Academic achievement and sense of belonging among non-native-speaking immigrant students: The role of linguistic distance

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Abstract

This paper examines the association between how distant the language spoken by non-native-speaking immigrant students is with respect to the language of instruction and their outcomes using data on 15-year-old students participating in the Programme for International Student Assessment (N=21,618). Linguistic distance is associated with achievement in reading, mathematics and science but not with sense of belonging to the school community. The negative association between linguistic distance and academic achievement is stronger among students who arrived in their country of destination at or after the age of 12, those with a more advantaged socio-economic background and those who attend school in education systems that select students into different tracks at an early age.

1. Introduction

International migration flows are changing classroom composition in many countries and linguistic diversity is one of the new demands to which education systems must respond (Suárez-Orozco, Suárez-Orozco & Todorova, 2008). Immigrant-origin children's fluency in the language of instruction is key if they are to fully benefit from learning opportunities offered by schools (Geay, McNally & Telhaj, 2013), participate actively in the social life of their school, and develop a sense of belonging with their school community and beyond (Dawson & Williams, 2008).

A key driver of language fluency is the extent to which immigrant-origin children speak the language of instruction at home, although the effect depends on parental fluency in

such language (Bohman, Bedore Peña, Mendez-Perez & Gilliam, 2010). Previous studies show that native- and non-native-speaking immigrant-origin students differ in their participation in education and attainment (Buchmann & Parrado, 2006; Suárez-Orozco, Suárez-Orozco & Todorova, 2008). However, little is known about the association between the degree of dissimilarity between students' native language (L1) and the language they use in instructional settings (L2) (referred to here as linguistic distance), and immigrant-origin children's academic achievement and sense of belonging to their school community. Linguistic distance is determined by comparing vocabulary, phonetic inventories and grammar of L1 and L2.

Previous studies indicate that the math and reading achievement of immigrant-origin children is lower when the language they speak at home considerably differs from the language spoken in instructional settings (Isphording, Piopiunik, & Rodríguez-Planas, 2015). However, such research failed to investigate how linguistic dissimilarity is related with other educational outcomes, such as students' sense of belonging to the school community, and to identify in which conditions linguistic dissimilarity plays an especially important role.

Sense of belonging to the school community represents the extent to which students feel accepted, respected, included and supported by their school community (i.e., peers, teachers and other adults) (Goodenow & Grady, 1993). It is strongly associated with academic performance and overall well-being, and is especially important for minority and disadvantaged groups (Fredricks, Blumenfeld & Paris, 2004; Goodenow & Grady, 1993).

To remedy these gaps, this research paper presents solid evidence on the association between linguistic dissimilarity and academic achievement in reading, mathematics and science, as well as sense of belonging to the school community. It also examines whether these associations vary among different groups of immigrant-origin students. Differences are tested across key individual, school and system level characteristics: gender, socio-economic

status, age at arrival, school level socio-economic composition, the concentration of language-minority students in a school and early selection policies at the education system level.

Unique data from multiple editions of a large-scale international assessment, the Programme for International Student Assessment (PISA), were analyzed. PISA contains information on large, representative and internationally comparable samples of 15-year-old students. In our study, immigrant-origin students are those who were born in a country that was different from the country in which they took part in PISA or had at least one parent who was born in a different country.

2. Theory and hypotheses

2.1. Language dissimilarity and second language acquisition

Models of language acquisition generally consider L1 as individuals' native language (the language they first acquired as children) and L2 as any language they consciously acquire, i.e. that is not a native language. In this study L1 refers to the language spoken at home by 15-year-old immigrant-origin students and L2 refers to the (different) language that is used in instructional settings. The language students report speaking most often at home could differ from the students' native language. This limitation is addressed in the methods section.

Theoretical and empirical evidence suggest that a greater dissimilarity between L1 and L2 in lexical, grammatical and phonological features could hinder the development of L2 proficiency while a greater L1-L2 similarity is generally associated with a faster rate of L2 acquisition among children (Paradis, 2011).

Proponents of the Language Transfer Hypothesis maintain that when L1 and L2 share similar grammatical features and linguistic structures - such as article systems, verb inflection

and word order - L2 learners can transfer knowledge and familiarity with these structures from their L1 to L2 instead of learning them anew (Bloom, Paradis & Duncan, 2012: Lightbown & Spada, 2000; Zdorenko & Paradis, 2011). It follows that the similar L1-L2 are grammatically, other things being equal, the faster the rate of L2 acquisition and the level of L2 proficiency (Takano & Noda, 1995).

According to the Contrastive Analysis Hypothesis and the Speech Learning Model, differences in phonology between L1 and L2 determine difficulties in learning L2 sounds (Chan, 2012) and, as a result, create difficulties in learners' overall success in acquiring L2 proficiency (Aoyama et al., 2013). Similar conclusions have been discussed when considering the effect of lexical similarities between L1 and L2 on L2 proficiency (Wolter, 2006)

2.2. Language dissimilarity, academic achievement and sense of belonging

When two or more cognitively demanding tasks are performed contemporaneously, they can interfere with each other (Norman & Bobrow, 1975). Most cognitive tasks require individuals to perform both linguistic (word decoding) and non-linguistic information processing (i.e. thinking) in parallel. Since linguistic processing is usually a prerequisite for thinking activities, when they interfere thinking tends to be sacrificed. When non-native speakers conduct tasks in L2, linguistic processing is more cognitively demanding, so it causes a decline in non-linguistic information processing ability that is known as the foreign language effect (Takano & Noda, 1995). This effect is separate from, and additional to, foreign language processing difficulty per se (Takano & Noda, 1993).

L2 knowledge influences performance in tasks in L2 both directly through the effect it has on linguistic processing (with greater L2 proficiency associated with better linguistic processing), and indirectly, by hindering thinking activities through the foreign language effect (Takano & Noda, 1995). The two effects work together, so that greater difficulty in

linguistic processing is associated with greater foreign language effects (Takano and Noda, 1993). A greater L1-L2 dissimilarity increases difficulty in linguistic processing and foreign language effects (Takano & Noda, 1995).

Since PISA achievement tests are problem-based, questions in all three testing domains (math, science and reading) have significant language requirements (OECD, 2017a). Therefore, all tasks require both linguistic and non-linguistic information processing activities, and students' performance should be negatively affected by L1-L2 dissimilarity through L2 proficiency and foreign language effects (Kao & Noda, 1995). Given the high language requirements of the PISA mathematics and science tests, we expect that language dissimilarity will be importantly associated with achievement in all PISA domains, not just reading, with no major differences in the strength of the associations. Consequently, the first hypothesis is:

H1: Language dissimilarity is negatively associated with academic achievement in text comprehension, science and mathematics.

Previous research indicates that immigrant-origin and language minority students tend to report lower levels of sense of belonging than native students (Arredondo, 1984; OECD, 2018). Immigrant-origin students' competence in L2 crucially impacts their likelihood to form intercultural relationships (Kudo & Simkin, 2003). Since a greater L1-L2 distance reduces non-native speakers' rate of L2 acquisition and delays their achievement of high levels of proficiency in L2 (Paradis, 2011), it could limit their ability to form strong ties with native-speakers and have large networks of friends, negatively impacting their sense of belonging (Goodenow & Grady, 1993).

Immigrant-origin students for whom L1 differs from L2 have to negotiate their identity and belonging to different groups, defined in terms of origin and language. Furthermore, their identity and belonging are questioned and attributed by others based on

tangible characteristics, such as physical aspect, speech and accent (Gabonton, Trofimovich & Magid, 2005). A greater L1-L2 dissimilarity is an indicator of greater differences between different groups and that could lead to greater acculturative stress. Acculturative stress is the stress that individuals (such as immigrant-origin students) experience while undergoing acculturation when they are called to express membership in two distinct cultural groups and they find this process psychologically or emotionally difficult. The use of L2 can be associated with acculturative stress for non-native-speaking immigrant-origin students and can lead them to adopt withdrawal strategies and lower their feelings of belonging (Berry, 2006). As a result, this study hypothesizes that:

H2: Language dissimilarity is negatively associated with students' sense of belonging.

