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ORIGINAL ARTICLE

Filtered Out, but Not by Skill: The Gender Gap in Pursing Mathematics at a High-Stakes Exam

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Abstract

The present paper concerns the gender gap in pursuing mathematics at high stakes matriculation exams in Poland. Results of the optional Extended Exam in Mathematics (EEM) serve as the main criterion in entering tertiary education in majority of technical and engineering majors and, therefore, the exam works as an important filter for future career paths. We investigate whether the wide, gross difference between men and women in the propensity to take EEM can be mostly explained by an underlying skill difference, school effects, or other non-cognitive factors. We also test a skill immunization hypothesis which predicts that the gender gap declines at higher levels of mathematical skill. For those purposes we use official data from the 2016 matriculation exams covering the complete cohort of a quarter of a million students in more than 5000 schools. The results show that with skill and school effects roughly held constant, women are still much less likely to take EEM and the gender gap does not narrow on the upper tail of performance in mathematics. Furthermore, higher verbal skill draws women away from pursuing mathematics more strongly than it draws away men. These combined results imply that non-cognitive factors play a key role in self-selection processes and that STEM majors are at higher risk of losing mathematically gifted women than mathematically gifted men.

Keywords Mathematics · Exit exams · Skill · Gender gap · STEM · High school · Poland · School effect

Although women constitute the majority of students in many countries, their presence in technology and engineering is relatively low (Cheryan 2012). Poland is not an exception. The share of women in universities in 2015 was 68% whereas in technical universities it was just 36%. The distribution between majors was even more unbalanced; for example, 87% of students in computer sciences were men. The critical filter for entering science, technology, engineering or mathematics (STEM) majors is mathematics (Sells 1980; Watt et al. 2017). This implies that the gender gap in STEM is at least partly a derivative of the gender gap in pursuing mathematics.

Many studies show that this gap has an attitudinal basis and cannot be entirely attributed to skill differences. Researchers link it particularly with a complex psychological syndrome consisting of lower mathematics self-esteem, worries about failure, mathematics anxiety and stereotype threat. It has been argued that those factors, at least to some extent, mediate women's avoidance of entering mathematics-oriented majors (Aschbacher et al. 2010; Catsambis 1994; Devine et al. 2012; Ellis et al. 2016; Gherasim et al. 2013; Goetz et al. 2013; Gunderson et al. 2012; Salikutluk and Heyne 2017; Wang et al. 2013). At the same time it is argued that "even small gender differences occurring at decision-making junctures can serve to carry males and females in substantially different occupational directions" (Correll 2001, p. 1725). Those junctures are therefore of special interest to research exploring the above-mentioned gap.

In our study we look at this problem by analyzing an extensive set of data from the Polish matriculation exams (or *Matura*) in mathematics administered in 2016. The *Matura* exam session consists of a series of high stakes exams. The results are crucial for the next step of a student's career.

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Successful entrance to tertiary education almost entirely depends on scores achieved in the *Matura* because no other form of evaluation is held by Polish higher education institutions. For students who are considering STEM majors, the decision to take the Extended Exam in Mathematics (EEM) is a key one. Although this particular exam in not mandatory, its results are taken into account on enrolment to STEM majors, usually as the criterion with the highest weight. As a consequence, in the Polish educational system EEM serves as a crucial filter in pursuing a career in STEM.

Our aim is to establish the relative importance of factors affecting the difference in the propensity of women and men to take the EEM. In particular, we want to measure the effects of school and skills because, by doing so, we can gain insight into the relative importance of institutional and cognitive factors. In our analysis the former is represented by inter-school variance in gender-specific propensities; the latter, by the results of the Basic Exam in Mathematics (BEM). This is another high stakes exam, which—contrary to EEM—is mandatory for all students, and hence it serves as an indicator of ability applied to a whole population immediately before EEM. The gap in propensity can be thus assessed by comparing the probability to take EEM in women and men of roughly matching skill. Such a framework can be revealing about the degree to which cognitive factors are involved in the choice of career. With ability held constant, we are also able to look into institutional factors, prominently school context and decision context (*Matura* format).

