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The development of ICT skills in adolescence at the intersection of gender and family background

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Abstract

We examine the intersection of gender and social as well as ethnic family background to explain individual differences in skills in information and communications technology (ICT) during adolescence. We used data from the National Educational Panel Study Starting Cohort 4 (NEPS-SC4), which contains repeated measures of ICT skills spanning three years (grades 9 and 12) in a sample of 5,507 students attending upper secondary schools [Gymnasium or comprehensive schools with Gymnasium track] in Germany. The results indicate a gender gap in ICT skills in grade 9 in favor of males, which widens further in grade 12. Moreover, ICT skills in grade 9 are a function of the interaction of gender and social background, with gender differences not observed among socially privileged students with high economic and cultural capital, suggesting more gender-egalitarian socialization among them. In contrast, the gender gap in the change in ICT skills in grade 12 remains largely unaffected by family background. Only income plays a role, with the gender gap disappearing for students with higher economic capital. The finding that intersectionality is less evident in the further development of gender-specific ICT skills points to the relevance of factors outside the family context.

Introduction

In the last two decades, advancements in information and communications technologies (ICT) have led to far-reaching changes in the labor market and earning structures (Carretero, Vuorikari, and Punie 2017) as well as in everyday lives, time use, and habits. Information has become a primary good (Sen 1999) and an independent source of productivity and power (Castells 1996), which is scarce and desired (van Dijk 2006). Accordingly, ICT skills, i.e. the ability to use information and communication technologies to successfully participate in society (OECD 2013), have become a new fault line along which social inequalities in terms of employability, income, and social participation emerge or are reinforced (Falck, Heimisch, and Wiederhold 2016; Grundtke et al. 2018; Nahuis and de Groot 2003). At the same time, research has shown that individual differences in ICT skills are not only a driver of social inequality in later life, but they are also stratified by key allocation criteria to life chances, such as social background, ethnicity, or gender (Wicht, Reder, and Lechner 2021). Gender differences in ICT skills are particularly important to study for (at least) two reasons. They might contribute to the persistent horizontal and vertical occupational gender segregation and the gender pay gap, and due to the ongoing process of digitization of the world of work both, male and female workers must possess these skills. Therefore, it is considered an important task for educational researchers and practitioners to counteract ICT skills gender gaps already in childhood and adolescence (International ICT Literacy Panel 2007).

Recent longitudinal studies have shown that gender is a crucial dimension of social inequality in the initial level and development of adolescents' self-assessed ICT skills in favor of males, while the findings regarding performance-based assessed ICT skill differences by gender are mixed (Gerick et al. 2019; Gnambs 2021; Park and Burford 2013; Siddiq and Scherer 2019). Theory and research indicate that gender differences in skills are based on widely shared gender stereotypes and role orientations that are shaped by the ongoing process of socialization (Master, Cheryan, and Meltzoff 2016; Wigfield and Eccles 2000). Since the reference groups to which students are exposed in school and private life convey more or less egalitarian gender stereotypes

and gender assignments, depending on their social and ethnic backgrounds, it is likely that the processes of gender socialization are not uniform (Parker et al. 2019; Gerick et al. 2019).

Additionally, previous research has shown that ICT skills vary substantially by parental economic and cultural capital as well as by ethnicity (Fraillon et al. 2014, 2019; Senkbeil 2017; Vennemann et al. 2019). These results suggest an as yet unexamined heterogeneity in gender differences in the development of ICT skills by different facets of family background.

In the present study, we aim to investigate how gender and family background intersect concerning the initial level and development of performance-based assessed ICT skills in adolescence, a period when major educational and vocational decisions are made based on individual proficiencies (Eccles 2011; Hadjar and Aeschlimann 2015). Hence, we ask: does the gender gap in the level and development of ICT skills vary by parental economic and cultural capital as well as ethnic background? To answer this question we use representative longitudinal two-wave data (grades 9 and 12) on students attending German upper secondary schools [Gymnasium or comprehensive schools with Gymnasium track] from the German National Educational Panel Study (NEPS; Blossfeld and Roßbach 2019), which capture the critical phase of growth in ICT skills. Studying the intersection of gender and family background in ICT skills provides us with new insights into how gender differences relate to other dimensions of social stratification and how we may be able to close the gender gap in ICT skills to work toward gender equality in future labor markets.

Gender gaps in ICT skills

Expectancy Value Theory (EVT, e.g., Wigfield and Eccles 2000) posits that individuals' engagement in certain activities relevant to skill acquisition is a function of (1) their expectation to succeed and (2) the subjective values they attribute to those activities, including interests and perceptions of the costs and utility of engaging in activities relevant to skill acquisition.

Expectations and values reciprocally interact with skill acquisition (Denissen, Zarrett, and Eccles

2007). In more recent work, Eccles and Wigfield (2020) have stressed the role of culture and situation in explaining differences in success expectations, subjective task values, and achievement-related choices and performance. Accordingly, they have adapted the name of the theory, now referring to *Situated Expectancy Value Theory (SEVT)*, to point out that perceptions, values, choices and performance are limited by “prior experience and by the cultural values, norms and characteristics that surround individuals as they mature” (Eccles and Wigfield 2020: 2). More specifically, Eccles, Jacobs, and Harold (1990) argue that gender differences in skills are primarily the result of gendered socialization experiences that affect young people’s expectations to succeed and their subjective task values. Gender stereotypes, that is, simplistic or oversimplified generalizations of men’s and women’s attributes, behaviors, and characteristics, reflect general expectations of how boys/men and girls/women will behave (Ellemers 2018). These stereotypes are widely shared by parents, teachers, and other significant others, who transmit them to children in day-to-day interactions. Furthermore, significant others tend to treat female and male students differently in response to their learning experiences. Via these two channels, they shape students’ expectations and values over time and thus affect skill acquisition. Since “science and technology are produced by, and constitutive of, masculine identities and male power” (Halford and Savage 2010), ICT is stereotypically considered a male domain, at least in terms of its technological core (Gebhardt et al. 2019). Halford and Savage have pointed out that the increased usage of the Internet might have changed this by making access to ICT easier than before (and a similar argument might be made for smartphones). But among adults, ICT-related jobs (Armstrong, Riemenschneider, and Giddens 2018), as well as private digital usage patterns, still differ widely along the lines of gender (van Deursen and van Dijk 2009; Dholakia, Dholakia, and Kshetri 2003).

Consistent with these assumptions, the broad body of research on ICT self-concepts, interests, usage patterns, and subjective evaluations of ICT skills consistently point to gender differences in favor of boys (Borokhovski et al. 2019; Gebhardt et al. 2019; Lau and Yuen 2015). These findings are confirmed by two recent meta-analyses (Borokhovski et al. 2019; Cai, Fan, and

Du 2017). Additionally, some recent studies show that during adolescence males exhibit higher growth in ICT self-confidence than females (Park and Burford 2013), while others do not find gender differences in the individual development of confidence (Gnambs 2021).