2.3. Differences in the association between linguistic distance and outcomes

Hypotheses 1 and 2 identify the expected association between language dissimilarity and academic achievement and sense of belonging. However, the mechanisms shaping predicted associations are likely to vary in strength depending on the circumstances individual students experience, either because of their personal characteristics, those of the schools they attend or of the education systems in their host country.

2.3.1. The role of individual level characteristics

Students who are exposed to an L2 after a specific cut-off age generally find it difficult to become proficient in it. Studies examining the academic outcomes of second language learners have identified the age of 12 as a critical threshold (Heath & Kilpi-Jakonen, 2012). Research shows that age-arrival penalties vary across destination countries (Heath & Kilpi-Jakonen, 2012) and across groups within a specific destination country (Van Ours & Veenman, 2006). Such differences may be related to the relative difficulty of

acquiring a language beyond a critical period according to the degree of dissimilarity between L1 and L2. After the critical age, L1-L2 differences are likely to be harder to compensate to reach L2 proficiency, negatively affecting academic achievement and sense of belonging. Therefore, we hypothesize that, other things being equal:

H3: Language dissimilarity is more negatively associated with academic achievement and sense of belonging among students who arrived in the country at or after the age of 12.

Socio-economic disadvantage is a key explanatory factor for the academic disadvantage experienced by immigrant-origin students (Marks, 2006). Families' economic, social and cultural status (ESCS) affect their childrearing practices and the amount of resources they can invest in their children's upbringing. High-SES families tend to engage in *concerted cultivation*, organizing their children's time to maximize their skills and likelihood of future success (Lareau, 2002). This includes investing in private tutoring as well as ensuring participation in early childhood education and out of school activities (Jæger & Breen, 2016; Lareau, 2002). These forms of additional support and occasions to come in contact with L2 speakers can compensate for a greater L1-L2 dissimilarity and mitigate its hypothesized negative effects on academic achievement and sense of belonging. Other things being equal, the fourth hypothesis is:

H4: Language dissimilarity is more negatively associated with academic achievement and sense of belonging among socio-economically disadvantaged students.

Boys tend to perform worse than girls in school and are especially likely to struggle with reading and be affected by reading disabilities (Olson, 2002; Smith & Wilhelm, 2009).

Although the literature indicates that gender gaps in academic achievement among immigrant-origin students tend to mirror those prevalent within native populations (Fleischmann & Kirsten, 2014), the higher prevalence of boys among students with poor literacy and reading disabilities could imply greater difficulties in acquiring an L2 that is linguistically dissimilar from L1. This should negatively impact boys' academic achievement and sense of belonging through lower L2 proficiency. Moreover, 15-year-old boys are more prone to fatigue effects in long tests such as PISA (Borgonovi & Biecek, 2016), and the additional challenge related to language dissimilarity may further reduce their ability to perform well in a long achievement test. The fifth hypothesis is that, other things being equal:

H5: Language dissimilarity is more negatively associated with academic achievement and sense of belonging among boys than among girls.

2.3.2. The role of school level characteristics

Studies suggest that socio-economically disadvantaged students and language minority students may particularly benefit from attending schools that offer high-quality resources and extracurricular activities (Agasisti & Longobardi, 2017), a better school climate (Thapa, Cohen, Guffey & Higgins-D'Alessandro, 2013) and an advantaged socio-economic composition (Rjosk et al., 2014). The availability of high-quality resources in the school - such as better infrastructure, more experienced teaching staff, greater availability of better educational and cultural equipment and experiences such as after-school activities - and a better school climate may benefit those who are at the greatest risk of falling behind (Thapa et al., 2013), such as non-native-speaking immigrant-origin students facing various L1-L2 distance combinations.

PISA data contain several indicators of school resources and disciplinary climate. However, the wording of questions related to these indicators changed over time, so the indicators cannot be used when analyses are based on pooling different PISA editions (as this study does). To overcome this limitation, an indirect indicator of school resources and climate was considered: the average socio-economic composition of the student body in a school. Schools that have a more socio-economically advantaged student body tend to enjoy more positive learning environments (Palardy, 2013), offer higher-quality resources and provide more extracurricular activities overall (Thapa et al., 2013). While individuals with a disadvantaged socio-economic condition are more likely to attend schools with a disadvantaged socio-economic intake, we consider the role of school level resources and environment to be independent and additional to any role played by children's own socio-economic background. Consequently, the sixth hypothesis is that, even after controlling for a students' own socio-economic background and other factors:

H6: The negative association between language dissimilarity and academic achievement and sense of belonging is stronger the more socio-economically disadvantaged the school attended by non-native-speaking immigrant students is.

In many countries, immigrant-origin students are concentrated in certain schools (Jenkins et al., 2008; OECD, 2018). Some studies do not find any association between achievement and immigrant concentration in a school (Cortes, 2006), others find a positive association (Schnepf, 2007) and some a negative association (Jensen & Rasmussen, 2011). Differences in findings could be explained by how studies refer to different groups of students who settled in different countries and with different L1 and L2 distance combinations.

A high presence of language minority students in a school could adversely influence language acquisition, since in such schools many social interactions in L2 occur among students for whom L1 differs from L2, or they could even occur in languages other than L2. At the same time, other things being equal, a high concentration of non-native language speakers in a school may be associated with additional training modules and targeted support for students whose L1 and L2 differ. Additionally, teachers in such schools may have more experience employing effective pedagogical approaches to support second language learners.

Finally, although a large presence of language minority students may challenge a school's ability to create a sense of community (Van Der Wildt, Van Avermaet & Van Houtte, 2015), the disadvantage experienced by students who speak an L1 that is very different from L2 is likely to be lower. This could be due to the greater presence of non-native speakers and the possible creation of a sense of international community. As a result, schools with a greater proportion of non-native-speaking students, accounting for the socio-economic composition of the school, might be better equipped at reducing disadvantages in academic achievement and sense of belonging due to dissimilarity between L1 and L2. Other things being equal, our seventh hypothesis is:

H7: Language dissimilarity will be less negatively associated with academic achievement and sense of belonging of non-native-speaking students who attend schools with a higher proportion of language minority students.

2.3.3. The role of system level characteristics

Selection is one of the main mechanisms used by education systems to deal with heterogeneity in achievement levels and the expected achievement potential of students. It usually occurs either at the end of primary school or lower secondary school. While the

intention of proponents of selection is that academic potential should guide track allocation, in practice academic achievement at the age of selection and stereotypes about the academic potential of different students often determine allocation (Buchmann & Park, 2009). Achievement and stereotypes are often influenced by students' background. For example, immigrant-origin students are more likely to be assigned to lower tracks even when their academic achievement does not differ from that other students (Lüdemann & Schwert, 2010). Tracks that prepare students for university degrees are more prestigious, tend to have more resources than other tracks, and tend to have teachers with more ambitious expectations for their students (Brunello & Cecchi, 2007).

For L2 learners, curricula and materials, as well as language use among peers can be less conducive to L2 learning in less prestigious tracks (Harklau, 1994). Given the hypothesized negative effect of L1-L2 dissimilarity on academic performance, and the evidence that tracking decisions are also influenced by students' background characteristics, we hypothesize that students with a large L1-L2 distance will be more likely to be placed in tracks that are less prestigious and where resources that aid academic progression will be scarcer (resources can encompass physical resources but also factors such as high expectations and ambitions for the students among teaching staff and high-achieving and motivated peer networks). In education systems where tracking occurs early, students spend a larger amount of time in differentiated learning environments thereby increasing the effects of track allocation on both academic progression and sense of belonging. The final hypothesis is:

H8: The earlier the age of selection for educational tracts in a country, the more negative is the association between language dissimilarity and the academic achievement and sense of belonging of non-native-speaking students.