Attitudinal Factors in Pursuing Mathematics

Existing studies have broadly documented that women and men differ significantly in many attitudinal dimensions concerning mathematics. For example, findings from the PISA (Programme of International Student Assessment) study show that, among 15-year-olds, worries about mathematics failure are more prevalent among female adolescents, that they have lower mathematics self-esteem, and that they are less interested in studying mathematics-related majors (Organisation for Economic Co-operation and Development [OECD] 2014). Other studies have repeatedly reported that girls and women show higher levels of mathematics anxiety (Arens et al. 2016; Devine et al. 2012; Goetz et al. 2013; Stoet et al. 2016), stronger aversion to competitiveness in test-taking environments (Niederle and Vesterlund 2010), and a more biased perception of their own skills (Correll 2001; Pajares and Miller 1994).

Those attitudinal differences imply the relative aversion of women (as compared to men) to making mathematics-related career choices. In the last three decades, this aspect has been explored by Eccles and her colleagues in the expectancy-value model (Eccles 1984, 1994; Wang et al. 2013). According to this theory, gender-related choices are linked to a complex set of social and psychological factors. Among them two play the most important roles: one is the value attached to a given alternative (task value) and the other is the individual's expectation of success. In other words, students who are optimistic about achieving success in mathematics and ascribe high value to it are more prone to invest time and energy to take a related path. At the same time, there is rich evidence showing that girls and women attribute lower value to mathematics than boys and men do, as well as underestimate their skills (Correll 2001; OECD 2015; Watt et al. 2012). This difference is at least in part attributed to the different socialization of girls and boys, starting in early childhood (Eccles 1984; Hyde et al. 2017; van Tuijl and van der Molen 2016). Studies show that negative parental attitudes toward mathematics (Maloney et al. 2015), stereotypes held by teachers (Gunderson et al. 2012), or insufficient support of mathematical interests (Murayama et al. 2016; Weiser and Riggio 2010; Zeldin and Pajares 2000) are related to the level of women's ambitions to pursue mathematics-related subjects. Even subtle situational clues are enough to decrease interest in STEM (Pavlova et al. 2014; Stout et al. 2011).

The Impact of Mathematical Skill

An important question in the context of the gender gap in the propensity to pursue mathematics-related career choices concerns the relation between attitudinal factors and skill. A systematic approach linking cognitive and non-cognitive factors has been elaborated by Bandura (1997) in the theory of self-efficacy. The theory explains how people build self-perception, beliefs, and judgment in their own competence in various domains. Bandura lists four sources of self-efficacy: vicarious experience (signals from the social environment), social persuasion (effect of significant others on decisions), emotional arousal (emotions associated with pursuing a particular task), and mastering experiences (previous performance). The last of these sources is most fundamental for gaining a positive image of one's own competences. Students' judgments concerning their own skill depend more on interpretation of actual performance rather than on some external signals. Positive evaluation of test results is a foundation of beliefs in one's own talent, and it gives a strong incentive to repeat certain actions (especially when they have been perceived as difficult or some obstacles have been successfully overcome). Pajares (2005) has shown that those beliefs have an actual impact on decision-making and women with lower self-efficacy in mathematics are more likely to drop out of mathematics majors in college. A similar conclusion has been reached by Ellis et al. (2016) and more recently by Watt et al. (2017). Other studies suggest that after controlling for previously measured student ability, those who have faith in their own talent are more likely to choose mathematics-oriented courses (Choi 2005; Goldman and Penner 2016).

As Chang and Beilock (2016) argue, stereotypes or mathematics anxiety are likely to have a smaller impact on decisions in more skilled students. If this is the case, we can expect a decreasing effect of non-cognitive factors at higher levels of performance. The previous section implies that attitudinal factors might be more important in the mathematics-related choices of women than of men because women have to overcome more cultural obstacles. Hence, female students with high mathematical ability can be relatively more immune to negative stereotypes and biased judgments ascribed by social roles. Within our research design, this logic translates to an expectation that the gender difference in the probability of taking EEM will effectively narrow with rising skill. More specifically, we might expect that men and women at the higher levels of mathematical ability present more similar propensity to take EEM than will men and women at average or low levels of ability. Such a hypothesis is based on a supposition that higher levels of mathematical skill neutralize the effects of non-cognitive factors that interfere with the decision to take the EEM.

