Achievement Gaps Associated with SES in Hamburg Schools:

How do they Change as Students get Older?

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Draft, 27 June 2007
Prepared for the ECINEQ 2007 Conference
(PLEASE DO NOT CITE)

ABSTRACT

The positive relationship between socio-economic status (SES) and academic achievement is well established, but the way in which this relationship varies with age is not. A better understanding of this issue could offer guidelines on when and how to target social investments aimed at equalizing educational opportunities of students coming from different socio-economic backgrounds. This study explores whether academic achievement gaps related to SES change as students get older and, if so, how they change. It is based on the Hamburg School Achievement Census 1996 to 2000 (LAU 5, 7 and 9; \( N \approx 14,000 \)) and focuses on the academic achievement in reading and math of students aged 10-16. Econometric techniques and hierarchical linear models (HLM) are applied to address this research question. Findings suggest that while the reading achievement gap between low and high SES students narrows with age, the math achievement gap remains relatively stable.

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Pre-doctoral fellow of the International Max Planck Research School “The Life Course: Evolutionary and Ontogenetic Dynamics” (LIFE).
This work is benefited from comments from Dr. Rainer Lehmann.
1. Background

Numerous studies have found a positive relation between students’ SES and their academic achievement (see, for example, White 1982). This relationship is referred to in the literature as a *socio-economic gradient*, or a *socio-economic gap*. It implies that low SES students will perform worse in school compared to high SES students, meaning that educational opportunities are unequal among students from different socio-economic backgrounds. In the longer term, the poor academic skills of low SES individuals make it less likely for them to successfully enter the labour market or pursue post-secondary training (OECD & Statistics Canada 2000; Raudenbush & Kasim 1998; Willms 1986).

A key research strand has focused on studying the processes that configure the relation between SES and educational outcomes. The tacit assumption underlying these studies is that a better understanding of this relationship could offer guidelines for the design and improvement of social policies aimed at equalizing educational opportunities for students coming from different socio-economic backgrounds. Different aspects of this relationship have been studied.

Willms (2003, 2002) has proposed a framework for the study of socio-economic gradients. This framework has been used to analyze different aspects of the relationship between SES and educational outcomes (Willms 2003, 2002, 1999; OECD & UNESCO-UIS 2003; Willms & Somers 2001; OECD & Statistics Canada 1995). In particular, three of these aspects are highlighted: the functional form, the strength of this relationship, and the degree of inequalities in educational outcomes attributable to SES. These three aspects provide a characterization of socio-economic gradients and offer relevant guidelines for social policy.

Researchers have explored other aspects of socio-economic gradients: the underlying processes through which SES influences educational outcomes or how different family factors
mediate\(^1\) in the relation between students’ SES and their outcomes (Willms 2003; Chao & Willms 2002; Hanson, McLanahan, & Thomson 1997); the extent to which socio-economic gaps in academic achievement are consistent across subject areas (Ma, 2000); and how different economic and political forces shape the relationship between socio-economic background and schooling outcomes over time (Willms & Raudenbush 1989; Heath & Clifford 1990).

Another interesting feature about this relationship is whether it changes as students get older. In this research area, the importance of socio-economic influences to educational outcomes during childhood has been well-established. Childhood is, indeed, a critical period in which the experiences of a child exert a strong effect on developmental outcomes (see, for example, Entwisle & Hayduck 1982; Kagan and Moss 1962), but some researchers maintain that the SES gap in academic achievement increases after the critical period of childhood (Guo 1998; Kerckhoff 1993).

For example, Guo (1998) suggests that the SES gap in academic achievement increases during early adolescence. Typically around the age of 11-12 years and beyond, individuals have the mental maturity to start understanding the full significance of the societal messages received from an impoverished environment. Low SES students realize that efforts in school often do not have the same outcomes for members of their group as do similar efforts for members of socially dominant groups. They thus perform badly, not because they lack ability, but because they know they are excluded from desirable jobs and therefore place less emphasis on academic pursuits. As a result, the academic achievement gap between high and low SES students increases during early adolescence.