3. Data and methods

3.1. The Programme for International Student Assessment (PISA)

PISA is a triennial large-scale assessment with over 70 countries participating at least once since the first study in 2000. The key instruments include a two-hour low-stakes assessment to test proficiency in reading, mathematics and science, and a 30-minute questionnaire. The PISA surveys are conducted on two-stage stratified representative samples of students, between the ages of 15 years and 3 months and 16 years and 2 months, enrolled in lower-secondary or upper secondary institutions (for details, see OECD, 2017b). Achievement tests and questionnaires are administered in the language of instruction. Participating countries are predominantly high and middle-income countries. Therefore, while this study is based on data from a large number of countries representing a variety of educational, cultural and social contexts, its findings may not be generalizable to all contexts.

3.2. Sample selection

In most participating countries, only a small percentage of the PISA sample is immigrant-origin students or students whose L1 differs from L2 (OECD, 2018). Furthermore, not all participating countries asked students to report detailed information about the language spoken at home and their (or their parents') country of birth. Therefore, to increase the sample size and, with it, the precision of the estimates, data were compiled from several PISA editions. Data on academic achievement are from 2006, 2009, 2012 and 2015. For sense of belonging, data are from 2003, 2012 and 2015, when data on sense of belonging was collected. Instruments for the academic assessment in the three subjects tested in PISA are fully comparable since 2006.

The sample was restricted to immigrant-origin students who reported: 1) speaking a language at home that is different from the language in which they sat the PISA assessment;

2) information on their (or their parents') country of birth; and 3) information on the specific language they speak at home. Table 1 reports the two most common countries of birth and languages spoken at home for each country in this sample.

The small number of students with missing information for the outcome and control variables, detailed in the next section, were removed from the dataset. This study does not use multiple imputation to address missing information because lack of data affected primarily country of birth and/or language spoken at home, two variables for which multiple imputation is unlikely to give accurate estimates given the other information present in the dataset. A total of 21,618 students were included in analyses of academic outcomes (11,436 students for sense of belonging). Differences in sample size are due to fewer measurements of sense of belonging (only asked in three editions, and in 2012 it was administered, at random, to only two thirds of the PISA sample).

3.3. Variables

Table 2 provides a summary of the variables used in the analysis (including outcome measures, key independent variables and control variables) and the sources from which they were obtained. Table 3 displays descriptive statistics.

3.3.1. Outcome measures

This study characterizes students' academic performance as their achievement in reading, science and mathematics. All achievement variables were standardized to have a mean of 0 and a standard deviation of one.

As an indicator of social connectedness, this study uses the PISA index of sense of belonging at school. The index is derived from students' reports on the extent to which they strongly agreed, agreed, disagreed or strongly disagreed to each of the following statements: (a) I feel like an outsider (or left out of things) at school; (b) I make friends easily at school; (c) I feel like I belong at school; (d) I feel awkward or out of place in my school; (e) other

students seem to like me; (f) I feel lonely at school. The index was standardized to have a mean of zero and a standard deviation of one. Country specific reliabilities of the sense of belonging index are available in the technical reports of PISA cycles. Reliabilities are generally higher in OECD countries where on average are between 0.75 and 0.85.

3.3.2. Linguistic distance

The distance between the language spoken at home by respondents and the language in which they sat the PISA test is based on a lexical-phonological measure of linguistic proximity developed in the context of the Automated Similarity Judgment Program (ASJP; Wichmann et al., 2016).

The ASJP compares the pronunciation of a standard set of words that have the same meaning in pairs of languages (the Swadesh list), using a composite Levenshtein distance indicator (Bakker et al., 2009). Words in the list are converted into their phonetic transcriptions. The Levenshtein distance is calculated as the minimum number of single-character edits that should be performed to change the transcription from the first to the second language. The average computed across all words in the Swadesh list is then corrected to obtain the Normalized and Divided Levenshtein distance (LDND) between two languages. The result is a continuous measure of distance between two languages that takes on values between 0 and just above 100 (due to the correction factor). Supplementary Online Appendix A provides a detailed description of the LDND construction.

A key limitation of the ASJP is that it only captures differences in pronunciation between languages in their spoken form, while PISA assessments are based on written text. However, differences in pronunciation are a good proxy for the number of cognates shared by languages, which indicate a closer ancestral relationship between them (Bakker et al., 2009; Wichmann et al., 2010). Language relations predicted using the ASJP closely match expert

opinions based on all available language characteristics (Bakker et al., 2009; Brown et al., 2008).

The ASJP offers several advantages compared to other measures of linguistic dissimilarity: 1) it does not rely on prior expert opinions on language families or any strong arbitrary decisions for its computation; 2) it is easily and transparently computed for any pair of languages; and 3) it is a continuous indicator. The most common alternatives to lexicostatistical measures are those based on linguistic trees (Spolaore & Wacziarg, 2016). However, they require arbitrary assumptions of cardinality along language trees, have a low number of increments and cannot be easily calculated for isolated languages such as Korean. Another alternative measure that is discussed in Appendix A and is rarely used because of limitations is based on the World Atlas of Language Structure (WALS).

Using the ASJP algorithm, the linguistic proximity for all pairs of languages in the sample were computed. The classification of some languages within PISA and the ASJP do not correspond perfectly (Appendix B illustrates the assumptions that were made to standardize classifications). Linguistic distance was standardized to have a mean of zero and a standard deviation of one in this sample.

To verify the sensitivity of results to the measure used, we replicated analyses using other metrics: a measure built using linguistic trees data from Spolaore and Wacziarg (2009) (see Appendix A for details), a logged transformation of the ASJP measure, and a categorical transformation of the ASJP measure (LDND greater than 0 and smaller than 70, between 70 and 90, between 90 and 100, and greater than 100). Results are robust to alternative threshold selections that respect the main distribution characteristics of the variable.

3.3.3. Key independent variables

Students' gender was reported by the student in the student questionnaire. Students' economic, social and cultural status was introduced using the PISA index of economic, social

and cultural status (ESCS), an aggregate indicator based on students' answers to specific items in the questionnaire. It is standardized to have a mean of zero and standard deviation of 1 across OECD countries. Migration history was constructed based on students' reports on whether they and their parents were born in the country of assessment. Students who were born in the country of the test from one native born and one foreign born parent were the reference group. We introduce two dichotomous indicators to identify 1) students born outside the country of test irrespective of the country of birth of the parents and 2) students born in the country of test having both parents born elsewhere. In models focusing only on foreign-born students we also introduce a variable indicating the age at arrival, as reported by the student. We construct an indicator of the socio-economic make-up of the school attended by the student by averaging the ESCS index of students from the original PISA sample that attended the same school (i.e. not only those in our analytic sample). Similarly we construct a school level indicator of average reading proficiency by averaging the reading proficiency of all students that participated in PISA in a specific school. Finally, we calculate the proportion of students in a school whose L1 differs from L2. In terms of system-level factors, our independent variable is the age at first selection centered at the age of 14.

3.3.4. Control variables

Most models also account for characteristics of students' countries of origin and setting effects (students' combination of origin and destination countries). To include these, the country of origin of each student was defined in the sample. This was defined as the country of birth reported by the student in the student questionnaire if this differed from the country in which the student sat the PISA test. For native-born students and foreign-born students with missing information for their country of birth, maternal country of birth (as reported by the student in the student questionnaire) was used to identify country of origin. If maternal country of birth was also missing, paternal country of birth was used to indicate

country of origin. All analyses were replicated assigning paternal country of birth instead of maternal country of birth. Findings were identical and results are available upon request.

Gross Domestic Product (GDP) per capita in purchasing power parity and Human Development Index (HDI) of students' country of origin were used to account for self-selection of the students' families into different countries of destination. Additionally, the study controls for the share of imports out of GDP in students' countries of origin to account for their level of international openness and exposure to foreign goods and media (van Tubergen & Kalmijn, 2005). Controls were calculated using 2002 because it is the year immediately preceding the earliest dataset, PISA 2003. Results are similar when controlling for indicators referring to other years within the study period or for averages over the study period.

This study controls for the geographic distance between country of origin and destination and whether two countries shared a colonial tie to account for self-selection and migrants' familiarity with the host language and culture. Finally, this study includes the genetic distance between host and origin countries computed by Spolaore and Wacziarg (2016), which has been shown to be a satisfactory summary of cultural distance, religious distance and differences in values measured by the World Value Survey.