In contrast to this line of research, findings from recent studies on gender differences in objective, performance-based assessments of ICT skills are inconsistent (for a recent overview, see Gnambs 2021). Some mainly cross-sectional and single-country studies indicate higher ICT skills of males (e.g., Goldhammer, Naumann, and Keßel 2013 [Germany]; Kuhlemeier and Hemker 2007 [Netherlands]). Others show higher skills of females (e.g., Aesaert and Van Braak 2015 [Belgium]; Fraillon et al. 2019 [different countries around the globe]; Gebhardt et al. 2019 [USA]; Hohlfeld, Ritzhaupt, and Barron 2013 [USA]; Kim, Kil, and Shin 2014 [Korea]). And still others show no gender differences in ICT skills (e.g., van Deursen and van Dijk 2009 [Netherlands]; Gnambs 2021 [Germany]; Hargittai and Shafer 2006 [USA]; Hatlevik and Christophersen 2013 [Norway]; Siddiq, Gochyyev, and Wilson 2017 [Norway]). A recent meta-study by Siddiq and Scherer (2019), based on 46 studies, estimated a small overall advantage for girls but found considerable heterogeneity in effects. Longitudinal evidence is scarce. One recent longitudinal study for Germany based on NEPS data found a stronger growth of ICT skills among males than among females in the age range of 15 to 18 years (Gnambs 2021).

In sum, the results from previous research suggest that ICT is a field, where skills are not consistently gendered in advanced societies, while self-concepts are. One explanation for the mixed results could be differences in measurement. Based on data on 14 countries participating in the 2013 *International Computer and Information Literacy Study* (ICILS), Gebhardt et al. (2019) found that results are sensitive to operational definitions of ICT skills and modes of assessment. Girls performed better than boys on items that required creating and transforming information, while boys outperformed girls on items that required knowledge about and understanding computer use or using information safely and securely. Also, item format made a difference: so-called “large tasks”,

which required creating a product, were relatively easier for girls, while constructed and multiple-choice items were relatively easier for boys.

Family background gaps in ICT skills

Although SEVT emphasizes the relevance of cultural background, socialization processes, and the transmission of stereotypes in explaining gender differences in skill development, the predominantly psychological research in this area has often overlooked the possibility that adolescents' differential learning environments, which are socially and culturally stratified, might shape their gendered learning experiences (Fox, Prilleltensky, and Austin 2009; Parker et al. 2019). In the case of ICT, this is particularly relevant. Similar to other school-based skill domains, such as languages, math, or science, ICT skills require literacy skills and intelligence (Senkbeil 2022). But in contrast to these domains ICT skills are largely acquired at home (Senkbeil 2017), which makes them more prone than other skills domains to “primary effects” of education—differences in performance induced by the family's social background (Boudon 1974).

The reasons for inequalities in skills by *social background* are manifold: besides differences in basic cognitive skills at birth due to genetic inheritance, families from different social backgrounds are differently equipped with resources, which may help their children in skill acquisition. According to Bourdieu (1979), helpful resources take three basic forms, economic, cultural, and social capital. Economic capital, for example, helps to acquire the necessary hard- and software to use ICT skills at home, such as computers, tablets, and smartphones. It can also be used to directly foster the children's ICT skills via private tutoring. Families' cultural capital is particularly important with regard to explaining the intergenerational transmission of educational inequalities. Following Bourdieu (1979), cultural capital consists of three closely interwoven aspects: objectified capital (cultural goods such as books or works of art), institutionalized capital (academic titles and certificates), as well as incorporated cultural capital (inherent attitudes, behaviors, and knowledge acquired through education). Familial cultural capital hence shapes the

home learning environment of children via the books at home, language use, subjects of family discussions, everyday interaction practices, and joint cultural activities. High economic and cultural resources usually go along with more and higher-quality social capital, because persons from a certain background tend to meet primarily members of the same background during their lives. This results in segregated social networks that differ in sources of information, support, values, practices, and role models, which could be relevant to ICT skills and practices.

Moreover, parents from higher social backgrounds have higher educational aspirations for their children, pay more attention to their specific skills, and try to promote them (Lareau 2011). Accordingly, Archer et al. (2012) found in a qualitative study in the UK that economic, cultural, and social capital intersects with family habitus to make science careers (in a broad sense, hence spanning more than ICT) either thinkable or unthinkable already for 10 to 11-year-old children. Next to general resources, also science-related capital was found more often in middle-class than in working-class families. Here, science capital was often accompanied by a pro-science habitus and practices of concerted cultivation (Lareau, 2011), which jointly fostered a desire for science.

Quantitative empirical studies showed as well pronounced social differences in ICT skills, in particular by parental cultural capital, in Germany (Senkbeil, Ihme, and Schöber 2019) as well as many other countries (Fraillon et al. 2020). ICT usage and equipment differ less. However, better-off students possess not only smartphones, but also computers, which allow more advanced ICT tasks, and they use ICT more often for school-related tasks at home (Senkbeil et al. 2019).

Similar to social background, pronounced ICT skill differences by *ethnic background* are visible in Germany, which are highest among the first generation of migrants, and decrease in later generations (Vennemann et al. 2019). Multivariate analyses showed that migration background per se is not relevant for explaining differences in ICT skills, but family language is highly significant when cultural capital and parental education are controlled for (Fraillon et al. 2020; Vennemann et al. 2019). The qualitative study by Archer et al. (2012) suggests that cultural discourses of science

as desirable career aspiration among ethnic minority families (here: from South Asia) may foster science aspirations even when general resources are low.

Intersections between gender and family background

Previous research has shown that skill differences by gender and their growth over time are unclear and seem to depend on the facets of ICT under view and their measurement (Gebhardt et al. 2019). At the same time, there are marked gaps in ICT skills by social background and family language. In sum, previous research suggests that the level and development of gendered skills might be socially and ethnically stratified.

This result is consistent with the concept of intersectionality, which highlights the heterogeneity of gender as a social category. In general, intersectionality refers to the idea that social categories such as class, gender, and ethnicity (among others) function not as single, mutually exclusive entities, but as reciprocally constructing phenomena that in turn shape complex social inequalities (Collins 2015). Accordingly, an individual's specific location at the interface of these categories determines one's experience of the world (Codioli McMaster and Cook 2019; Collins 1990; Crenshaw 1989, 1991). This idea may be transferred to quantitative research on educational inequalities by analyzing *intercategorical complexity*, an approach that calls for adopting existing analytical categories to document relationships of inequality among social groups and changing configurations of inequality along multiple and conflicting dimensions (McCall 2005: 1773). This perspective implies that it is not sufficient to focus on gender, social background, or ethnic disparities alone, as done in the studies mentioned so far, but in combination, these social categories produce more complex patterns of educational inequalities (Codioli McMaster and Cook 2019; Gross, Gottburgsen, and Phoenix 2016). In our study, we ask whether gender differences in ICT skills—the social category we focus on—are moderated by students' social background, reflected by their parents' economic and cultural capital, as well as by ethnic background.

Narrowing gender gaps in ICT skills by advantaged social and ethnic backgrounds

As yet, there is no research that addresses whether inequalities in ICT skills are shaped by intersections of gender and family background. However, to derive our hypotheses we rely on studies on gendered beliefs and gendered behaviors, as well as on research findings on other skill domains, such as math, which is considered a male domain in a similar way to ICT (Lindberg et al. 2010).