Kerckhoff (1993) argues that institutional arrangements cause a pattern of increasingly diverging achievements over the life course between low and high SES individuals. In

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\(^1\) The term mediator refers to a factor that is influenced by SES directly, and helps to explain why there is a relationship between SES and the social outcome. For a further understanding of this concept the reader may consult Kraemer, Stice, Kazdin, Offord, and Kupfer (2001).
particular, during school years, assignment to groups is socio-economically biased. Low SES students are located in low ability groups and high SES students in high ability groups. These locations are fairly stable: low SES students are located continuously in disfavoured groups and high SES students in favoured groups. Thus, high and low SES students repeatedly gain and lose from being in these locations. Kerckhoff (1993) suggests that students’ location in the structure has a cumulative effect that produces increasingly divergent outcomes between low and high SES students as they progress within the educational system.

Understanding how the academic achievement gap between low and high SES students changes as they get older is a key issue for social policy. In particular, social policy makers aim at reducing the academic achievement gap among students from different backgrounds and, consequently, provide them with the same opportunities throughout their life. An increase in the SES gap in academic achievement during early adolescence and beyond would suggest that inequalities not only perpetuate but cumulate in spite of these institutions. If this is the case, a better understanding of the processes that lead to an increase in this gap should offer a guide on when and how to target social investments in order to reduce these inequalities.

Thus far, few studies provide empirical evidence on the timing of socio-economic influences on educational outcomes (Guo 1998; Kerckhoff 1993; Pungello, Kupersmidt, Burchinal, & Patterson 1996). Findings from these studies do not provide conclusive evidence on whether the SES gap in academic achievement increases, decreases, or remains stable with age. Additionally, most studies have used a cross-sectional design or a longitudinal design of two time points, which has proven to be limited to address this research topic (Baltes, Reese, & Nesselroade, 1988; Bryk & Raudenbush, 1987).

This study adds to our understanding of the timing of the effects of SES on educational outcomes by analyzing the influence of SES on math and reading achievement for students aged 10-16 in Hamburg, Germany. Additionally, it explores whether the differences
attributable to students’ migration background change as students get older and, if so, how they change.

This study differs from previous research in two main aspects. First, it is framed by the characteristics of the German educational system, where tracking of students to three or four school types starts as early as age 10, at the end of primary school (Grade 4). This research covers the period beginning after the transition to secondary school (Grade 5) and up to the end of compulsory education (Grade 9). Second, methodologically, this study uses econometric models, hierarchical linear models (HLM), and a longitudinal framework of three time points to address its research questions. The nature of the German educational system and the methodology of this research are discussed in the next two sections, separately.

2. The German Education System

In Germany, federal states have jurisdiction over formal education. They define their own goals, structures, instructional content, and procedures in their respective systems. It is therefore difficult to characterize the German educational system in a single picture. But, in general terms, Figure 1 depicts the formal structure of this system.

Primary education normally includes the first four years of education with normal entry at age 6. At the end of Grade 4 students are given a recommendation for the three-tiered secondary system (i.e., lower track, intermediate track and academic track plus a comprehensive school form). The recommendation is based largely on the student’s academic performance and the final decision as to which track the student will attend starting Grade 5 rests with the parents.

Students are allocated to the lower, intermediate, and academic track at a rather early stage. These secondary school tracks differ importantly with regard to the depth and breadth of the curriculum. Therefore, in Germany, the tracking decision has profound influences on future educational and professional opportunities of students.
The majority of students (about 60%) are enrolled in the lower or intermediate school track, which comprise 9 and 10 years of schooling, respectively. After graduation, these students typically pursue a half-time or full-time vocational apprenticeship, which usually involves a 3-year training program in a company in combination with course-work offered in a public vocational school once or twice a week. About 30% of students attend the academic track. Those who successfully complete the final examination at the end of Grade 12 or 13 of this track are entitled to attend university.
In addition to these three school tracks, some federal states include a mixed track or comprehensive schools, such as the case of Hamburg. Students in comprehensive schools may obtain school leaving certificates equivalent to those from any of the three schools tracks. These schools operate with internal streaming by subject. In Hamburg, around 30% of students attend comprehensive schools between Grades 7 and 9. Overall in Germany, 6% of the Grade cohorts 7 through 9 attend this type of school.

In Hamburg, the first phase of secondary school (see Figure 1) includes an “observational” stage between Grades 5 and 6. During this stage changes between school tracks are possible and no distinction exists between the lower and intermediate track. As a result of this institutional rule, around 6% of students in this integrated track are promoted to the academic track. Similarly, around 6% of students from the academic track are relocated to lower tracks and comprehensive schools (Lehmann, Vieluf, Nikolova, & Ivanov, 2006).