3.4. Methods

All results were obtained using OLS regressions that account for PISA wave fixed effects and country of destination fixed effects (except for models examining age at selection, in which this study controls for country of destination GDP per capita in purchasing power parity as a broad measure accounting for country differences and removes country of destination fixed effects). This study also accounts for the plausible values in the PISA measures of academic achievement (for 2015 the first five plausible values were used to match prior editions), and for the within-country stratification of the PISA samples (with

students nested in schools) through the use of 80 balanced repeated replicate (BRR) weights. Multiple sets of models were developed, each with one plausible value, and resulting estimates were combined using Rubin's rule as per OECD recommendations (Little and Rubin, 1987; OECD, 2017b). BRR weighting is the most suitable technique to consider sampling variability given the school-level stratification of PISA samples (OECD, 2017b). Multilevel models were not used because this study is interested in a setting effect variable (linguistic distance), which varies at the individual level, and treats country level factors as controls. In this context, BRR weighting outperforms other hierarchical linear models and the study does not aim to partition the overall variance of the outcomes.

Differences in strengths of associations across different groups of students were tested by interacting the linguistic distance indicator with students' gender, socio-economic status, age at arrival, school and system-level indicators. All analyses were carried out using Stata (version 14.0).

3.5 Accounting for measurement problems and endogeneity

PISA contains information on the language spoken by immigrant-origin children at home but not on the language/s they first learnt as children. Some parents may encourage their children to adopt the language that is used in school settings at home as a way to promote achievement or broader integration, thereby biasing estimates. Factors that are associated with the choice to adopt a language in the home setting may also be associated with children's academic achievement and sense of belonging.

Although PISA does not collect information about the first language individuals learnt as children, the use of information in PISA is validated using evidence available in the Programme for International Assessment of Adult Competences (PIAAC). PIAAC is an international large-scale assessment of 16 to 65 year-olds that shares many features with PISA (see http://www.oecd.org/skills/piaac/ for details). Contrary to PISA, PIAAC collects

information on the first and second languages individuals learnt as children and that they can still understand at the time of the survey, as well as the language respondents reported speaking at home at the time in which they sat the PIAAC test. Comparisons of the extent to which young adults in PIAAC report using their native language at home at the time of the test (the same measure used in this PISA-based study) were conducted. Given the small age-specific sample in PIAAC, this study considers 16-19-year-olds, the age group closest to the PISA sample. Among individuals aged 16-19 who were either foreign-born or the children of foreign-born parents and most often spoke a language at home that was different from the test language, 95% spoke most often at home either the first or second language that they learnt as children (89% the first and 6% the second language). The remaining 5% did not differ along observable characteristics from the rest of the sample (parental educational attainment, number of books in the home). More details on these analyses can be requested from the authors. This evidence suggests that estimates in the paper are unlikely to be biased because of endogeneity of the language indicator used.

Second, students participating in PISA are not randomly allocated to different schools and classes within schools. The sample stratification (which includes some indirect proxies that may be associated with school self-selection) and nesting are accounted for through BRR weighting. This study further controls for school-level economic, social and cultural status in all models, because many of the mechanisms guiding school-level selection are associated with the economic, social and cultural status of respondents. Similarly, the study controls for country of origin and settling in effects, because these factors guide many of the attitudes and behaviors that determine school selection and the choice of where to live of groups with different L1-L2 distances. Unfortunately, accounting for any within school sorting is not possible with PISA data.

Finally, identifying the independent role of setting effects in shaping second language acquisition is complicated by migrants' self-selecting behavior (Chiswick & Miller, 2001). This study deals with potential endogeneity by controlling for contextual effects associated with self-selection, such as the geographical and cultural distance or the presence of colonial ties between host and origin countries.

Remaining limitations are discussed in the discussion and conclusion section.

4. Results

4.1. Homogeneous effects of linguistic distance

This study reports the association between linguistic dissimilarity and reading in Table 4, mathematics in Table 5, and science achievement in Table 6. Seven models are presented in each table. Models 1 to 4 provide information on the main associations between linguistic distance and outcomes of interest, while models 5 to 7 identify differences in these associations across individuals. In model 1, linguistic distance, gender, ESCS, migration background and school level ESCS are all controlled for. In models 2, 3 and 4, controls are introduced to address endogeneity due to selection effects: model 2 controls for country of origin characteristics, model 3 further controls for setting effects and model 4 further contains destination country fixed effects. Coefficients for the country of origin and setting effects control variables are available from authors upon request.

Results are fairly stable across specifications. For example, a difference of one standard deviation (SD) in the index of linguistic distance is associated with a reduction of 0.08 of a SD in reading model 1, and 0.10 of a SD in model 4 (see Table 4). While the effect may appear to be very small according to standard levels first introduced by Cohen (1988), when reliably estimated (a condition that this analysis arguably satisfies given the large sample and analytical setup), what is typically considered to be a very small effect for the explanation of single events can have potentially consequential effects (Funder and Ozer,

2019). These results help identify the large variability in outcomes observed among immigrant-origin students. Using model 4 as a benchmark, estimates reveal that, other things being equal, the expected additional disadvantage in reading for Italian speakers attending school in a German speaking country compared to Dutch speakers is roughly equivalent to the difference in reading observed between boys and girls.

Results from Tables 4, 5 and 6 support *H1* and indicate that there is a negative association between linguistic distance and academic achievement. Conversely, *H2* is not supported: in models 2 to 4 of Table 7, when controls are introduced, the relationship between the linguistic distance indicator and sense of belonging is not statistically significant and close to zero quantitatively.

As a robustness check, Table 8 shows results obtained when models 4 presented in Tables 4, 5, 6 and 7 were re-estimated using the measure of linguistic distance based on linguistic trees. Results are very similar to those obtained using the ASJP. Results from using categorical indicators of the ASJP measure or the logarithmic transformation of the variable are also in line with those reported and can be requested from the authors.

4.2. Differences in the association between linguistic distance and outcomes

4.2.1 The role of individual-level characteristics

Models 5 in Tables 4, 5, 6 and 7 indicate that *H3* is not supported: the association between linguistic distance and academic achievement and between linguistic distance and sense of belonging is similar among boys and girls. Contrary to *H4*, findings reported in models 6 of Tables 4, 5 and 6 indicate that the association between linguistic distance and academic achievement is less negative among socio-economically disadvantaged students. A difference of one SD in linguistic distance is associated with a difference of 12% of a SD in reading among socio-economically advantaged students (students with values of 1 in the ESCS index) and 7% of a SD among socio-economically disadvantaged students (students

with values of -1 in the ESCS index). The heterogeneity of the association between linguistic distance and mathematics and science achievement is even more pronounced.

Models 7 indicate that for all academic outcomes, the negative association between linguistic distance and achievement reflected, primarily, a strong negative association among those who arrived in their destination country at or after the age of 12 while the association was quantitatively small among those who migrated at a younger age, thus confirming *H3*.

Models 5, 6 and 7 in Table 8 show that the association between linguistic distance and sense of belonging is not statistically significant irrespective of any individual level factors.

4.2.2 The role of school and system level characteristics

Table 9 indicates that *H6* could not be supported: results from the set of models 1 show that both associations between linguistic distance and academic achievement and between linguistic distance and sense of belonging do not vary significantly with a school's socio-economic condition. Results presented in model 2a provide weak support for *H7*: results are not precisely estimated for reading and are quantitatively small for mathematics and science. When school average reading scores are accounted for in model 2b, the size of the interaction is further reduced, although it remains statistically significant for math and science. When considering sense of belonging, support for *H7* cannot be established.

Table 10 indicates that early tracking is negatively associated with achievement in reading, math and science and is associated with lower overall levels of sense of belonging. Consistent with *H8*, L1-L2 dissimilarity has a stronger association with academic achievement in systems with early tracking. A difference of one SD in linguistic distance is associated with an additional negative association of around 3% of a SD in reading and science and 6% in mathematics for each year in which students are tracked before the threshold age of 14. No differential effect can be identified for sense of belonging.