Explanations for social and ethnic differences in gendered self-concepts, interests, and attitudes relevant to skill acquisition often relate to habitus-specific socialization (see the review by Hartung, Porfeli, and Vondracek 2005), which results in more egalitarian gender ideologies among adolescents from a more advantageous parental background (Kulik 2002). First, parents with high cultural capital are less likely than those with low cultural capital (and similarly, ethnic minorities) to work in gender-segregated occupations, thus representing less traditional role models for their children (Hadjar and Aeschlimann 2015). Studies showed that females show more egalitarian gender roles (Boehnke 2011) and are more likely to pursue male-dominated occupations (Fiebig and Beauregard 2011) if their mothers hold non-traditional positions in education, occupational status, and labor force participation. Second, parents with higher cultural capital and without migration background are more exposed to gender-egalitarian ideas and less accepting of gender stereotypes (Brooks and Bolzendahl 2004; Davis and Greenstein 2009). A study by Bryant (2003) showed that the level of traditionalism among college students decreases after four years of college. As a result, parents with higher cultural capital may raise their children in a more gender-egalitarian way. According to research findings on gender ideologies and socialization, gender should have a lower influence on ICT interests, attitudes, aspirations, and thus ICT skills of socially privileged compared to disadvantaged young people and ethnic minorities, leading to narrowing gender gaps in ICT skills among privileged youths. Several studies corroborated these assumptions. For example, in the UK, Codioli McMaster (2017) found that young women from disadvantaged

backgrounds were less likely to study STEM compared to advantaged young women. In the Netherlands, similar patterns were found (Van de Werfhorst 2017).

Widening gender gaps in ICT skills by advantaged social and ethnic backgrounds

Other studies, which focussed on study choices in STEM fields, however, showed inconsistent results related to gendered beliefs and gendered behaviors that do not uniformly support the above assumptions (Codioli McMaster and Cook 2019). In the U.S., young disadvantaged women were more likely than advantaged women to study STEM subjects, while social background had no effect on young men (Ma 2011). Zarret et al. (2006) found that among young adults in the U.S., white females were the least interested in computer tasks and considered themselves the least competent at hard computer tasks (e.g., programming and software development). In contrast, African American females were as self-confident and interested in computing tasks as males (Zarrett et al. 2006). Similarly, a study by Sáinz and López-Sáez (2010) showed that the gender gap in attitudes toward computers is stronger among adolescents from high-SES families, compared to low-SES families.

Also, several studies suggest the gender gap in math achievement to be larger among adolescents from high- than from low-SES families (Lubienski et al. 2013; McGraw, Lubienski, and Strutchens 2006). Bécars and Priest (2015) found that parental SES and wealth strongly decide performance disadvantages among eighth-graders in the US and explain profound ethnic inequalities. Within these groups of advantages and disadvantages, math and science skills turned out to be gendered, particularly among the most privileged students, with boys outperforming girls, while interests and perceived skills in these two domains were less consistently gendered. Gottburgsen and Gross (2012) analyzed intersectionalities in students' math skills in more than 50 countries, based on PISA 2006 data. Their results suggest as well that math skills are strongly determined by social background, and less consistently by gender or migration background. Girls with a migration background and low SES performed particularly low, followed by boys with

similar background characteristics and girls without a migration background and low SES. The highest math scores were reached by boys with high SES and no migration background.

A recent explanation for these counterintuitive results stems from comparative research on occupational gender segregation. Several studies showed that gender segregation is higher in more affluent countries, suggesting that women in more affluent contexts have a greater leeway to “indulge their gendered aspirations” (Charles 2017) for non-STEM education and occupations, which involve less lucrative careers because these contexts allow them to carry the economic costs associated with these career decisions. Additionally, attitudes towards different occupational fields seem to be more gendered in more affluent societies, possibly because concerns about material security are less salient in these contexts (Charles 2011; Charles et al. 2014; Charles and Bradley 2009; Sikora and Pokropek 2012). In line with these results, Breda et al. (2020) recently showed that stereotypes associating math with men are more pronounced among adolescents in affluent and egalitarian societies. As an explanation for this so-called “gender-equality paradox”, they argue that economic development and increasing gender equality do not go along with a suppression of traditional gender norms, but with a re-shaping into more horizontal forms of gender differentiation.

As Budge et al. (2023) recently showed for aspirations for computing jobs in Israel, the gender-equality paradox might not only refer to the macro level of countries’ affluence and gender composition but also be visible on the micro level within a single country at a single point in time. Higher gender gaps in ICT skills might be expected among socially and ethnically advantaged adolescents, (a) because affluence and the risks of making economically insecure choices are distributed unequally among social groups, and (b) ethnic minorities keep their culturally shaped attitudes towards different occupational fields after migration, at least for some time. An additional argument supporting these assumptions comes from work on socially stratified child-rearing practices (Lareau 2011): it is particularly high-SES parents who are sensitive to specific interests and skills of their offspring and cultivate these interests and skills. Hence, high-SES adolescents

might be more exposed to gendered parenting patterns and extra-curricular activities than low-SES adolescents (Lubienski et al. 2013).

The Present Study

This study aims to shed light on the social and ethnic heterogeneity of initial gender-specific ICT skills and their development in upper-secondary education in Germany, taking into account adolescents' familial economic and cultural capital as well as ethnic background. We draw on data from the National Educational Panel Study, Starting Cohort Grade 9 (NEPS-SC4). We restrict our analysis sample to students attending the academic track in the highly stratified German secondary school system [Gymnasium or comprehensive schools with Gymnasium tracks], keeping the institutional context constant. In the study, performance-based ICT skills were measured twice, first in grade 9, followed by a second assessment in grade 12. Hence, our study refers to a phase in upper-secondary education that is particularly relevant for the investment in specific skills that shape study choices in post-school vocational and academic education. While basic skills such as reading or math are taught from the beginning of school, ICT skills are more specific and are imparted much later during the school career. Our study taps into a phase of growing up when career choices are being made, based on gendered stereotypes towards different occupational fields, which require ICT skills to a highly different degree. Analysing the intersection of gender and social as well as ethnic background not only at one, but two points in time enables us to derive conclusions about the timing of the impact of family background on the gender gap in skills during this crucial phase.

The NEPS ICT assessments were conducted in paper-pencil mode, used multiple-choice questions, focussed not only on basic, but also on advanced skills, and did not encompass large, creative tasks. For these reasons, we expect advantages for boys in the initial level and growth of ICT skills. We also expect that low parental financial and cultural capital, as well as a non-German ethnic background hampers ICT skills. We consider these effects to be less pronounced than in

previous research because our study focuses solely on students in upper secondary schools in a strongly stratified education system. Since most students with disadvantaged social and ethnic background are concentrated in other school types, students from these groups might be positively selected in our sample.

With regard to intersecting social inequalities, we examine whether the gender gap in ICT skills narrows or widens with social background and ethnicity. Two competing hypotheses can be derived: (1) Based on theory and research findings of more gender-egalitarian socialization among privileged youth, the gender gap in ICT skills level and growth should narrow among youth from families with higher cultural capital, higher financial capital, and German ethnic background. (2) In contrast, the gender gap in ICT skills level and growth among these youth should widen in line with theories postulating and studies supporting the gender equality paradox.

Method

Sample

We conducted our analyses based on two-wave data on students' ICT skills from the National Educational Panel Study (NEPS), Starting Cohort 4 "School and Vocational Training: Educational Pathways of Students in Grade 9 and Higher" (Blossfeld and Roßbach 2019). The data comprise a large and representative sample of 16,425 ninth-grade secondary school students in 648 schools in Germany. The first survey was carried out in the fall of 2010, followed by semi-annual or annual follow-up surveys. NEPS offers extensively validated standardized assessments of ICT skills, which were administered repeatedly to the same respondents.