The recent studies, however, do not provide full backing for such a hypothesis. Results are mixed, and skill and preference are considered in varying causal orders. Wang et al. (2015) showed that women's lower aspirations to pursue careers in STEM in the United States were linked to poor mathematics scores, but performance itself was associated with the lower task value ascribed to mathematics. Guo et al. (2015), using the Hong Kong TIMSS dataset, showed that higher mathematics self-concept improved achievements in men, but was neutral in women. Preckel et al. (2008) compared average and gifted sixth grade students and showed that the impact of affective variables toward mathematics (interest, mastery goal orientation, or performance goal orientation) on test scores is uniform among female adolescents, yet among male adolescents differences significantly favored the gifted group (implying positive interaction between skill and preference). Korhonen et al. (2016) have shown that men's mathematics achievements turned out to be a more important predictor of educational aspirations, whereas for women a more important factor was an interest in mathematics. The two latter studies seem to support a competing hypothesis—that it is in male students whose skill boosts the propensity to pursue mathematics (hence the immunization effect in female students might not occur).

Skill Profiles and Choice Options

The mathematics track is usually one of many available. In every school system and at some point in an educational career, students have to choose one track, and as the literature asserts, people prefer options with a higher probability of success and higher ascribed value. Because women have, on average, relatively more negative attitudes towards mathematics, it is reasonable to assume that other tracks affect the gender gap by drawing women away from mathematics. Jonsson (1999) studied this phenomenon in the framework of comparative advantage. He showed that the absolute difference in school grades in mathematics-related subjects in Swedish youth was narrow, yet men had a much more skewed achievement profile, whereas women presented more balanced grades. The ability profile accounted for 10–30% of the gender effect. With the ability profile controlled, however, women and men still displayed gender-typical choice patterns.

More recent studies seem to confirm the comparative advantage hypothesis. Wang et al. (2013) compared the probability of choosing a STEM career by students with high mathematical and verbal abilities against those with high mathematical and average verbal abilities. The study showed that the equally skilled group had a lower probability of later pursuing a career in STEM and, at the same time, there were more women in that group. The authors concluded that the "study provides evidence that it is not lack of ability that causes females to pursue non-STEM careers, but rather the greater likelihood that females…can consider a wider range of occupations than their male peers…" (Wang et al. 2013, p. 5). We have to point out, however, that this conclusion might not be fully accurate because "there were no gender differences in math and verbal scores within these two groups" (Wang et al. 2013, p. 4), which means that with both skills held constant, a gender gap was not observed (i.e., the group x gender interaction was not statistically significant).

A similar framework was used in a study by Coyle et al. (2014), where in a sample of students who took SAT, ACT and PSAT exams, each individual had a "tilt profile" established. Tilt was defined as a difference between mathematics and verbal scores in a particular test. Students who had a mathematics tilt (higher score in math than in the verbal score) were mostly men, and they were more likely to pursue STEM majors. Moreover, the study showed that men and women with a math tilt differed significantly in preferences toward STEM: 47% of men favored it compared with just 26% of women. In general, with the mathematics tilt held constant, men presented a stronger aversion to humanities than did women. More recently, Dekhtyar et al. (2018) confirmed a similar pattern using a Swedish sample. These studies seem to support Jonsson's (1999) argument that relatively high concurrent abilities might be drawing women away from pursuing mathematics. In our study we expect that adding the results of another obligatory *Matura* exam will interact with the studied gender gap.

The Role of School Context

Another factor which is known to interact with the propensity toward mathematics-related career choices is the school context. School or classroom characteristics have been recognized as pivotal mediators of inequalities. In the context of the gap in STEM, the notion of the school effect has been applied in different ways (Bottia et al. 2015; Carrell et al. 2010). Some scholars debate whether single-gender schools favor women's aspiration to STEM compared with co-education (Doris et al. 2013; Sikora 2014). In other approaches, researchers investigate variations in the size of the gender gap between seemingly similar schools. Bessudnov and Makarov (2015) studied links between school characteristics and gender differences in test scores and showed that men performed better in schools with an advanced curriculum. Legewie and DiPrete (2012) demonstrated that the gender gap in reading decreased with average school performance and that schools differ in terms of their ability to attract students to STEM fields, which in turn contributes to an increase in the gender gap (Legewie and DiPrete 2014). They have shown that even with the attitudes of peers and teachers, as well as personal relations, held constant, the school's organizational structure and extracurricular activities impact students' aspirations and challenge presuppositions on gender roles.