5. Discussion and conclusions

This study investigated the role of linguistic dissimilarity in shaping the academic achievement and sense of belonging of non-native-speaking immigrant-origin students. The sample covers many origin and destination countries and it is statistically representative of the wider 15-year-old student population in countries of destinations. The materials are real-world education assessment tasks developed, translated and validated by internationally recognized experts, which are field trialed to ensure the cross-cultural validity and relevance of the test questions. Each of these features greatly enhances the external validity of this study and the conclusions that can be drawn from it.

The literature indicates that immigrant-origin students who at home routinely speak a language that is different from the language of instruction, face academic penalties (see OECD, 2018 for a review). Consistent with the hypotheses, this study documents that such penalties are larger the greater the dissimilarity between the language children speak at home and the language in which they sat the test. By contrast, and contrary to the hypothesis, no evidence was found of penalties in feelings of belongingness to the school community.

Contrary to the hypotheses, the association between linguistic distance and academic achievement is more negative among socio-economically advantaged students. This could be because disadvantaged students face so many constraints to developing academic proficiency that language barriers play a less significant role. The more advantaged the students, the more salient language difficulties are in influencing their academic results.

The associations between linguistic distance and outcomes of interest do not vary with the socio-economic condition of the school. There is weak evidence that the negative association between linguistic distance and academic outcomes is weaker when students attend schools that host a greater share of non-native speakers. This may be due to teachers in such schools having more experience with supporting non-native-speaking students and/or

such schools having more resources to support second language learning. It could also be a statistical artefact due to the lower performance variation in poor performing schools hosting large numbers of non-native speakers. This result warrants further investigation.

Overall, this study's findings suggest that, among adolescents, the disadvantage arising from linguistic dissimilarity is limited if children arrive in their country of destination at an early age. The disadvantage from linguistic dissimilarity for children who arrive after the age of 12 is considerably larger. The participants in this study are all 15 years old so age effects (i.e. if students arrive prior to or after age 12) and exposure effects (i.e. the number of years of exposure to L2) cannot be disentangled. Arrival at or after the age of 12 reduces the amount of time children have to become proficient in L2 before the age of 15, but also means that they are exposed to a different language after a critical period for language learning. Future work should address this limitation by identifying the relative importance of the two components.

The academic disadvantage related to linguistic distance is smaller in systems that do not stream by ability until a late age and larger in systems with early tracking. For example, a one SD difference in linguistic dissimilarity is associated with a disadvantage of 16% of a SD in reading in countries with tracking occurring at age 11, while in systems with no tracking until age 15, the disadvantage is 3% of a SD in reading.

Early tracking is one of the many ways in which education systems can strive to create homogeneous learning groups: for example, within school ability grouping is widely used to allocate students across different classes or even to different groups within classes. Evidence from PISA indicates that school level ability grouping is used both in conjunction with and independent of early tracking and that, contrary to early tracking, it is not associated with socio-economic disparities in academic achievement (OECD, 2013). When grouping by ability occurs within schools, allocation to different groups can be easily changed over time

so that it is adapted to students' progress. Moreover, students can be allocated to different groups in different subjects, thereby reducing the negative effects of stigma and stereotypes that could be associated with being allocated to low ability groups. For students with large L1-L2 disparities the presence of within school ability groups could even be beneficial if it were designed to tailor instruction to their specific learning needs and pace of progress. Further research could attempt to examine this association.

Similarly, this study cannot show the extent to which targeting resources to students with very distant L1-L2 combinations can close achievement gaps before early tracking occurs. However, research on learning indicates that the presence of individualized corrective feedback and the spacing of practice sessions over time enhances students' learning more than packing a lot of material in individual long practice sessions (Roediger & Butler, 2011). This research suggests that delayed tracking or creating permeability in the system are more promising alternatives to ensure the long-term development of immigrant-origin students who are faced with very distant L1-L2 combinations, rather than intense training to prepare students for early selection on a par with others.

The present study has some limitations, which should be addressed in future research. First, the linguistic distance indicator could be endogenous if the choice of language to be spoken at home by students and their families is associated with unobserved factors related with academic achievement and sense of belonging. This could also be the case if selection processes of students in different schools and of migrants in different countries of destination are associated with factors shaping achievement and sense of belonging. The study complemented findings based on PISA data with external data to show that only a small minority of adolescents decide to speak, at home, the language of instruction rather than their native language and that those who do are similar in observable characteristics to other students. Furthermore, the study includes several controls that should account for most

of the selection processes resulting from country of origin effects and setting effects. Nonetheless, future research could attempt to deal with limitations using different approaches to validate these results.

Second, the language information used is limited and does not consider the experiences of bilingual and multilingual children who may speak different languages with different individuals and in different contexts. Similarly, the frequency with which L2 is spoken at home and students' proficiency in L1 and L2 could not be determined. Some students may always speak L1 at home, and others may speak L1 slightly more often than L2 at home. Linguistic barriers should also differ based on students' proficiency in their L1, but this could not be controlled for with available data.

Third, in the present study it was not possible to consider the role played by internal factors such as self-beliefs, motivation and attitudes in shaping observed associations. Although PISA contains detailed information on these aspects, they are specific to the main subject domain tested in each wave of the assessment and therefore are not comparable across editions.

The focus of this paper was on the relationship between linguistic distance and the academic achievement and sense of belonging of 15-year-old students. However, linguistic distance is also likely to be related to the outcomes of immigrants at an older age both directly and indirectly through the effect it has on academic outcomes. Past research indicates that, for specific countries, immigrants' proficiency in the host language is related to their success in the labor market, their health and broader social outcomes such as marriage and fertility (see Clarke & Isphording, 2016 for a review). Future research could build on the framework presented and investigate the relationship between linguistic distance and the outcomes of adult immigrants in several countries simultaneously, using for example, data from the OECD Survey of Adult Skills.

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TABLES AND FIGURES

Table 1
Description of the analytical sample

Destination country	1st most common country of origin	2nd most common country of origin	1st most common home language 1	2nd most common home language
Argentina	Paraguay	Brazil	Portuguese	
Australia	China	Vietnam	Cantonese	Mandarin
Austria	Turkey	Croatia	Turkish	Croatian
Belgium	Turkey	Germany	Turkish	French
Ciudad Autónoma de Buenos Aires	Brazil	Bolivia	Portuguese	
Switzerland	Italy	Portugal	Swiss German	Portuguese
Costa Rica	Nicaragua	Panama	English	French
Cyprus	United Kingdom	Greece	English	Greek
Czech Republic	Vietnam	Ukraine	Vietnamese	Slovak
Germany	Turkey	Poland	Turkish	Polish
Denmark	Turkey	Iraq	Turkish	Arabic
Dominican Republic	U.S.A.	Haiti	English	French
Finland	Russian Federation	Estonia	Russian	Estonian
Great Britain	Ireland	Pakistan	Irish	English
Greece	Albania		Albanian	
Hong Kong	China		Mandarin	English
Croatia	Serbia	Italy	Serbian	Hungarian
Ireland	United Kingdom		English	Irish
Israel	U.S.A.	France	English	French
Kyrgyzstan	Uzbekistan	Russian Federation	Uzbek	Kyrgyz
Korea	China	U.S.A.	English	Chinese
Luxembourg	Portugal	Italy	Portuguese	Luxembourgish
Latvia	Russian Federation	Belarus	Russian	Ukrainian
Macao (China)	China	Hong Kong	Cantonese	Mandarin
Moldova	Ukraine	Russian Federation	Russian	Ukrainian
Mexico	U.S.A.		English	
North Macedonia	Serbia	Albania	Serbian	Albanian
Montenegro	Serbia	Albania	Albanian	Bosnian
Norway	Sweden	Denmark	Swedish	Danish
New Zealand	China	Korea	Chinese	Korean
Qatar	Egypt	Jordan	Arabic	English
Slovak Republic	Czech Republic	Hungary	Romany	Hungarian
Slovenia	Hungary	Italy	Romany	Hungarian
Uruguay	Brazil	Argentina	Portuguese	