We restricted our sample to students who attended an academic upper secondary school track [*Gymnasium* or *Gesamtschule* with gymnasium branch] in grade 9. Students from other secondary schools usually leave school after grade 9 or 10. Among them, the second ICT skill measurement was taken in widely heterogeneous life situations, presented individually at home instead of group testing in school, and characterized by a high amount of panel attrition. More

importantly, our analysis sample is homogeneous given the highly stratified school system in Germany. We excluded three students for whom information on gender was missing. Our analytical sample consists of 5,507 students (54.6% females) attending 163 upper secondary schools.

Variables and Measures

ICT skills. Assessments of students' ICT skills were developed in NEPS specifically for longitudinal analyses. They were first assessed in grade 9 (wave 1; 2010/11), followed by a second assessment in grade 12 (wave 7; 2013/14). The tests for grades 9 and 12 contain different items that allow an accurate measurement of ICT skills in each age group. The two tests were linked with an anchor group design (Senkbeil and Ihme 2012).

ICT skills were defined as the abilities needed for a problem-oriented use of ICT in everyday life. The assessment framework covers five types of applications (word processing, spreadsheet, presentation software, e-mail, and internet and search engines) and four process components (access, create, manage, and evaluate). The process components represented either technological literacy (access or create) or information literacy (manage or evaluate) (Senkbeil, Ihme, and Wittwer 2013).

Students' skills were assessed through a paper-pencil-based test in the classroom. One test instructor from the survey institute and one supervisory person from the teaching staff were present. The question formats were simple or complex multiple-choice (Ihme, Senkbeil, and Wittwer 2015). The grade 9 test included 36 items and the grade 12 test 31 items. Both tests were speeded. Reliability was good (Grade 9 WLE reliability = .81; Grade 12 WLE reliability = .73) (Senkbeil and Ihme 2012, 2017). Validity analyses with NEPS data revealed high content validity and test fairness by gender and school type (Senkbeil et al. 2013).

NEPS provides Warm's mean-weighted likelihood estimator (WLE; Warm 1989) scores as estimates of each individual's skills, which are derived from an Item-Response-Theory model (Pohl and Carstensen 2012). The WLEs are on a logit-scale with a mean of zero and unconstrained variance. The WLEs express individuals' most likely skill scores given their item responses. The

tests were linked across waves to allow for longitudinal mean level comparisons (Fischer et al. 2016).

Gender. In the NEPS student survey, respondents were asked whether they are female or male, which in our view reflects their self-defined gender, however only in a binary way (cf. Westbrook and Saperstein 2015 for a critical discussion on questions as these). We coded gender so that students who characterized themselves as male were the reference group. We used the first available measurement between waves 1 and 7 of the student survey.

Family economic capital. We used monthly equivalence income to measure families' economic capital. The variable is based on information on household composition and monthly net household income from the parent survey in the first survey wave. If respondents declined to report the exact value of their income, they were asked for income intervals. To harmonize the data, the mean value of the income interval was used. We used the equivalence weight proposed by the OECD (factor of 0.5 for other persons over 14 years in the household, 0.3 for children up to 14 years). To normalize the right-skewed income distribution, the variable was logarithmized.

Family cultural capital. We measured cultural capital within the family using two variables: parents' highest educational qualification, and the number of books in the household. Regarding the parents' highest educational qualification, we used the highest degree mentioned in waves 1 to 7 in the student and parent survey. We distinguished between a tertiary education degree (ISCED levels 5 and 6) and lower qualifications (reference category). The number of books available at home is the most frequently used measure of (objectified) cultural capital (see Heppt, Olczyk, and Volodina 2022; Sieben and Lechner 2019, for validation studies). The measure was collected from students in wave 1. The scale ranges from 1 (none or only very few books) to 6 (enough to fill a shelf unit); the questionnaire supports students' assessments of the number of books by visual illustration.

Ethnic background. We considered students' language use at home and distinguished between (a) students who speak predominantly or exclusively a language other than German with parents or siblings and (b) students who speak predominantly or exclusively German with both

parents and siblings. The questions were surveyed in wave 1. Students who speak at least mostly German at home formed the reference category.

Data Analysis

Our analyses of ICT skills were conducted in two steps. First, we examined whether there are gender differences in ICT skills in grade 9 and in change from grade 9 to grade 12. For this purpose, we estimated general linear models with gender and students' family background variables (income, forms of cultural capital, and ethnic origin) as predictors of initial skills and their change. For the model predicting change, we followed the ANCOVA or conditional approach and regressed grade 12 ICT skills on grade 9 ICT skills (Werts and Linn 1970). In the next steps, we additionally included interaction terms between the different family background variables and gender in separate models, to examine whether gender differences in initial levels of ICT skills and their development vary according to students' family backgrounds. The sample characteristics by gender and the total sample are presented in Table 1.

—Insert Table 1—

All analyses were conducted using Stata 17. To take into account the clustering of observations within schools, we used a Huber-White sandwich estimator to obtain cluster-robust standard errors (Williams 2000). We *z*-standardized all continuous variables. Thus, the regression parameters indicate standardized mean differences and as such a measure of effect size. To deal with missing values in the dependent and independent variables, we drew on a two-level multiple imputation procedure with random intercepts to create 30 imputations using Blimp 3.1 (Enders, Keller, and Levy 2018). This imputation procedure allowed us to take into account the multilevel structure of the data. The imputation model included all variables used in the analysis models.

The analysis code will be uploaded to a publicly accessible registry system (e.g., OSF) upon the acceptance of the manuscript.

Results

Descriptive results show that male students in grade 9 had, on average, .08 higher ICT skills (SE .02, $p < .01$) than female students and also a .19 higher change in ICT skills from grade 9 to grade 12 (SE .02, $p < .001$). With a Cohen's d of .11 (grade 9) and .22 (change), these unadjusted mean differences correspond to small (grade 9) and medium (change) associations according to recent guidelines (Gignac and Szodorai 2016).

Table 2 shows the results of the basic model (i.e., the model with all control variables, but without interaction terms) for ICT skills in grade 9 and their changes from grade 9 to 12 after controlling for family background. The results indicate gender differences in ICT skills, both regarding initial levels and change, in favor of males. In terms of effect size, the results are comparable to the unadjusted models presented previously. We also found that students who do not speak at least mostly German at home have significantly lower initial ICT skills and also lower growth. Regarding cultural capital, the results show that students whose parents had a college degree and who had more books at home had higher initial ICT skills. The increasing number of books at home was also beneficial to the development of ICT skills. In contrast, on average, household income as a measure of financial capital was not related to either initial ICT skills or their development.

—Insert Table 2—

Does the gender gap in ICT skills vary by economic capital?

Figure 1 shows the gender gap in ICT skills in grade 9 (left) and the change from grade 9 to grade 12 (right) for different monthly household equivalence income values and 95% confidence intervals. As men form the reference group in our analyses, values above the zero line indicate gender differences in favor of females, and values below the zero line indicate gender differences to the detriment of females. Unless the 95% confidence interval for the predicted gender gap includes zero, the differences can be considered statistically significant. Due to the standardization of all

continuous variables, the x-axis labels refer to standard deviations of the income scale and the predictions refer to gender differences in initial skills and skill change in standard deviations. Full results of regression analyses can be found in Table A1 in the appendix.