Schools may differ in profiles, quality, and effectiveness of STEM teaching, and all those differences may in fact run along the feminization and masculinisation of schools (in terms of sheer gender prevalence). If schools that receive more female students turn out to be the same ones that are less effective in encouraging mathematics-related choices, then the structure of the educational system and choices preceding education in high school might in fact account for much of the gender difference in the propensity to pursue mathematics. In technical schools, students are already segregated according to occupational tracks, and therefore we can expect, for example, more men in electrical schools. The gender gap is therefore observable at the between-schools level. In the case of general high schools, there is a variety of tracks within each school, but students—even though they have different curricula—share many other contextual factors (e.g., teachers, peer groups) influencing their education. The general high schools might be, therefore, considered to offer more uniform education resulting in more equal gender-related career opportunities.

Overview of Polish Secondary Education

From 1999 to 2017 the Polish educational system comprised primary school (6 years), followed by junior high school (*Gimnazjum*; 3 years), and upper secondary schools (high schools) (Jakubowski et al. 2010). In the 2017 reform, the introduction of junior high schools was rolled back, but the data we analyze in this article (*Matura* of 2016) applies to students who followed the educational path that still included *Gimnazjum*. After *Gimnazjum* students chose between a general high school (*Liceum*), an upper vocational high school (*Technikum*), and a basic vocational school. Those three types of schools differed in several important respects. The core curriculum of *Liceum* (3 years) was designed to prepare students for tertiary education and covered a variety of humanistic, science, and foreign language subjects. In *Technikum* (4 years) curricula prepared students to enter the labor market rather than tertiary education, but in practice it became common that its graduates entered full tertiary studies at technical universities. Lower vocational schools (3 years) provided basic qualifications in mostly manual occupations (if students decided to pursue higher education, they had to be admitted to either of the two types of high schools). General high schools and upper vocational high schools offer the matriculation exam, which is not mandatory to graduate, yet necessary to enter tertiary education. A positive *Matura* score is the basic requirement for admission to higher education, and thus it is considered a high-stakes exam. The exam is taken at the end of the senior year of high school.

The procedure of Polish matriculation has certain advantages for studying gender differences according to the framework we described in the previous section. Although taking EEM is a matter of choice, since 2010 all students have had to take the BEM, along with the mandatory exam in a foreign language, and the Basic Exam in Polish (BEP) covering comprehensive reading and essay writing, thus attesting to one's verbal skills. Since 2015 they also have to take at least one (and up to five) additional extended exams (until 2015 students could choose to skip extended exams altogether). Subjects are chosen from a pool that includes mathematics, Polish, biology, computer science, physics, and history, among others. The selection of those subjects formally takes place at the beginning of the senior class, but students are allowed to change their decisions until 3 months before the exams. In the case of mathematics, exams at basic and extended levels are taken shortly one after another. The choice of mathematics for the extended exam does not depend on results achieved at BEM. On average about one third of students take the EEM. The basic exam is considered passed when a student achieves at least a 30% score, but regardless of the result, he or she is still admitted to the extended exam. However, scores in BEM and EEM (for those who sat both) are highly correlated (Spearman's rho of .86), which allows us to treat them as indicators of one latent trait (mathematics skill).

Conceptually, the EEM serves as a final filter which separates student into mathematics-related and other educational paths in higher education. It is important to note that the gender differences in mathematics performance at the previous level of education (*Gimnazjum*) have been small and nonsignificant (Grudniewska and Kondratek 2012). This might suggest that the choice of EEM to a large degree depends on the non-cognitive factors we described in the previous sections. We can assume that the decision to take the EEM is based on a mixture of actual abilities and various other factors, including perceptions of one's own abilities, mathematics self-concept, and future career plans, formulated both at present as well as in the past (in Gymnasium). The result of the BEM can serve as a gauge of the degree to which the mathematics-pursuing decision is based on actual mathematics skills because it is an independent measurement made in a high-stakes context (passing the mandatory basic mathematics exam is a more general precondition to pursuing tertiary education).