Hamburg’s school system is known for its relatively large inclusion of immigrants. While 10% of students in Germany attending the lower, intermediate, mixed, and academic track between Grades 5 to 10 are immigrants, in Hamburg 20% of students in these tracks are immigrants. Moreover, the distribution of immigrants across school tracks in Hamburg is markedly different from the national distribution (see Figure 2).
The immigrant student population in Germany is located in lower school tracks with respect to students in Hamburg. For instance, around 64% of immigrant students attend the lower or intermediate track in Germany and around 33% of immigrant students attend these tracks in Hamburg. The majority of immigrant students in Hamburg attend either the academic or mixed track. Immigrants in the academic track in Hamburg represent around 28% of the immigrant student population and immigrants in this track in Germany represent around 20% of the student population in Germany.
3. Method

3.1 Sample

Sources of information for this study are the Hamburg School Censuses for Grades 5, 7, and 9. These censuses are part of the project “Study of Initial Achievement Levels and Academic Growth in Secondary Schools in the City of Hamburg” (LAU, for its abbreviation in German). The LAU project gathered information on the learning progress and experiences of the student population in Hamburg throughout secondary school. It started in September 1996 with students enrolled in Grade 5 (LAU 5), continued in September 1998 with students in Grade 7 (LAU 7), September 2000 with students in Grade 9 (LAU 9), September 2002 with students in Grade 11 (LAU 11), and concluded in April 2005 with students at the end of Grade 13 (LAU 13).

LAU 5 addressed the transition from primary to secondary school and depicted the respective achievement levels observed at this point (Lehmann & Peek, 1997). In particular, it focused on student performance in language, reading, and mathematics. The following studies examined changes in student performance over time and across school tracks. Language awareness was evaluated up to Grade 9 and reading performance up to Grade 11. In addition to the subject areas evaluated in LAU 5, English performance was evaluated from Grade 7 and beyond.

The sample for the present analysis is restricted to those students in Grades 5, 7, and 9 aged 10-16 who took the math and reading test. Overall, it consists of 32,981 observations and 14,017 students (75% of the student population). Out of these students, 22%, 21% and 57% have one, two, and three time-point observations, respectively. Thus, the sample is

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2 There is also a continuation of the longitudinal design into the vocational upper secondary schools.
unbalanced, or the number of academic achievement measures or time-points varies among individuals. The age distribution of the sample is presented in Table 1.

Table 1
Sample Distribution by Age
(Number of Observations)

<table>
<thead>
<tr>
<th>Age (in years)</th>
<th>Grades</th>
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<tr>
<td></td>
<td>5</td>
<td>7</td>
<td>9</td>
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<td>11</td>
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</tr>
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</tr>
<tr>
<td>14</td>
<td>7</td>
<td>484</td>
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<tr>
<td>15</td>
<td>1</td>
<td>24</td>
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</tr>
<tr>
<td>16</td>
<td>0</td>
<td>6</td>
<td>786</td>
</tr>
<tr>
<td>Total</td>
<td>12,060</td>
<td>10,719</td>
<td>10,202</td>
</tr>
</tbody>
</table>

Source: LAU 5, 7, and 9.

3.2 Measures

The dependent variables are math and reading achievement. They are based on students’ scores in the math and reading tests part of the test batteries KS HAM 4/5 in Grade 5 (Mietzel & Willenberg 1996), SL-HAM 6/7 in Grade 7 (Behörde für Schule, Jugend und Berufsbildung, Amt für Schule, Hamburg, 1998), and SL-HAM 8/9 in Grade 9 (Behörde für Schule, Jugend und Berufsbildung, Amt für Schule, Hamburg, 2000). These tests were developed by a group of experts in Hamburg.

The math test included 30, 35, and 64 multiple choice format tasks in Grades 5, 7, and 9, respectively. Overall, they covered the areas of arithmetic, geometry, algebra, and stochastic problems. The reading test included 27, 29, and 72 multiple choice format tasks in Grades 5, 7, and 9, respectively. It evaluated students’ ability to extract and locate relevant information and make direct inferences from a text. The difficulty of the math and reading items varied across grades and between school tracks in Grade 9.

