep.	CZ	0.9	274.6	277.7	7.9	70.8	21.3	51.4	39.0	95.2	0.1	2.2	2.4	10.7	3191
Denmark	DK	0.4	276.1	284.5	17.6	39.2	43.2	50.4	40.3	86.7	0.7	1.7	10.9	27.6	3724
Estonia	EE	0.4	276.9	275.3	11.7	45.2	43.1	48.6	39.3	87.3	2.1	9.3	1.3	21.8	4519
Finland	FI	0.0	300.1	294.3	8.2	44.0	47.8	51.1	39.8	94.4	1.8	1.5	2.3	31.4	3051
France	FR	0.9	264.5	257.7	21.1	45.9	33.0	49.2	39.9	84.1	2.3	5.2	8.3	7.7	4121
Germany	DE	1.2	271.0	274.0	10.8	55.1	34.1	51.3	40.6	83.4	1.6	3.1	11.9	22.3	3375
Ireland	IE	0.5	268.6	258.5	22.6	39.5	37.9	48.5	38.8	75.4	0.9	12.6	11.1	16.8	4097
Italy	IT	0.8	252.4	250.6	46.4	38.3	15.3	49.4	40.0	86.5	2.0	2.1	9.4	17.2	3037
Japan	JP	1.1	302.0	292.8	8.1	40.3	51.6	49.3	39.6	99.0	0.1	0.5	0.4	3.2	3206
Korea	KR	0.3	273.9	266.2	11.2	42.8	46.0	50.8	40.1	97.8	0.3	0.9	1.0	13.9	4330
Netherlands	NL	2.0	285.7	281.8	25.0	38.3	36.7	50.0	40.2	83.5	1.0	3.6	11.9	26.1	3027
Norway	NO	2.9	279.2	279.5	19.5	38.9	41.6	51.2	39.7	80.8	1.1	1.1	17.0	21.9	3145
Poland	PL	0.0	268.7	262.7	7.8	58.9	33.3	49.8	38.8	98.7	1.2	0.0	0.1	15.5	3813
Slovak Rep.	SK	0.3	275.2	278.0	13.2	63.5	23.3	50.5	38.9	92.6	5.6	0.9	0.8	10.6	3411
Spain	ES	0.6	256.1	250.7	42.0	22.6	35.4	50.6	39.7	81.8	2.7	9.5	6.0	22.4	3929
Sweden	SE	0.0	284.5	283.4	15.4	49.5	35.1	50.5	39.9	78.0	2.5	2.0	17.6	24.6	2557
UK	UK	1.2	275.1	263.5	22.4	35.3	42.4	49.9	39.6	82.3	1.8	6.7	9.3	14.1	5695
US	US	3.8	264.4	249.1	13.0	47.6	39.4	48.3	39.7	77.3	2.8	4.1	15.8	24.5	3095

Abbrevations: ISCED International Standard Classification of Education; NB native-born; FB foreign-born; NL native-language; FL foreign-language; LRNR Literacy-related non-respondent.
Sample includes all adults aged 25-54 who did not obtain their highest degree in a foreign country (i.e., in a different country than where they took part in PIAAC).
It also includes LRNR who mostly because of language difficulties did not take part in the PIAAC assessment. For LRNR only information on gender and age is available.
Following OECD (2013:69), LRNR were assigned numeracy/literacy scores of 85. For all other characteristics values were then multiply imputed (10 imputations) using gender, age, and the assumed literacy scores as predictors. Figures in columns 4-6 and 9-13 are thus partly based on these imputed values.

Source: PIAAC 2012, authors' calculations, survey weights applied.