—Insert Figure 1—

The results suggest that the gender gap in ICT skills in grade 9 as well as the gender gap in ICT skill change from grade 9 to grade 12 decrease with household income. For example, if income declines by two standard deviations from the mean (a value of 0), the predicted gender gap in ICT skills in grade 9 amounts to 0.5 standard deviations of the ICT skills scale in favor of males. Above an income of plus two standard deviations in income, no differences can be found in grade 9 ICT skills between both genders. Also, the gender gap in the change in ICT skills from grade 9 to 12 disappears for students from families with incomes greater than four standard deviations. However, at mean levels, only the interaction term for the gender differences in ICT skills in grade 9 is statistically significant at the 10% level (Table A1).

Does the gender gap in ICT skills vary by cultural capital?

Figures 2 and 3 show the results for the relationships between gender differences in ICT skills in grade 9 and in change from grade 9 to 12 as a function of cultural capital, including the highest parental educational qualification, and the number of books in the household. The full regression results can be found in Tables A2 and A3 in the appendix.

—Insert Figure 2—

—Insert Figure 3—

The results indicate that gender differences in ICT skills in grade 9 are only observed for students whose parents do not have a college degree. The estimated interaction relationship is only statistically significant at the 10% level, and the main relationship for parents holding a college degree (i.e., the estimated relationship for males) is statistically insignificant (see Table A2). In terms of change in ICT skills, there is a gender gap for both groups of students, i.e., those whose

parents have a college degree and those whose parents do not. This is also indicated by the statistically insignificant interaction relationship (Table A2). A similar pattern was found for the number of books at home: Gender differences in ICT skills in grade 9 decrease as the number of books increases. This association is statistically significant at the 10% level (see Table A3). Gender differences in the change in ICT skills from grade 9 to grade 12 exist independently of the number of books in the parental home (also see Table A3).

Does the gender gap in ICT skills vary by ethnic background?

Figure 4 shows the results for the interaction between gender differences in ICT skills in grade 9 and their change from grade 9 to grade 12 with ethnic background as measured by language use at home. The full regression results can be found in Table A4 in the Appendix.

—Insert Figure 4 here—

The results suggest that the gender differences in ICT skills in grade 9 are larger for students who (mostly) do not speak German than for students who do. However, the confidence intervals for students who (mostly) do not speak German are quite large. The regression results presented in Table A4 also show no statistically significant interaction association. This might be due to the small number of cases in this group. Only the gender difference for students who (mostly) speak German is statistically significant at the 1% level (also see Table A4). Looking at the results for the gender differences in the change in ICT skills, we found no statistically significant differences in the gender gaps between groups.

Discussion

We examined performance-based assessed ICT skills of adolescents in grade 9 and their change over three school years at the intersection of gender and family background, including economic and cultural capital as two aspects of social background as well as ethnic background. We relied on large-scale representative longitudinal data of students attending an academic-track school

in Germany. Thus, our sample consists of a relatively homogeneous social group of students, which is particularly important in Germany's highly selective early school tracking system (see Henniges, Traini, and Kleinert 2019 for a recent overview).

First, investigating additive associations with ICT skills, we found significant gender differences in initial ICT skills and skill changes in favor of male students. This result adds to the inconsistent findings on gender differences in primarily cross-sectional previous research, which found either no gender differences or advantages for one gender or the other (see Gnams 2021 for a longitudinal study; Siddiq and Scherer 2019 for a meta-analysis). In line with previous research (Fraillon et al. 2020; Gerick et al. 2019; Vennemann et al. 2019), we found significant social and ethnic differences in ICT skills and their change, with students who (mostly) do not speak German at home and students with low cultural capital forming the groups with lower ICT skills and also lower ICT skill growth compared to their (mostly) German-speaking counterparts and students with higher cultural capital. In contrast, economic capital was found to play no role for ICT skills in grade 9 and their development, controlling for cultural capital and ethnicity. This could be explained by the fact that the differences in ICT skills and their development among students from academic-track schools are more related to cultural practices than to the economic resources needed to access digital technologies.

Second, we found interactive associations for predicting ICT skills in grade 9 by gender and family background. Thus, examining overall gender differences in skills alone conceals heterogeneity in these relationships. They suggest that the gender gap in favor of males decreases as familial cultural capital (measured by parental education and the number of books at home) increases. With respect to ethnic background, we found a larger gender gap in ICT skills among students who mostly speak a language other than German, but the evidence is not robust due to the small number of cases. This finding is in line with the results of Gottburgsen and Gross (2012), who used 2006 PISA data to analyze intersectional inequalities in students' mathematics skills. They found that the lowest-performing group in grade 9 is female students with an immigrant background

and low SES. Given the interrelation of ICT skills, self-concepts, and value orientations (Eccles et al. 1990), this finding supports previous research on differential gendered ICT self-concepts, interests, and aspirations that vary with cultural capital (Hadjar and Aeschlimann 2015; Kulik 2002), as more privileged students might be exposed to more gender-egalitarian ideas and role models.

As for the change in ICT skills from grade 9 to grade 12, we found no differences in gender gaps concerning ethnic background and cultural capital. However, the gender gap narrowed with increasing parental economic capital. This finding contrasts with studies from the U.S. on gender differences in math and science skills, which indicate larger gender gaps among high SES students (Bécares and Priest 2015; Lubienski et al. 2013; McGraw et al. 2006). The reason for the decline in gender differences as a function of family income could lie in the motives for and patterns of use of digital technologies, which vary according to social background (Senkbeil et al. 2019). Considering that the young people in the sample are about to make important educational and career decisions, acquiring ICT skills is related to career aspirations and interests. From this perspective, the narrowing gender gap by parental income may be related to pursuing STEM subjects that promise social success in today's world, which may be less gender-typical in high-income families.

Overall, our results on the gender gap in ICT skills are largely in line with hypothesis 1, which assumed a more gender-egalitarian socialization among youth with a privileged family background. Regarding the skills gap in grade 9, we found a smaller gender gap among students with higher cultural capital and German language background. Regarding the gender gap in skills growth, we found a declining gender gap with higher financial capital. In contrast, none of our results spoke in favor of the competing hypothesis 2, which assumed a wider gender ICT gap among socially and ethnically advantaged students along the lines of the gender equality paradox. Furthermore, our analyses showed that gender differences in initial ICT skills in grade 9 were moderated more by social background, in particular cultural capital, and by ethnic background characteristics than gender differences in the development of ICT skills. The reason for this could

be on the one hand path dependency in skill development, and on the other hand the observation period studied. With increasing age, social contexts outside the family, such as peer groups or teachers, might play an increasingly important role for affecting students' investment in ICT skills, leaving behind the influence of family social context. These results resonate with the claim of situated expectancy-value theory that it is mainly the cultural milieu that forms culturally grounded belief systems, which get internalized into subjective task values and achievement-related choices and performance, when children grow up (Eccles and Wigfield 2020). Later in their lives, these internalization processes have already been taken place, which might explain both path dependence and the larger impact of social contexts outside the family.

Limitations and directions to future research

Despite the large-scale and longitudinal advantages of the data, our study has several limitations. The NEPS measurement of ICT skills corresponded to a unidimensional construct and did not allow for a distinction between the technological and informational dimensions of ICT skills (Katz 2007). Not distinguishing these dimensions may suppress gender differences in ICT skills in favor of male students, as female students are consistently found to have stronger literacy skills compared to males (see meta-analyses by Lietz 2006; OECD 2019; Yu and Hu 2022), which are especially related to the information dimension of ICT skills. Literacy skills are particularly important for informational internet use (e.g. finding, selecting, selecting, and evaluating information), and strategic internet use (e.g. using the internet by developing a direction toward a specific goal or taking the right action to achieve that goal; van Deursen and van Dijk 2016). Future research on gender differences in ICT skills could benefit from distinguishing between the two dimensions.