Table 2
Description of variables

Variable	Description	Source
	Outcome variables and variable of interest	
Reading proficiency	PISA reading score	PISA assessment
Math proficiency	PISA math score	PISA assessment
Science proficiency	PISA science score	PISA assessment
Sense of belonging	PISA index of sense of belonging at school. Mean zero and standard deviation of 1 across OECD countries	PISA background questionnaire
Linguistic distance	Levenshtein distance normalized and divided, calculated using ASJP	ASJP
	Individual-level variables	
Female student	Dummy=1 if female	PISA background questionnaire
Socio-economic status (ESCS)	PISA index of economic, social and cultural status (ESCS). Mean zero and standard deviation of 1 across OECD countries	PISA background questionnaire
School socio-economic make-up (school ESCS)	Average PISA ESCS score of the students sampled in a school	PISA background questionnaire
Child of two foreign-born parents	Dummy=1 if the child of two foreign-born parents	PISA background questionnaire
Foreign-born student	Dummy=1 if foreign-born	PISA background questionnaire
Early arrival	Dummy=1 if foreign-born and arrived before the age of 12	PISA background questionnaire
	School-level variables	
School share of non-native speakers	School average share of students who most frequently speak a language at home that is different from the one of assessment	PISA background questionnaire
School average reading score	Average PISA reading assessment score of the students sampled in a school	PISA background questionnaire
	Educational system-level variables	
Age at first selection	First age at selection in the education system	PISA 2015 database
	Country of origin controls	
GDP per capita	Gross Domestic Product per capita in 2002 in the origin country, measured in 2011 international dollars and at PPP	World Bank
HDI	Human Development Index in the origin country in 2002	UNDP
Imports/GDP	Share of imports over GDP in the origin country in 2002	World Bank
	Setting effects	
Ex-colony	Dummy=1 if origin and destination country were in a colonial relationship	CEPII GeoDist
Geographic distance	Distance between capitals of origin and destination countries (km)	CEPII GeoDist
Genetic distance	Dominant Fst genetic distance between plurality groups	Spolaore and Wacziarg, 2009
	Country of origin controls	
Country fixed effects	Destination country fixed effects	
GDP per capita	Gross Domestic Product per capita in 2002 in the destination country, measured in 2011 international dollars and at PPP	World Bank

Table 3
Descriptive statistics

	Academic outcomes dataset (PISA 2006, 2009, 2012, 2015)				Sense of belonging dataset (PISA 2003, 2012, 2015)			
	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
Reading proficiency	0.00	1.00	-3.59	3.89	-	-	-	-
Math proficiency	0.00	1.00	-3.98	3.47	-	-	-	-
Science proficiency	0.00	1.00	-3.94	3.89	-	-	-	-
Sense of belonging	-	-	-	-	0.00	1.00	-3.47	2.36
Linguistic distance	0.00	1.00	-4.57	0.84	0.00	1.00	-4.81	0.84
Female student	0.48	0.50	0	1	0.50	0.50	0	1
ESCS	-0.34	1.03	-6.36	3.91	-0.43	1.04	-4.06	3.91
School ESCS	-0.06	0.59	-2.65	1.64	-0.10	0.58	-2.50	1.41
Child of two foreign-born parents	0.76	0.43	0	1	0.78	0.41	0	1
Foreign-born student	0.31	0.46	0	1	0.35	0.48	0	1
Early arrival (among foreign-born students)	0.76	0.43	0	1	0.77	0.42	0	1
School share of non-native speakers	0.29	0.23	0	1	0.28	0.22	0	1
School average reading score	0.00	1.00	-4.09	2.75	0.00	1.00	-4.20	2.69
Age at first selection	-2.06	2.35	-4.00	2.00	-1.92	2.43	-4.00	2.00
Country of destination GDP per capita	38754	12118	2144	111482	38548	11296	3228	111482
Origin country GDP per capita	18802	11916	1064	59482	17875	11757	1064	59482
HDI	0.73	0.09	0.37	0.92	0.72	0.09	0.37	0.92
Imports/GDP	30	15	13	168	30	12	13	124
Ex-colony	0.12	0.32	0	1	0.11	0.32	0	1
Geographic distance	2537	2896	60	19147	2741	3149	60	19147
Genetic distance	0.05	0.04	0.00	0.23	0.05	0.05	0.00	0.23
Observations	21618				11436			

Note: Descriptive statistics are calculated for our final analytical sample, where the students with missing information for the outcome and control variables were removed. Age at first selection was missing for Argentina, Kyrgyzstan, Liechtenstein and Moldova, so the total number of observations for this variable differs from the one for the overall analytical sample. ESCS is the PISA Index of Economic, Social and Cultural status; GDP is Gross Domestic Product; and HDI is the World Bank Human Development Index. Measures involving GDP and the HDI are measured in 2002.

Table 4
The association between linguistic distance and proficiency in reading

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Linguistic distance	-0.080**	-0.080**	-0.12**	-0.098**	-0.10**	-0.097**	-0.14*
	(0.014)	(0.016)	(0.017)	(0.018)	(0.018)	(0.018)	(0.048)
Female student	0.31**	0.31**	0.32**	0.31**	0.31**	0.31**	0.28**
	(0.027)	(0.027)	(0.026)	(0.026)	(0.026)	(0.026)	(0.047)
ESCS	0.084**	0.082**	0.060*	0.048*	0.048*	0.049*	0.072*
	(0.021)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.032)
School average ESCS	0.78**	0.77**	0.71**	0.76**	0.76**	0.76**	0.65**
	(0.048)	(0.049)	(0.048)	(0.049)	(0.049)	(0.049)	(0.078)
Child of two foreign-born parents	0.045	0.022	-0.0020	0.035	0.035	0.038	0.044
	(0.046)	(0.047)	(0.048)	(0.050)	(0.050)	(0.050)	(0.080)
Foreign-born student	-0.072*	-0.087*	-0.14**	-0.19**	-0.19**	-0.19**	
	(0.036)	(0.036)	(0.036)	(0.039)	(0.039)	(0.039)	
Linguistic distance*Female student					0.0076		
					(0.018)		
Linguistic distance*ESCS						-0.026*	
						(0.0099)	
Arrived before the age of 12							0.31**
							(0.061)
Linguistic distance*Early arrival							0.10*
							(0.047)
Observations	21618	21618	21618	21618	21618	21618	7047
Adjusted R-squared	0.31	0.31	0.33	0.37	0.37	0.37	0.34
Country of origin characteristics	No	Yes	Yes	Yes	Yes	Yes	Yes
Setting effects	No	No	Yes	Yes	Yes	Yes	Yes
Destination country FE	No	No	No	Yes	Yes	Yes	Yes

Notes: OLS estimates. Standard errors in parentheses, computed using replicate weights and the mean of plausible values, considering the sampling structure. ***p<0.001 **p<0.01 *p<0.05 (Two-tailed tests). All estimates include PISA wave fixed effects. ESCS is the PISA index of Economic, Social and Cultural Status. Early arrival is a dummy variable identifying students who arrived before the age of 12. Country of origin characteristics include: country of origin GDP per capita in 2002 measured in 2011 international dollars and at PPP; HDI in the origin country measured in 2002; and share of imports over GDP in the origin country in 2002. Setting effects include: an indicator of whether the country of origin and destination shared a colonial tie; the distance between the capitals of origin and destination countries; and the average genetic distance between plurality groups in the two countries as measured by Spolaore and Wacziarg (2009).