The Present Study

The theories and research we discussed here provide a comprehensive framework for understanding the importance of cognitive and non-cognitive factors in an individual's decision to invest time and energy in developing mathematics skills and pursuing a related career. Yet the precise interaction of those factors is still open to debate. There are important questions that can arise in this respect, specifically: Does the gender gap in propensity to take EEM change with level of skill? and How do institutional factors (profile of school, its curriculum) influence this propensity?

We hypothesize that higher mathematics performance effectively decreases the difference in the probability of taking EEM between genders (Hypothesis 1). More specifically, we expect to observe that men and women with higher results at BEM present more similar susceptibility to take EEM than their peers with average or low BEM scores. In other words, the gap in the probability of taking EEM should narrow when mathematics skill goes up. This narrowing pattern is expected because higher levels of mathematics ability should neutralize the effects of non-cognitive factors which interfere with the decision to take the advanced mathematics exam. We call it *skill immunization*. Some recent studies, however, imply that the opposite might be true (Guo et al. 2015; Korhonen et al. 2016; Wang et al. 2015), that is, that skill does not effectively offset non-cognitive factors. We evaluate those competing hypotheses in our statistical models.

Additionally, we aim to test the comparative advantage model (skill tilt) which states that women are less prone to choose a mathematics-related career because of relatively better performance in other subjects, especially language. Because the *Matura* involves taking the obligatory exam of verbal skills in the Polish language (BEP), we are going to check if its results influence the propensity to sit for the EEM in both women and men. We expect that higher BEP score will lower probability of choosing extended mathematics, but more so in women than in men (Hypothesis 2).

The school's effect is another important factor we need to consider, both as a control variable and as an independent variable. In the current study, we distinguish between general and technical (vocational) high schools to investigate whether the type of school modifies the propensity to take EEM. We expect a wider net difference between genders in the propensity to pursue a mathematics-oriented career in technical schools, whereas general high schools can be deemed an institutional instrument for diminishing that difference (Hypothesis 3). Such an effect might be considered valid only if it holds with the between-school variance (random effect) taken into account.

Method

To address our research questions concerning the impact of skill, school, and educational options on the gender gap in taking EEM, we utilize 2016 *Matura* Exam Data collected and stored by the Educational Research Institute (Szaleniec et al. 2015). The dataset covers the whole cohort sitting the Polish matriculation exams and comprises multiple variables, including main binary outcome: whether students decided to take the EEM. Key independent variables are test-takers' gender (261,132 students; 144,223, 55%, women) and the results of basic matriculation exams (average score on BEM was 28.0, $SD = 12.6$, range 0–50; average score on BEP was 41.6, $SD = 10.6$, range 0–70). The average score for men at BEM was 28.3 ($SD = 12.8$, range 0–50), and in case of women it was 27.8 ($SD = 12.5$, range 0–50). A result of BEM can be considered a valid measure of current mathematics skill for students deciding on taking EEM because it is a high stakes test, it involves standard high school curriculum, and its failure threshold is not negligible (Daniel et al. 2016). One point to consider would be the ceiling effect, that is, whether the sensitivity of the gauge is limited by the upper point limit. Yet, only 2.4% of all exam takers achieved 50 points, and therefore truncation is relatively small. More men ($n = 3407$) than women ($n = 2756$) reached the maximum score.

Finally, one has to take into account the school environment and all the effects involved. At the most general level, we distinguish two main types of schools: *Liceum* (with 65% of the student population) and *Technikum* (35%). Because the *Technikum* is more diverse in the offered profiles of education, we expect more variance in decisions made by its students. There is also a considerable gender imbalance in those two types of schools, with women constituting 62% of students in *Liceums* and 40% of students in *Technikums* in 2016. The school effect is not limited to differences between the two mentioned types, and this is why we need to make use of the two-level structure of data, with students nested in particular high schools. This allows for the inclusion of random effects in the statistical modeling, that is, to account for variance between particular schools. There are 3402 general high schools and 1821 technical high schools in the database (total of 5223). Mean age of test-takers was 19.7 years ($SD = 2.1$, range 16–73, $mdn = 19$).