Appendix Table A2: Distributions of the country–level variables

	Mean numeracy score			Numeracy gap (raw / adjusted)			Indices of		System of upper secondary education	Between-school inequality of instructional resources	% foreign-born and/or foreign language	Training gaps	
	Low education (ISCED 0–2)	Intermediate education (ISCED 3–4)	Higher education (ISCED 5–6)	ISCED 3–4 vs. 0–2	ISCED 5–6 vs. 3–4	Perfor-mance sorting	External differen-tiation	Vocatio-nal orien-tation				ISCED 3–4 vs. 0–2	ISCED 5–6 vs. 3–4
	1	2	3	4	5	6	7	8	9	10	11	12	13
AT	242.8	283.2	313.1	40.4 / 34.6	29.9 / 29.9	57.4	1.82	1.70	AS	0.013	7.6	17.1	23.3
BE	199.0	272.8	314.3	73.8 / 43.1	41.5 / 40.8	51.6	1.02	0.94	VS	0.010	12.8	22.0	26.2
CA	214.4	262.5	293.6	48.1 / 47.8	31.1 / 31.9	18.4	-1.32	-1.72	GEN	0.027	19.7	23.7	18.0
CZ	221.2	273.1	314.0	52.0 / 49.1	40.9 / 40.3	48.2	1.62	1.74	MIX	0.011	4.8	27.9	19.3
DK	241.1	280.2	306.2	39.1 / 31.4	26.0 / 29.3	15.6	-0.87	0.46	AS	0.033	13.3	18.4	17.6
EE	233.6	269.0	293.4	35.3 / 38.1	24.4 / 25.8	21.8	-0.00	-0.44	MIX	0.018	12.7	13.3	28.1
FI	260.8	280.6	312.7	19.8 / 14.2	32.1 / 35.7	6.1	-0.87	0.74	VS	0.015	5.6	18.2	20.2
FR	203.9	253.1	298.5	49.2 / 38.6	45.4 / 44.9	18.8	-0.47	0.39	VS	0.020	15.9	14.9	21.5
DE	201.4	268.3	306.1	66.9 / 55.4	37.8 / 37.1	56.9	1.86	0.89	AS	0.019	16.6	29.0	21.0
IE	216.1	255.1	287.2	39.0 / 41.8	32.1 / 32.1	17.7	-0.30	-0.35	GEN	0.031	24.6	17.0	25.9
IT	226.8	266.4	283.4	39.6 / 38.7	17.0 / 16.8	51.4	0.17	0.95	VS	0.023	13.5	16.5	25.5
JP	242.5	283.2	308.3	40.7 / 35.7	25.1 / 25.2	49.7	-0.47	-0.73	GEN	0.015	1.0	8.6	21.3
KR	217.6	257.3	286.4	39.8 / 32.2	29.1 / 26.6	38.2	0.07	-0.55	GEN	0.022	2.2	19.5	27.7
NL	233.4	284.2	312.3	50.8 / 38.9	28.1 / 28.1	58.5	0.94	1.26	MIX	0.012	16.5	19.5	16.3
NO	235.1	270.6	308.6	35.6 / 26.7	37.9 / 38.2	9.0	-1.04	0.88	MIX	0.017	19.2	17.6	14.9
PL	220.1	251.7	292.1	31.6 / 30.6	40.5 / 40.6	14.6	-0.08	0.30	VS	0.015	1.3	6.6	40.7
SK	219.9	279.5	307.0	59.6 / 57.0	27.5 / 27.5	42.9	1.62	1.49	MIX	0.023	7.4	27.5	26.9
ES	222.7	256.4	280.2	33.7 / 33.5	23.8 / 21.3	18.1	-1.02	-0.00	GEN	0.021	18.2	19.0	21.5
SE	234.2	279.1	311.2	44.8 / 30.1	32.2 / 36.2	11.0	-0.87	0.69	VS	0.016	22.0	19.5	14.9
UK	218.2	263.2	287.7	45.0 / 42.4	24.5 / 28.8	23.6	-1.04	0.47	VS	0.023	17.7	21.8	16.4
US	162.6	239.5	289.2	76.9 / 54.6	49.6 / 51.0	28.1	-1.32	-1.84	GEN	0.024	22.7	25.1	28.2

Abbrevations: ISCED International Standard Classification of Education; AS Apprenticeship system; GEN General system; MIX Mixed system; VS Vocational school system.

1–5: Based on PIAAC 2012, 25-to-54-year-olds who did not obtain their highest degree in a foreign country, survey weights applied; literacy-related non-respondents (LRNR) are included, assuming numeracy scores of 85 (OECD 2013:69); for LRNR highest degree obtained and other key characteristics were multiply imputed (10 imputations) using age and gender (which are available for LRNR) and the assumed numeracy scores. See Section 3 of the article and notes to Table A1 for further information.

4, 5: Adjusted numeracy gaps are controlled for gender, age, being 25 to 29 years old and (still) in formal education, and foreign-birth/foreign-language status.

6: Performance sorting index is school-level (i.e., between-school) variation in student performance as a percentage of total variation. The OECD regularly reports this measure (or its inverse, the so-called “index of vertical inclusion”) in its PISA reports. The value reported here is the unweighted average of all available measurements from the 2000, 2003, 2006, and 2009 PISA studies (i.e., across all different domains such as reading or science and different years). Polish estimates for 2000 were exluded because of implausibly large differences to subsequent years.

7, 8: Values taken from version 4 of the *Educational Systems Data Set* by Bol and van de Werfhorst (2013). External differentiation index (7) is based on the age of first selection, the proportion of the total curriculum that is tracked, and the number of available to 15-year-olds. External differentiation index is missing and multiply imputed (10 imputations) for Estonia. Index of vocational orientation (8) is based on the proportion of students in upper secondary education who are enrolled in vocational programs, with values taken from OECD, UNESCO, or both if available. See Bol and van de Werfhorst (2013) for further information.

9: Sources for classification: European Centre for the Development of Vocational Training (2013), Müller (1994), OECD (2000).

10: Theil index of between-school inequality of instructional resources: School resources are measured using an additive index of 17 items indicating whether shortages in various domains limit a school’s capacity to provide instrucations (responses of school principals). See Park and Kyei (2011) for further details. The measure used and reported here is the unweighted average of all availlable values from the 1995, 1999, 2003, and 2007 waves fo the TIMSS (grade 8). The measure is missing and multiply imputed (10 imputations) for Poland.

11-13: Authors' calculations based on PIAAC 2012, 25-to-54-year-olds (including LRNR), survey weights applied.

12-13: Missing and multiply imputed (10 imputations) for Austria.

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