Item Response Theory (IRT) was used to scale the math and reading items. In particular, item difficulty for each item was estimated through a one-parameter Rasch model
(Rasch, 1960; Masters & Wright, 1997). Based on these estimates, the final math and reading achievement IRT scores were obtained using weighted likelihood estimation. These scores are measured in a continuous scale and were standardized to have a mean of 100 and a standard deviation of 20 in Grade 5.

The student’s age, SES, and migration background are three key explanatory variables in this study. Age is summarized in dichotomous variables for each age level and is also measured in months in a single variable centered in 156 months. SES is a composite of parents’ education, parents’ vocational training, and family wealth (Caro, 2007). It is a time-invariant covariate measured in a continuous scale with a mean of zero and a standard deviation of one for the population of students in Grades 5, 7, and 9\(^4\). Migration background characteristics are summarized in three dichotomous variables: Germans without migration background (i.e., with German nationality and mother tongue), Germans with migration background (i.e., with German nationality but a foreign mother tongue), and foreigners (i.e., no German nationality and a foreign mother tongue).

Descriptive statistics of the dependent and independent variables used in this study are presented in Annex A. Note that 42% and 32% of students in the final sample (14,017) have missing values in SES and migration background, respectively. These values have been imputed using the Hot Deck method (Little & Rubin 1987)\(^5\). See also that students in the excluded sample come from lower socio-economic backgrounds. Therefore, SES estimates based on the final sample are potentially biased. This study focuses, however, on the SES effects as students get older, which are not necessarily affected.

\(^4\) SES measures the relative position of an individual or family within a hierarchical social structure, based on their access to, or control over, wealth, prestige, and power (Mueller & Parcel 1981)

\(^5\) Regression estimates without imputing lead to the same findings of this study. They are available on request from the author.
3.3 Model

Two model specifications are estimated. Random effects panel data models are applied to the first specification. In this specification the reading or math achievement score for each individual $i$ in each period or cycle $j$ is

$$y_{ij} = \alpha_0 + \alpha_1 age_{ij} + \alpha_2 ses_i + \alpha_3 ses_i age_{ij} + \epsilon_{ij}.$$  \hspace{1cm} \ldots(1)$$

where $y_{ij}$ is the reading or math achievement measure, $age_{ij}$ is a set of 6 dummy variables for each age level from 11 to 16 years (i.e., age 10 is the group of comparison), $ses_i$ is students’ SES and it is fixed over time, and $ses_i age_{ij}$ is the interaction between SES and age, which allows the effect of SES to vary at each age level. In this specification the SES effects across age are not restricted to any particular functional form.

The second specification is estimated through random effects panel data models and hierarchical linear models (HLM). The latter are typically specified in two levels. The first level model is

$$y_{ij} = \pi_{0i} + \pi_{1i} agem_{ij} + \pi_{2i} agem_{ij}^2 + \epsilon_{ij}.$$  \hspace{1cm} \ldots(2)$$

where $agem_{ij}$ is the age of the individual in months. The intercept, $\pi_{0i}$, is the initial status and represents the average academic achievement score of person $i$ at age 13. The linear component, $\pi_{1i}$, is the rate of change in math achievement for person $i$ at the age of 13, and $\pi_{2i}$ captures the acceleration in each growth trajectory. The initial status and the rate of change vary depending on where the age of the individual is centered and the acceleration parameter is a characteristic of the entire trajectory.

There is a separate equation for each level 1 coefficient at level 2:

$$\pi_{0i} = \beta_{00} + \beta_{01} ses_i + \beta_{02} migra_{1i} + \beta_{03} migra_{2i} + \mu_{0i}$$ \hspace{1cm} \ldots(3)$$

$$\pi_{1i} = \beta_{10} + \beta_{11} ses_i + \beta_{12} migra_{1i} + \beta_{13} migra_{2i} + \mu_{1i}$$ \hspace{1cm} \ldots(4)$$

$$\pi_{2i} = \beta_{20} + \beta_{21} ses_i + \beta_{22} migra_{1i} + \beta_{23} migra_{2i}$$ \hspace{1cm} \ldots(5)$$

6 The reader may refer to Bryk and Raudenbush (2002) for an introduction of HLM.
where \( migra_{1i} \) and \( migra_{2i} \) are dummy variables taking the value of 1 if the student is German with migration background and foreign, respectively. The reference category for these variables is Germans students without migration background.