Moreover, our study is based only on two-wave data during adolescence. For this reason, we cannot make any statements about the stability and the shape of change over the entire life course within the individual groups studied. Therefore, it remains an open question at which points in the

life course changes occur and at which points stabilities are evident. Further studies with multiple measurement time points could provide answers to these questions.

Finally, our analyses of differences in ICT skills at the intersection of gender and family background are only descriptive, leaving us to question why the observed differences in ICT skills as well as in their growth over time occur. Future research could examine the social and psychological mechanisms underlying gender differences in ICT skills development along with economic and cultural capital as well as ethnicity. For example, a recent study found that ICT-related self-confidence, motives, and breadth of ICT usage incrementally predicted secondary school students' ICT skills (Senkbeil 2022). Such factors could reveal why there are differences in gender gaps in ICT skills along family background.

Conclusion

The results of our study reinforce the growing interest in intersectionality in quantitative empirical research. It shows that neglecting intersections of gender and family background masks crucial heterogeneities in gender differences in students' ICT skills and their development along social background characteristics. We found that gender in interplay with social and ethnic background is important for predicting ICT skills in grade 9 and also their growth over three years of schooling. However, we also found that family context, with its sociostructural characteristics, played a weaker role in predicting ICT skill growth and interacting with gender differences in ICT growth than it did for initial ICT skills in grade 9. This shifts the focus to social contexts outside the family, such as schools or peer groups, that might play a more important role in the development of ICT skills during adolescence. These factors should be focussed in future research to ensure that more socially disadvantaged females, with initially lower proficiencies, acquire the ICT skills essential in the 21st century to meet the challenges of an increasingly digitized world.

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Tables

Table 1. *Sample statistics.*

| | Male | | Female | | Total | | | | |
|---|-------|------|--------|------|-------|------|-------|-------|-------|
| | Mean | S.D. | Mean | S.D. | Mean | S.D | Min | Max | N |
| ICT skills grade 9 (WLE) | 0.73 | 0.77 | 0.65 | 0.74 | 0.69 | 0.75 | -2.23 | 4.05 | 3,932 |
| ICT skills grade 12 (WLE) | 1.44 | 0.75 | 1.20 | 0.62 | 1.31 | 0.69 | -1.73 | 4.44 | 3,517 |
| Monthly equivalence income, in €, logarithmized | 7.40 | 0.45 | 7.38 | 0.46 | 7.39 | 0.45 | 3.65 | 12.58 | 2,649 |
| Highest parental education, ref. no college | 0.50 | | 0.46 | | 0.48 | | | | 3,829 |
| No. of books at home (categories 1-6) | 4.51 | 1.24 | 4.70 | 1.16 | 4.61 | 1.20 | 1.00 | 6.00 | 3,903 |
| Language use at home, ref. (mostly) German | 0.06 | | 0.07 | | 0.07 | | | | 3,804 |
| Age at first measurement (in years) | 14.52 | 0.60 | 14.43 | 0.57 | 14.47 | 0.59 | 12.00 | 17.00 | 3,928 |
| Gender, ref. male | | | | | 0.55 | | | | 4,056 |

Source: <http://dx.doi.org/10.5157/NEPS:SC4:12.0.0>

Table 2. Unconditional regression models predicting ICT skills in grade 9 and their change in grade 12.

| | Grade 9 | | Change | |
|--|----------|--------|----------|--------|
| | <i>B</i> | S.E. | <i>B</i> | S.E. |
| Female, ref. male | -0.13*** | [0.03] | -0.29*** | [0.03] |
| Language use, ref. (mostly) German | -0.33*** | [0.09] | -0.12* | [0.06] |
| College or university degree, ref. other | 0.10* | [0.04] | 0.02 | [0.03] |
| Number of books, std. | 0.14*** | [0.02] | 0.07*** | [0.02] |
| Equivalence income (ln), std. | -0.02 | [0.02] | 0.02 | [0.02] |
| Grade 9 ICT skills, std. | | | 0.53*** | [0.01] |
| Constant | 0.05 | [0.03] | 0.16*** | [0.03] |
| Max. FMI | 0.25 | | 0.44 | |
| Average RVI | 0.10 | | 0.24 | |

Notes. Source: <http://dx.doi.org/10.5157/NEPS:SC4:12.0.0>. Cluster robust S.E., 30 imputations, N(schools) 149, N(persons) 4,056, continuous variables standardized. + p<0.1, * p<0.05, ** p<0.01, *** p<0.001.

Table A1. Regression models predicting ICT skills in grade 9 and their change in grade 12, with interaction of gender and income.

| | Grade 9 | | Change | |
|---|-----------------|---------------|-----------------|---------------|
| | <i>B</i> | S.E. | <i>B</i> | S.E. |
| Female, ref. male | -0.13*** | [0.03] | -0.29*** | [0.03] |
| Language use, ref. (mostly) German | -0.33*** | [0.09] | -0.12* | [0.06] |
| College or university degree, ref. other | 0.10* | [0.04] | 0.02 | [0.03] |
| Number of books, std. | 0.14*** | [0.02] | 0.07*** | [0.02] |
| Equivalence income (ln), std. | -0.05+ | [0.03] | 0.01 | [0.03] |
| Female × equivalence income (ln), std. | 0.06+ | [0.04] | 0.03 | [0.03] |
| Grade 9 ICT skills, std. | | | 0.53*** | [0.01] |
| Constant | 0.05 | [0.03] | 0.16*** | [0.03] |
| Max. FMI | 0.25 | | 0.39 | |
| Average RVI | 0.14 | | 0.24 | |

Notes. Source: <http://dx.doi.org/10.5157/NEPS:SC4:12.0.0>. Cluster robust S.E., 30 imputations, N(schools) 149, N(persons) 4,056, continuous variables standardized. + p<0.1, * p<0.05, ** p<0.01, *** p<0.001.

Table A2. Regression models predicting ICT skills in grade 9 and their change in grade 12, with interaction of gender and parental education.

| | Grade 9 | | Change | |
|---|-----------------|---------------|-----------------|---------------|
| | <i>B</i> | S.E. | <i>B</i> | S.E. |
| Female, ref. male | -0.18*** | [0.04] | -0.33*** | [0.04] |
| Language use, ref. (mostly) German | -0.33*** | [0.09] | -0.12* | [0.05] |
| College or university degree, ref. other | 0.04 | [0.06] | -0.03 | [0.05] |
| Female × college or university degree | 0.11+ | [0.06] | 0.09 | [0.06] |
| Number of books, std. | 0.14*** | [0.02] | 0.07*** | [0.02] |
| Equivalence income (ln), std. | -0.02 | [0.02] | 0.02 | [0.02] |
| Grade 9 ICT skills, std. | | | 0.53*** | [0.01] |
| Constant | 0.07* | [0.04] | 0.18*** | [0.03] |
| Max. FMI | 0.25 | | 0.44 | |
| Average RVI | 0.09 | | 0.23 | |

Notes. Source: <http://dx.doi.org/10.5157/NEPS:SC4:12.0.0>. Cluster robust S.E., 30 imputations, N(schools) 149, N(persons) 4,056, continuous variables standardized. + p<0.1, * p<0.05, ** p<0.01, *** p<0.001.