Table 5
The association between linguistic distance and proficiency in mathematics

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Linguistic distance	-0.11**	-0.12**	-0.17**	-0.12**	-0.13**	-0.12**	-0.14**
	(0.013)	(0.015)	(0.015)	(0.017)	(0.019)	(0.017)	(0.043)
Female student	-0.14**	-0.14**	-0.14**	-0.14**	-0.14**	-0.15**	-0.15*
	(0.035)	(0.035)	(0.033)	(0.032)	(0.032)	(0.032)	(0.055)
ESCS	0.10**	0.10**	0.078**	0.061*	0.061**	0.062**	0.098*
	(0.018)	(0.019)	(0.019)	(0.018)	(0.018)	(0.018)	(0.032)
School average ESCS	0.80**	0.79**	0.72**	0.76**	0.76**	0.76**	0.69**
	(0.047)	(0.049)	(0.045)	(0.041)	(0.041)	(0.041)	(0.066)
Child of two foreign-born parents	0.047	0.022	-0.0041	0.033	0.033	0.039	0.0012
	(0.047)	(0.048)	(0.049)	(0.051)	(0.051)	(0.051)	(0.078)
Foreign-born student	-0.036	-0.043	-0.11*	-0.16**	-0.16**	-0.15**	
	(0.036)	(0.034)	(0.034)	(0.037)	(0.037)	(0.037)	
Linguistic distance*Female student					0.012		
					(0.017)		
Linguistic distance*ESCS						-0.043**	
						(0.0093)	
Arrived before the age of 12							0.17*
							(0.059)
Linguistic distance*Early arrival							0.092*
							(0.041)
Observations	21618	21618	21618	21618	21618	21618	7047
Adjusted R-squared	0.3	0.31	0.34	0.4	0.4	0.4	0.4
Country of origin characteristics	No	Yes	Yes	Yes	Yes	Yes	Yes
Setting effects	No	No	Yes	Yes	Yes	Yes	Yes
Destination country FE	No	No	No	Yes	Yes	Yes	Yes

Notes: OLS estimates. Standard errors in parentheses, computed using replicate weights and the mean of plausible values, considering the sampling structure. ***p<0.001 **p<0.01 *p<0.05 (Two-tailed tests). All estimates include PISA wave fixed effects. ESCS is the PISA index of Economic, Social and Cultural Status. Early arrival is a dummy variable identifying students who arrived before the age of 12. Country of origin characteristics include: country of origin GDP per capita in 2002 measured in 2011 international dollars and at PPP; HDI in the origin country measured in 2002; and share of imports over GDP in the origin country in 2002. Setting effects include: an indicator of whether the country of origin and destination shared a colonial tie; the distance between the capitals of origin and destination countries; and the average genetic distance between plurality groups in the two countries as measured by Spolaore and Wacziarg (2009).

Table 6
The association between linguistic distance and proficiency in science

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Linguistic distance	-0.11**	-0.12**	-0.17**	-0.14**	-0.14**	-0.14**	-0.16*
	(0.012)	(0.014)	(0.015)	(0.016)	(0.017)	(0.016)	(0.049)
Female student	-0.047	-0.044	-0.041	-0.047	-0.047	-0.048	-0.065
	(0.029)	(0.029)	(0.027)	(0.028)	(0.028)	(0.028)	(0.053)
ESCS	0.11**	0.11**	0.078**	0.061*	0.061*	0.062*	0.092*
	(0.019)	(0.019)	(0.019)	(0.020)	(0.020)	(0.020)	(0.033)
School average ESCS	0.78**	0.77**	0.70**	0.75**	0.75**	0.75**	0.65**
	(0.050)	(0.053)	(0.049)	(0.046)	(0.046)	(0.046)	(0.076)
Child of two foreign-born parents	0.024	-0.011	-0.036	0.0087	0.0086	0.015	-0.066
	(0.045)	(0.048)	(0.047)	(0.051)	(0.051)	(0.051)	(0.10)
Foreign-born student	-0.043	-0.058	-0.12**	-0.18**	-0.18**	-0.18**	
	(0.035)	(0.035)	(0.034)	(0.039)	(0.039)	(0.039)	
Linguistic distance*Female student					0.011		
					(0.018)		
Linguistic distance*ESCS						-0.041**	
						(0.0093)	
Arrived before the age of 12							0.26**
							(0.057)
Linguistic distance*Early arrival							0.096*
							(0.046)
Observations	11436	11436	11436	11436	11436	11436	4067
Adjusted R-squared	0.019	0.024	0.033	0.054	0.054	0.054	0.071
Country of origin characteristics	No	Yes	Yes	Yes	Yes	Yes	Yes
Setting effects	No	No	Yes	Yes	Yes	Yes	Yes
Destination country FE	No	No	No	Yes	Yes	Yes	Yes

Notes: OLS estimates. Standard errors in parentheses, computed using replicate weights and the mean of plausible values, considering the sampling structure. ***p<0.001 **p<0.01 *p<0.05 (Two-tailed tests). All estimates include PISA wave fixed effects. ESCS is the PISA index of Economic, Social and Cultural Status. Early arrival is a dummy variable identifying students who arrived before the age of 12. Country of origin characteristics include: country of origin GDP per capita in 2002 measured in 2011 international dollars and at PPP; HDI in the origin country measured in 2002; and share of imports over GDP in the origin country in 2002. Setting effects include: an indicator of whether the country of origin and destination shared a colonial tie; the distance between the capitals of origin and destination countries; and the average genetic distance between plurality groups in the two countries as measured by Spolaore and Wacziarg (2009).

Table 7
The association between linguistic distance and sense of belonging

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Linguistic distance	-0.045***	-0.020	0.015	-0.028	-0.020	-0.028	-0.059
	(0.014)	(0.015)	(0.017)	(0.017)	(0.022)	(0.017)	(0.045)
Female student	-0.054	-0.056	-0.059	-0.051	-0.051	-0.050	0.013
	(0.039)	(0.039)	(0.038)	(0.038)	(0.038)	(0.038)	(0.064)
ESCS	-0.00069	-0.0037	0.0083	0.023	0.023	0.023	0.052
	(0.028)	(0.028)	(0.027)	(0.027)	(0.027)	(0.027)	(0.052)
School average ESCS	0.031	0.033	0.072	0.042	0.042	0.042	-0.00026
	(0.048)	(0.049)	(0.052)	(0.059)	(0.058)	(0.058)	(0.075)
Child of two foreign-born parents	-0.044	0.010	0.0050	-0.034	-0.034	-0.030	0.11
	(0.057)	(0.055)	(0.055)	(0.058)	(0.058)	(0.058)	(0.083)
Foreign-born student	-0.26***	-0.26***	-0.23***	-0.16**	-0.16**	-0.16**	
	(0.049)	(0.053)	(0.054)	(0.060)	(0.060)	(0.060)	
Linguistic distance*Female student					-0.016		
					(0.031)		
Linguistic distance*ESCS						-0.016	
						(0.017)	
Arrived before the age of 12							0.33***
							(0.063)
Linguistic distance*Early arrival							0.034
							(0.051)
Observations	11436	11436	11436	11436	11436	11436	4067
Adjusted R-squared	0.019	0.024	0.033	0.054	0.054	0.054	0.071
Country of origin characteristics	No	Yes	Yes	Yes	Yes	Yes	Yes
Setting effects	No	No	Yes	Yes	Yes	Yes	Yes
Destination country FE	No	No	No	Yes	Yes	Yes	Yes

Notes: OLS estimates. Standard errors in parentheses, computed using replicate weights and the mean of plausible values, considering the sampling structure. ***p<0.001 **p<0.01 *p<0.05 (Two-tailed tests). All estimates include PISA wave fixed effects. ESCS is the PISA index of Economic, Social and Cultural Status. Early arrival is a dummy variable identifying students who arrived before the age of 12. Country of origin characteristics include: country of origin GDP per capita in 2002 measured in 2011 international dollars and at PPP; HDI in the origin country measured in 2002; and share of imports over GDP in the origin country in 2002. Setting effects include: an indicator of whether the country of origin and destination shared a colonial tie; the distance between the capitals of origin and destination countries; and the average genetic distance between plurality groups in the two countries as measured by Spolaore and Wacziarg (2009).