In (4), parameter \( \beta_{11} \) informs on the effect of SES on an individual’s growth rate at the age of 13. A positive estimate would indicate that the math achievement gap associated with SES widens with age, and vice versa. Similarly, \( \beta_{12} \) and \( \beta_{13} \) indicate how the gap between German students with and without migration background and the gap between foreign students and German students without migration background changes with age, respectively.

In (5), \( \beta_{21}, \beta_{22}, \beta_{23} \) evaluate whether the achievement gaps associated with SES, between Germans with and without migration background, and between foreign students and Germans without migration background are curvilinear with age, respectively. In other words, these coefficients test if these gaps widen or narrow at a decreasing or increasing rate with age. Notice that the acceleration parameter is fixed over time. This parameter needs of 4 data points to be random.

As it has been mentioned before, this study focuses primarily on the SES influences on academic achievement as students get older and secondarily on how the academic achievement gaps associated with migration background change with age. This is reflected in the specifications presented above: the first one does not include the migration dummy variables as these gaps across age are not explored at this level of detail (i.e., at each age level).

The specification of equations (3) to (5) varies depending on whether the SES effects or the migration background gaps with age is the question being addressed. On one hand, the SES effects are estimated excluding the dummy variables for migration background. These effects are thus not net of other aspects that may intervene in the relationship between SES and academic achievement. But these are the effects of interest for this research. On the other hand, the migration background gaps in equations (3) to (5) are estimated including only the
SES effects on the initial status. Therefore, these gaps exclude those differences in migration background associated with SES.

4. Findings

Estimates of the two main model specifications introduced above are presented in Appendix B.

Tables B1-B2 in Appendix B and Figures 3-4 include the estimates of the SES effects on math and reading achievement between the ages of 10 to 16 and a graphical representation of these effects, respectively. Notice that Figures 3-4 depict these effects in terms of the trajectory of the math and reading achievement gaps between students in the top and bottom SES quarters. Similarly, results of this section regarding the SES achievement gap refer to the gap between these two groups of students.

Table B1 includes the estimates underpinning Figure 3 (i.e., the estimates of equation (1)) and Table B2 the estimates underpinning Figure 4 (i.e., the estimates of equation (2) to (5)). Similarly, Table B3 and Figure 5 present estimates of the migration background achievement gaps as students get older and a summary figure of these results, respectively.

In general, estimates of both the SES effects and migration background gaps across age are fairly robust among the model specifications and regressions techniques used. The main findings from these estimates are summarized next.

The student’s SES has a positive influence on his or her reading and math performance at each age level between 10 to 16 years (see Figures 3 and 4). In other words, students in Hamburg aged 10-16 coming from high SES families achieve better results in reading and math compared to those coming from low SES families. On average, the math and reading achievement gaps associated with SES amount to 80% and 70% of a standard deviation of these measures in Grade 5, respectively. Thus, there is also some indication that the SES effects on math achievement are slightly stronger, at least during this life period.
The SES reading achievement gap seems to narrow with age at a constant rate (see Figure 3). Indeed, the trajectory of this gap fits a linear function from the age of 10 and up to the age of 16 (see Figure 4). In particular, the gap narrows because low SES students grow at faster rates than high SES students. While students from the bottom SES quarter grow 41% in their mean reading achievement between the ages of 11 and 15, students in the top SES quarter grow in 26%. As a result, the SES gap in reading achievement shrinks in 42% during this period.

The reading achievement gap narrows at a rate of 14% per year between the ages of 10 and 16. It represents almost one standard deviation of the reading achievement measure at the age of 10 and about 40% of a standard deviation of this measure at the age of 16 (see Figures 3 and 4). In other words, although the SES reading achievement gap narrows during this life period, it still persists to a considerable extent at the age of 16.

**Figure 3**

**Reading and Math Achievement Gaps Associated with SES**

*(Panel Data Random Effects Estimates)*

Note:
The SES achievement gap between students in the top and bottom SES quartiles in the first Y-axis is expressed as a proportion of an achievement SD in the second Y-axis.