Table A3. Regression models predicting ICT skills in grade 9 and their change in grade 12, with interaction of gender and books at home.

| | Grade 9 | | Change | |
|--|-----------------|---------------|-----------------|---------------|
| | <i>B</i> | S.E. | <i>B</i> | S.E. |
| Female, ref. male | -0.12*** | [0.03] | -0.29*** | [0.03] |
| Language use, ref. (mostly) German | -0.33*** | [0.08] | -0.12* | [0.06] |
| College or university degree, ref. other | 0.10* | [0.04] | 0.02 | [0.02] |
| Number of books, std. | 0.11*** | [0.03] | 0.07** | [0.02] |
| Female × number of books | 0.06+ | [0.03] | 0.00 | [0.03] |
| Equivalence income (ln), std. | -0.02 | [0.02] | 0.02 | [0.02] |
| Grade 9 ICT skills, std. | | | 0.53*** | [0.01] |
| Constant | 0.04 | [0.03] | 0.16*** | [0.03] |
| Max. FMI | 0.25 | | 0.44 | |
| Average RVI | 0.09 | | 0.23 | |

Notes. Source: <http://dx.doi.org/10.5157/NEPS:SC4:12.0.0>. Cluster robust S.E., 30 imputations, N(schools) 149, N(persons) 4,056, continuous variables standardized. + p<0.1, * p<0.05, ** p<0.01, *** p<0.001.

Table A4. Regression models predicting ICT skills in grade 9 and their change in grade 12, with interaction of gender and language use at home.

| | Grade 9 | | Change | |
|---|-----------------|---------------|-----------------|---------------|
| | <i>B</i> | S.E. | <i>B</i> | S.E. |
| Female, ref. male | -0.11*** | [0.03] | -0.29*** | [0.03] |
| Language use, ref. (mostly) German | -0.23* | [0.11] | -0.16+ | [0.09] |
| Female × language use | -0.18 | [0.15] | 0.07 | [0.10] |
| College or university degree, ref. other | 0.10* | [0.04] | 0.02 | [0.03] |
| Number of books, std. | 0.14*** | [0.02] | 0.07*** | [0.02] |
| Equivalence income (ln), std. | -0.02 | [0.02] | 0.02 | [0.02] |
| Grade 9 ICT skills, std. | | | 0.53*** | [0.01] |
| Constant | 0.04 | [0.03] | 0.16*** | [0.03] |
| Max. FMI | 0.25 | | 0.44 | |
| Average RVI | 0.10 | | 0.24 | |

Notes. Source: <http://dx.doi.org/10.5157/NEPS:SC4:12.0.0>. Cluster robust S.E., 30 imputations, N(schools) 149, N(persons) 4,056, continuous variables standardized. + p<0.1, * p<0.05, ** p<0.01, *** p<0.001.

Figures

Figure 1. Predicted gender differences in ICT skills in grade 9 and change from grade 9-12 as a function of equivalence income (\ln), ref. males.

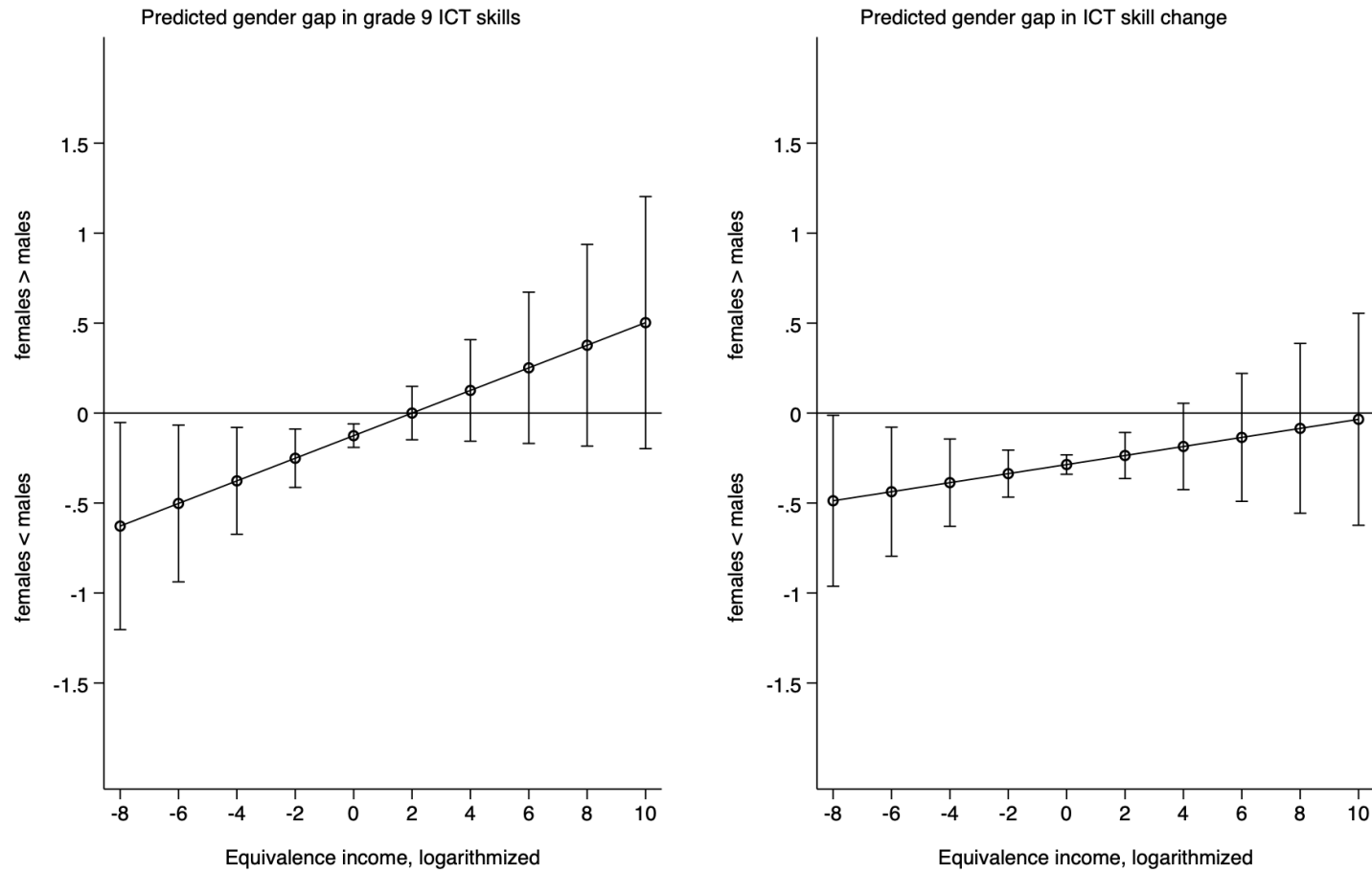


Figure 2. Predicted gender differences in ICT skills in grade 9 and change from grade 9-12 as a function of parental education, ref. males.