Table 8
Tree-based linguistic distance and academic achievement and sense of belonging

Variables	Reading	Math	Science	Sense of belonging to the school community
Linguistic distance	-0.17**	-0.22**	-0.24**	-0.058
	(0.034)	(0.032)	(0.032)	(0.037)
Female student	0.32**	-0.14**	-0.040	-0.055
	(0.026)	(0.032)	(0.028)	(0.038)
ESCS	0.059*	0.071**	0.074**	0.019
	(0.021)	(0.019)	(0.020)	(0.027)
School average ESCS	0.76**	0.76**	0.75**	0.041
	(0.049)	(0.041)	(0.047)	(0.059)
Child of two foreign-born parents	0.038	0.037	0.0064	-0.0030
	(0.050)	(0.051)	(0.051)	(0.059)
Foreign-born student	-0.21**	-0.18**	-0.20**	-0.16*
	(0.040)	(0.038)	(0.040)	(0.061)
Observations	19168	19168	19168	10264
Adjusted R-squared	0.38	0.41	0.39	0.051
Country of origin characteristics	Yes	Yes	Yes	Yes
Setting effects	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes

Notes: OLS estimates. Standard errors in parentheses, computed using replicate weights and the mean of plausible values, considering the sampling structure. ***p<0.001 **p<0.01 *p<0.05 (Two-tailed tests). All estimates include PISA wave fixed effects. ESCS is the PISA index of Economic, Social and Cultural Status. Early arrival is a dummy variable identifying students who arrived before the age of 12. Country of origin characteristics include: country of origin GDP per capita in 2002 measured in 2011 international dollars and at PPP; HDI in the origin country measured in 2002; and share of imports over GDP in the origin country in 2002. Setting effects include: an indicator of whether the country of origin and destination shared a colonial tie; the distance between the capitals of origin and destination countries; and the average genetic distance between plurality groups in the two countries as measured by Spolaore and Wacziarg (2009).

Table 9

How the association between linguistic distance and academic achievement and sense of belonging depends on school-level factors

	Reading			Math			Science			Sense of belonging to the school community		
	Model 1	Model 2a	Model 2b	Model 1	Model 2a	Model 2b	Model 1	Model 2a	Model 2b	Model 1	Model 2a	Model 2b
Linguistic distance	-0.098**	-0.10**	-0.095**	-0.12**	-0.16**	-0.15**	-0.14**	-0.16**	-0.15**	-0.026	-0.015	-0.015
	(0.018)	(0.024)	(0.020)	(0.017)	(0.022)	(0.018)	(0.016)	(0.021)	(0.016)	(0.017)	(0.025)	(0.025)
Female student	0.31**	0.31**	0.25**	-0.14**	-0.15**	-0.19**	-0.047	-0.049	-0.099**	-0.050	-0.051	-0.064
	(0.026)	(0.025)	(0.020)	(0.032)	(0.032)	(0.028)	(0.028)	(0.028)	(0.025)	(0.038)	(0.038)	(0.037)
ESCS	0.048*	0.055*	0.081**	0.060*	0.064**	0.086**	0.061*	0.068**	0.090**	0.022	0.027	0.028
	(0.022)	(0.022)	(0.018)	(0.019)	(0.018)	(0.014)	(0.020)	(0.019)	(0.016)	(0.027)	(0.027)	(0.026)
School average ESCS	0.76**	0.71**	-0.14*	0.76**	0.74**	0.047	0.76**	0.71**	-0.018	0.045	0.0043	-0.16*
	(0.048)	(0.052)	(0.044)	(0.040)	(0.047)	(0.049)	(0.045)	(0.051)	(0.047)	(0.057)	(0.058)	(0.080)
Child of two foreign-born parents	0.034	0.038	0.024	0.034	0.038	0.026	0.0095	0.014	-0.12**	-0.034	-0.030	-0.027
	(0.050)	(0.050)	(0.040)	(0.051)	(0.050)	(0.042)	(0.051)	(0.050)	(0.030)	(0.058)	(0.057)	(0.057)
Foreign-born student	-0.19**	-0.19**	-0.13**	-0.16**	-0.15**	-0.10**	-0.18**	-0.18**	0.0012	-0.16*	-0.15*	-0.14*
	(0.039)	(0.037)	(0.026)	(0.037)	(0.036)	(0.032)	(0.039)	(0.038)	(0.040)	(0.060)	(0.061)	(0.064)
Linguistic distance*School ESCS	0.0088			-0.019			-0.017			-0.037		
	(0.020)			(0.020)			(0.021)			(0.033)		
School share of non-native speakers (10% increase)		-0.031*	0.032**		-0.019*	0.032**		-0.031*	0.023*		-0.021	-0.010
		(0.0097)	(0.0063)		(0.0092)	(0.0069)		(0.0095)	(0.0070)		(0.012)	(0.011)
Linguistic distance*School share of non-native speakers		0.0069	0.0027		0.017**	0.013**		0.014**	0.010**		-0.0027	-0.0039
		(0.0037)	(0.0028)		(0.0034)	(0.0029)		(0.0032)	(0.0024)		(0.0058)	(0.0058)
School average reading score			0.73**			0.59**			0.63**			0.14*
			(0.019)			(0.027)			(0.024)			(0.049)
Observations	21618	21618	21618	21618	21618	21618	21618	21618	21618	11436	11436	11436
Adjusted R-squared	0.37	0.37	0.56	0.40	0.40	0.53	0.38	0.38	0.52	0.054	0.055	0.062
Country of origin characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Setting effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Destination country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: OLS estimates. Standard errors in parentheses, computed using replicate weights and the mean of plausible values, considering the sampling structure. ***p<0.001 **p<0.01 *p<0.05 (Two-tailed tests). All estimates include PISA wave fixed effects. ESCS is the PISA index of Economic, Social and Cultural Status. Early arrival is a dummy variable identifying students who arrived before the age of 12.
Country of origin characteristics include: country of origin GDP per capita in 2002 measured in 2011 international dollars and at PPP; HDI in the origin country measured in 2002; and share of imports over GDP in the origin country in 2002. Setting effects include: an indicator of whether the country of origin and destination shared a colonial tie; the distance between the capitals of origin and destination countries; and the average genetic distance between plurality groups in the two countries as measured by Spolaore and Wacziarg (2009).

Table 10

How the association between linguistic distance and academic achievement and sense of belonging depends on age at selection

Variables	Reading	Math	Science	Sense of belonging to the school community
Linguistic distance	-0.061*	-0.076**	-0.10**	-0.015
	(0.019)	(0.020)	(0.019)	(0.021)
Female student	0.32**	-0.13**	-0.037	-0.062
	(0.025)	(0.033)	(0.027)	(0.036)
ESCS	0.050*	0.068**	0.070**	0.021
	(0.022)	(0.019)	(0.020)	(0.027)
School average ESCS	0.73**	0.72**	0.71**	0.067
	(0.047)	(0.043)	(0.047)	(0.054)
Child of two foreign-born parents	0.023	0.022	-0.0066	-0.045
	(0.048)	(0.049)	(0.049)	(0.050)
Foreign-born student	-0.21**	-0.17**	-0.18**	-0.18*
	(0.035)	(0.036)	(0.037)	(0.057)
Age at first selection (centered at 14)	0.046**	0.047**	0.048**	-0.052**
	(0.011)	(0.0099)	(0.011)	(0.011)
Linguistic distance*age at first selection	0.034**	0.055**	0.039**	-0.013
	(0.0084)	(0.0083)	(0.0078)	(0.0093)
Observations	21440	21440	21440	11347
Adjusted R-squared	0.34	0.35	0.34	0.043
Cultural and Geographic distance	Yes	Yes	Yes	Yes
Country of origin characteristics	Yes	Yes	Yes	Yes
Country of destination GDP	Yes	Yes	Yes	Yes

Notes: OLS estimates. Standard errors in parentheses, computed using replicate weights and the mean of plausible values, considering the sampling structure. ***p<0.001 **p<0.01 *p<0.05 (Two-tailed tests). All estimates include PISA wave fixed effects. ESCS is the PISA index of Economic, Social and Cultural Status. Early arrival is a dummy variable identifying students who arrived before the age of 12. Country of origin characteristics include: country of origin GDP per capita in 2002 measured in 2011 international dollars and at PPP; HDI in the origin country measured in 2002; and share of imports over GDP in the origin country in 2002. Setting effects include: an indicator of whether the country of origin and destination shared a colonial tie; the distance between the capitals of origin and destination countries; and the average genetic distance between plurality groups in the two countries as measured by Spolaore and Wacziarg (2009).