Source: LAU 5, 7, and 9.
The math achievement gap associated with SES seems to follow a different trajectory (see Figures 3 and 4). It widens from the age of 10 to the age of 12 and narrows thereafter up to the age of 16. The trajectory of this gap between the ages of 10 and 16 fits roughly a quadratic functional form: the gap increases during the first two years and decreases afterwards. Overall, the math achievement gap between high and low SES students remains relatively stable between the ages of 10 and 16 years.

It should be noted that although the math achievement gap widens between the ages of 10 and 12 years, both students in the top and bottom SES quarter grow 18% in their mean math achievement score during this period. The gap widens, however, because initial levels of achievement at the age of 10 years are higher and lower for students in the top and bottom SES quarters, respectively. Thus, high SES students make more progress in absolute terms but not in relative terms, where both progress equally. This should be taken into account in order to make a fair comparison of math achievement growth between these two groups of students.

The math achievement gap between high and low SES students narrows at the age of 12 and up to the age of 16. As with the reading achievement gap, it narrows because low SES students grow at faster rates. In particular, students in the bottom and top SES quarter grow 11% and 7%, respectively, in their mean math achievement score from the age of 12 to the age of 14.

Overall, the math achievement gap between high and low SES students narrows between the age of 10 and 16 years, but to a lesser extent compared to the reduction of the reading achievement gap during this same period. As with the reading achievement gap, math achievement differences between students in the top and bottom SES quarter still remain at the age of 16 and they amount to about 57% of a standard deviation of the math achievement measure in Grade 5 (see Figures 3 and 4).
Foreign students perform worse than German students without migration background in both reading and math achievement. Differences between these two groups of students after controlling for SES amount to about 50% and 45% of a standard deviation of the reading and math achievement measures in Grade 5, respectively, between the ages of 10 and 16 (see Figure 5). This suggests that the influence of migration background is slightly stronger for reading achievement.

Students with migration background perform better than foreign students but worse than students without migration background. The differences between students with and without migration background are, however, rather small (see Figure 5). In particular, these gaps, after controlling for SES, amount to around 18% and 12% of a standard deviation of the
reading and math achievement measures in Grade 5, respectively. Moreover, these gaps seem to remain stable with age, at least from the age of 10 to 16 years.

**Figure 5**
Achievement gaps associated with migration background

Notes:
1. Germans with migration background and foreigners are compared with Germans without migration background.
2. The solid and dashed lines depict the HLM and Panel Data Random Effects estimates, respectively.
3. Differences in the second Y-axis are expressed as a proportion of an achievement SD.
4. Results control for SES.
Source: LAU 5, 7, and 9.

In contrast, the differences between foreign students and German students without migration background narrow with age during this same period (see Figure 5). The reading achievement gap controlling for SES amounts to around 70% at age 10 and reduces to around 40% at age 16. Similarly, the math achievement gap amounts to around 54% at age 10 and reduces to around 33% at age 16.
5. Discussion

The students’ SES is positively related to his or her math and reading achievement. Students in Hamburg aged 10-16 living in high SES families achieve better results in math and reading than those who live in low SES families. This finding is not new and has been largely documented by the literature (White 1982; Willms 2002, 2003; DuBois, Felner, Meares, & Krier 1994).

Additionally, findings from this study consistently indicate that the gap in reading achievement between low and high SES individuals narrows from the age of 10 to the age of 16. While the math achievement gap widens from the age of 10 to the age of 12 and narrows from the age of 12 to the age of 16, the reading achievement gap associated with SES narrows at a constant rate as students get older from the age of 10 to the age of 16.

This research focused secondarily on the math and reading achievement gaps associated with the student’s migration background. Evidence from this study indicates that there are small achievement differences between German students with and without migration background after accounting for their SES. Also, these differences do not change as students get older from the age of 10 to the age of 16. In contrast, the gap between foreign students and German students without migration background is large, even after controlling for SES. German students without migration background perform better than foreign students, especially in reading.

The reading and math achievement differences between foreigners and Germans without migration background narrow with age from the age of 10 to the age of 16. By the end of Grade 9, both the reading and math achievement gap have reduced in around 40%, but they persist to a considerable extent. The gaps between foreign students and German students with migration background are reducing throughout this period as well. In particular, foreigners are getting closer to German students with migration background in terms of their
math and reading achievement. Ultimately, these gaps reduce in more than 50% from the age of 10 to the age of 16 and are rather small by the end of this period.