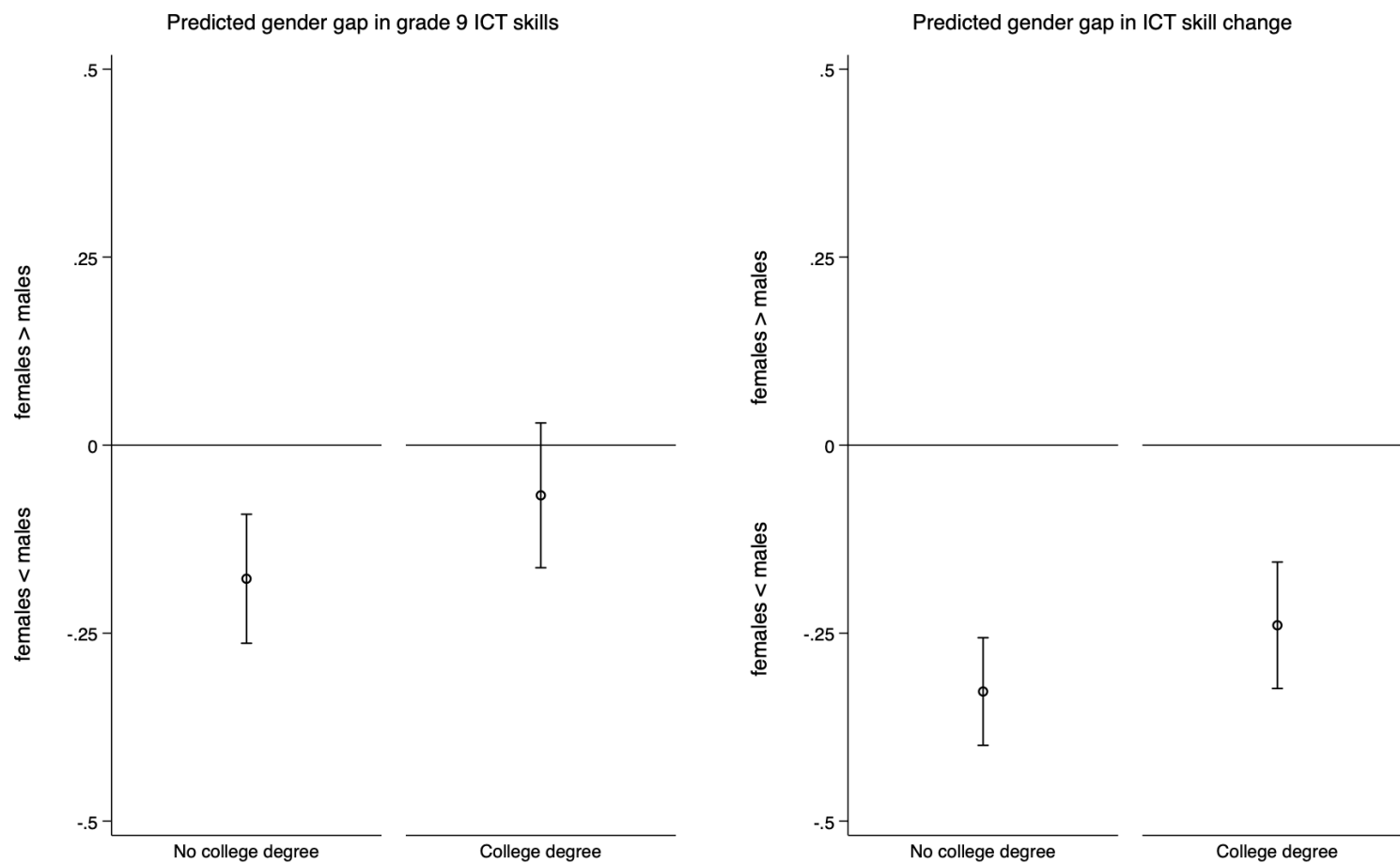


Figure 3. Predicted gender differences in ICT skills in grade 9 and change from grade 9-12 as a function of the number of books at home, ref. males.

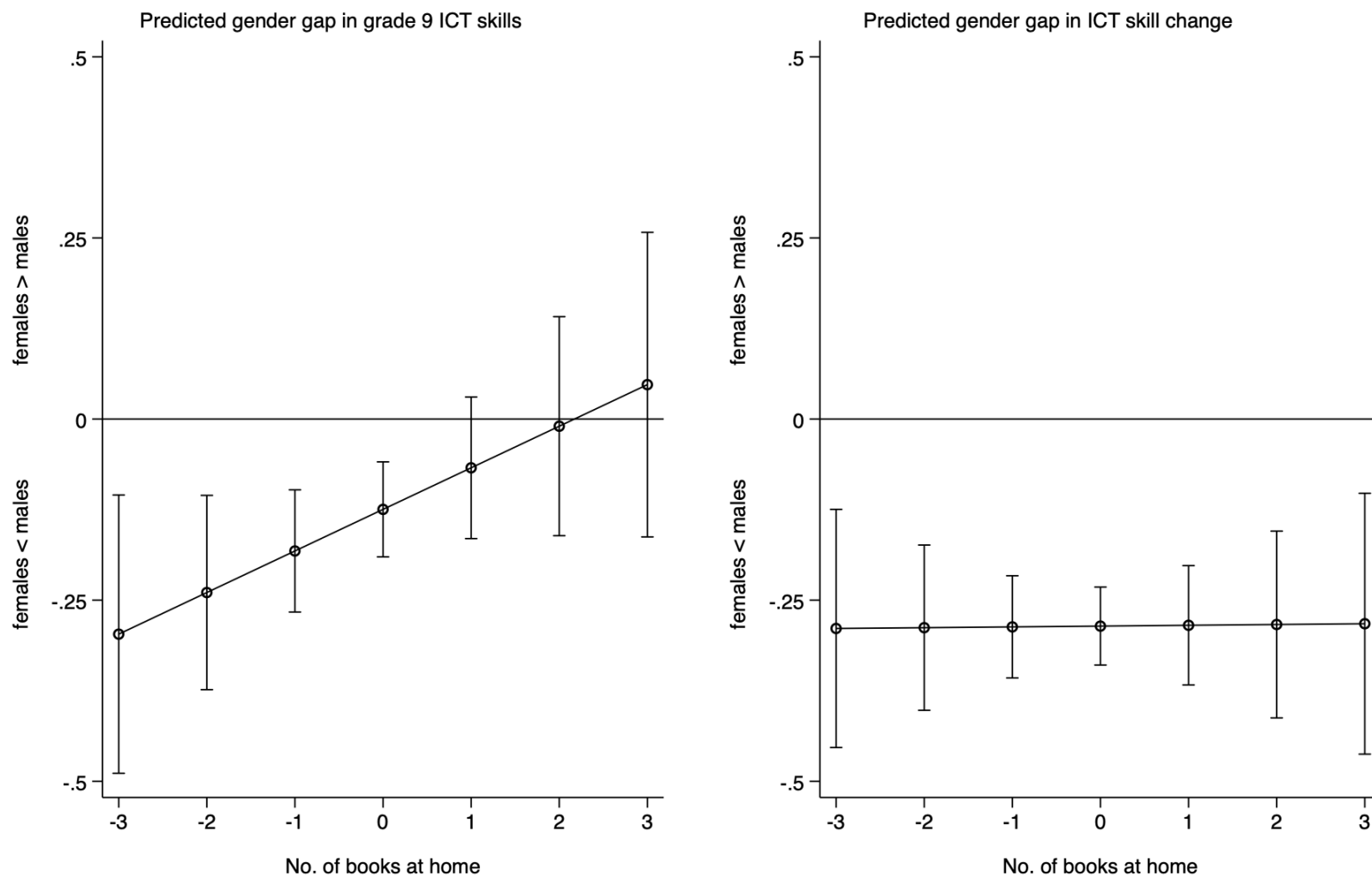


Figure 4. Predicted gender differences in ICT skills in grade 9 and change from grade 9-12 as a function of language use at home, ref. males.