Overall, findings from this study suggest that the academic achievement gap attributable to family socio-economic characteristics either remains stable (math) or reduces (reading and math) as students get older from the age of the age of 10 to the age of 16. These findings are fairly robust with respect to different model specifications and regression techniques. Yet, they are not consistent with what the literature in this field suggests (Guo 1998; Kerckhoff 1993), namely that the gap between high and low SES students widens with age.

The literature in this field, however, is scarce and far from being conclusive. Additionally, most studies are based on cross-sectional or two time point longitudinal designs. Changes in the SES gap due to aging and cohort effects are confounded in a cross-sectional research design (Baltes, Reese, & Nesselroade, 1988; Glenn, 1977). Two time-point longitudinal designs contain a very limited amount of information to study change. Instead, with three or more time points the straight-line growth model can be evaluated and the precision of the parameter estimates improves (Raudenbush and Liu, 2001; Rogosa, Brand, & Zimowski, 1982).

The structure of Hamburg’s educational system and the socio-economic composition of its student population should be taken into account while interpreting these findings. Hamburg includes a comprehensive school system and immigrant students in Hamburg are better distributed between school tracks compared to the national picture. The combination of these aspects might provide better educational opportunities for low SES and immigrant students as they progress within the education system.

In fact, as shown in this study, the reading achievement gap associated with SES narrows between the ages of 10 and 16 years because low SES students are growing at faster rates. In this regard, the key research question emanating from this research is: Why are low
SES students growing at faster rates during this life stage? Or, is the Hamburg school system creating a learning ceiling for high ability students? In the latter case the gap narrows not because low SES students are learning at faster rates but because high SES students’ growth is constrained.
References


### APPENDIX A - MAIN STATISTICS OF THE VARIABLES INCLUDED IN THIS STUDY

#### Table A
Main Statistics of the Dependent and Independent Variables

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<th>Variables</th>
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<td>0.33</td>
<td>36005</td>
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<td>3024</td>
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<td>1.00</td>
<td>8379</td>
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<td>1.00</td>
<td>1218</td>
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<td>1.00</td>
</tr>
<tr>
<td>German with migration background</td>
<td>9499</td>
<td>0.08</td>
<td>0.28</td>
<td>10687</td>
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<td>0.28</td>
<td>2461</td>
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<tr>
<td>background (German without migration</td>
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**Note:**
N represents the number of observations and individuals for the variables within and between individuals, respectively.
Source: LAU 5, 7 and 9.
### APPENDIX B – REGRESSION ESTIMATES

#### Table B1
SES Effects on Math and Reading Achievement as Students get Older: Estimates of Equation (1)

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<tbody>
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<td>Beta</td>
<td>SE</td>
<td>Beta</td>
<td>SE</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>101.428</td>
<td>(0.209)</td>
<td>100.597</td>
<td>(0.218)</td>
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</tr>
<tr>
<td>SES</td>
<td>7.187</td>
<td>(0.290)</td>
<td>6.691</td>
<td>(0.304)</td>
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<tr>
<td>age11</td>
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<td>(0.347)</td>
<td>-0.630</td>
<td>(0.354)</td>
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<tr>
<td>age12</td>
<td>16.943</td>
<td>(0.188)</td>
<td>16.980</td>
<td>(0.193)</td>
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<tr>
<td>age13</td>
<td>16.819</td>
<td>(0.342)</td>
<td>16.207</td>
<td>(0.353)</td>
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<tr>
<td>age14</td>
<td>30.267</td>
<td>(0.198)</td>
<td>28.088</td>
<td>(0.204)</td>
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<tr>
<td>age15</td>
<td>29.161</td>
<td>(0.339)</td>
<td>26.624</td>
<td>(0.352)</td>
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<tr>
<td>age16</td>
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<td>(0.581)</td>
<td>32.423</td>
<td>(0.597)</td>
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<tr>
<td>SESage11</td>
<td>-0.978</td>
<td>(0.459)</td>
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<tr>
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<td>(0.375)</td>
<td>-0.094</td>
<td>(0.372)</td>
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<tr>
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<td>-1.531</td>
<td>(0.216)</td>
<td>-0.123</td>
<td>(0.215)</td>
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<tr>
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<td>-2.805</td>
<td>(0.397)</td>
<td>-1.474</td>
<td>(0.394)</td>
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<tr>
<td>SESage16</td>
<td>-4.375</td>
<td>(0.718)</td>
<td>-2.304</td>
<td>(0.655)</td>
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</table>

Note. Coefficients in bold are statistically significant (p<0.05).
Source: LAU 5, 7, and 9.

#### Table B2
SES Effects on Math and Reading Achievement as Students get Older: Estimates of Equations (2) to (5)

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<th></th>
<th></th>
<th>Math</th>
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<td>Panel Data</td>
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<tr>
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<td>Beta</td>
<td>SE</td>
<td>Beta</td>
<td>SE</td>
<td>Beta</td>
<td>SE</td>
<td>Beta</td>
<td>SE</td>
</tr>
<tr>
<td>Intercept</td>
<td>121.091</td>
<td>(0.151)</td>
<td>120.475</td>
<td>(0.158)</td>
<td>119.656</td>
<td>(0.168)</td>
<td>119.167</td>
<td>(0.165)</td>
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<tr>
<td>SES</td>
<td>6.161</td>
<td>(0.146)</td>
<td>6.229</td>
<td>(0.291)</td>
<td>7.350</td>
<td>(0.166)</td>
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<td>(0.289)</td>
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<tr>
<td>age1m</td>
<td>0.586</td>
<td>(0.004)</td>
<td>0.587</td>
<td>(0.003)</td>
<td>0.525</td>
<td>(0.003)</td>
<td>0.525</td>
<td>(0.003)</td>
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<tr>
<td>SESage1m</td>
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<td>(0.003)</td>
<td>-0.041</td>
<td>(0.004)</td>
<td>-0.022</td>
<td>(0.003)</td>
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<td>(0.004)</td>
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<tr>
<td>age2m</td>
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<td>(0.000)</td>
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<td>(0.000)</td>
<td>-0.005</td>
<td>(0.000)</td>
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<td>(0.000)</td>
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<tr>
<td>SESage2m</td>
<td>0.000</td>
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<td>(0.000)</td>
<td>-0.001</td>
<td>(0.000)</td>
<td>-0.001</td>
<td>(0.000)</td>
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</tbody>
</table>

Note. Coefficients in bold are statistically significant (p<0.05).
Source: LAU 5, 7, and 9.
### Table B3
Migration Background Gaps with Age:
Estimates of Equations (2) to (5)

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<tr>
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<th>Math Panel Data</th>
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<td>Beta (SE)</td>
<td>Beta (SE)</td>
<td>Beta (SE)</td>
<td>Beta (SE)</td>
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<tr>
<td>Intercept</td>
<td>123.712 (0.177)</td>
<td>123.107 (0.250)</td>
<td>121.731 (0.202)</td>
<td>121.235 (0.242)</td>
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<tr>
<td>SES</td>
<td>5.272 (0.127)</td>
<td>5.620 (0.227)</td>
<td>6.109 (0.138)</td>
<td>6.187 (0.205)</td>
</tr>
<tr>
<td>migra1</td>
<td>-3.562 (0.432)</td>
<td>-4.110 (0.647)</td>
<td>-2.327 (0.482)</td>
<td>-2.574 (0.657)</td>
</tr>
<tr>
<td>migra2</td>
<td>-10.394 (0.379)</td>
<td>-10.380 (0.458)</td>
<td>-8.730 (0.408)</td>
<td>-8.928 (0.458)</td>
</tr>
<tr>
<td>agem</td>
<td>0.569 (0.004)</td>
<td>0.574 (0.004)</td>
<td>0.510 (0.004)</td>
<td>0.515 (0.005)</td>
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<tr>
<td>migra1agem</td>
<td>0.014 (0.010)</td>
<td>0.016 (0.011)</td>
<td>0.022 (0.010)</td>
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<td>0.000 (0.001)</td>
<td>0.000 (0.000)</td>
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<td>0.000 (0.000)</td>
<td>0.001 (0.000)</td>
<td>0.001 (0.000)</td>
</tr>
</tbody>
</table>

**Note.**
Coefficients in bold are statistically significant (p<0.05).
Source: LAU 5, 7, and 9.