Results

Analysis Plan

To test our hypotheses we use binary logistic models explaining variance (deviance) of propensity to take EEM (see Table 1). Models are ordered according to their nested structure, which allows us to compare relative contribution of each set of variables and to test the validity of results with incremental statistical control of relevant factors. Models 1–4 involve only fixed effects whereas Models 5–7 add random effects. Our attention is focused mainly on the gender gap represented by the Female dummy code (coded 1 for female; 0 for male) and its interactions. The basic empty Model 1 (includes only the intercept) shows average log-odds of −.94, which translates to roughly 28%, computed as: (exp(b)/(1 + exp.(b)), probability of picking extended mathematics in *Matura* exams.

Dissecting the coefficient by test-takers' gender (Model 2) produces log-odds −.44 for men and − 1.44 for women. This shows that the gross gap between the genders in choosing extended mathematics is very wide, corresponding with a probability of 39% for men and 19% for women. This difference constitutes a substantive departure point in our analyses because it indicates a gross gender gap. It might be considered spurious if there are other underlying factors producing that difference. As we already laid out, it might be that one of the genders is more prone to choose the mathematics track because of actual, underlying difference in skill. Other hypothesized explanations involve language skill and school effects, also tested here (Models 5–7). The validity of results at each step are either corroborated or questioned by subsequent ones (with more factors involved). Missing data on each of the variables in the models were filtered out listwise (no imputation), leaving 247,958 cases in the main analysis.

Skill Effects

The immediate measure of the mathematical skill is the individual result of the compulsory Basic Exam in Mathematics (variable RBEM). Not surprisingly, RBEM proves to be a very important factor in determining the probability of taking the EEM (in Model 3, deviance is reduced by almost a third). Because the relation is not strictly linear, RBEM is introduced

Table 1 Logistic models of taking the Extended Exam in Mathematics (EEM)

Model	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Fixed effects							
Constant	−.94 (.00)*	−.44 (.01)*	−1.02 (.01)*	−.98 (.01)*	−1.00 (.04)*	−1.14 (.04)*	−1.26 (.05)*
Female		−1.00 (.01)*	−1.39 (.01)*	−1.47 (.02)*	−1.01 (.04)*	−.89 (.04)*	−.93 (.05)*
RBEM			1.44 (.01)*	1.41 (.01)*	1.91 (.01)*	2.09 (.01)*	2.09 (.01)*
RBEM sq			.39 (.01)*	.36 (.01)*	.48 (.01)*	.45 (.01)*	.44 (.01)*
RBEM x Female				.06 (.02)*	.02 (.02)	.11 (.02)*	.10 (.02)*
RBEM sq. x Female				.06 (.01)*	−.05 (.02)*	−.05 (.02)*	−.04 (.02)*
RBEP						−.38 (.01)*	−.38 (.01)*
RBEP x Female						−.16 (.02)*	−.16 (.02)*
Liceum					−1.04 (.05)*	−.99 (.05)*	−.77 (.05)*
Liceum x Female					−.14 (.04)*	−.14 (.04)*	−.08 (.05)
Random effects							
Constant					1.46 (.05)*	1.49 (.05)*	
Female					.40 (.03)*	.39 (.03)*	
Liceum							.77 (.04)*
Technikum							2.58 (.13)*
Liceum x Female							.11 (.02)*
Technikum x Female							1.28 (.11)*
Model's fit							
-2*log likelihood	294,463.6	282,249.4	200,076.0	200,021.6	177,828.4	174,755.4	174,202.4
Δ-2ll		12,214.2	82,173.4	54.4	22,193.2	3073.0	553.0

Coefficients reported are log-odds (fixed part), variance (random part), and standard errors (in parentheses). Binary outcome: Student took the extended *Matura* exam in mathematics (coded 1) or did not (0)

RBEM Results of Basic Exam in Mathematics (standardized), *RBEP* Results of Basic Exam in Polish (standardized)

$n_1 = 247{,}958$ (students), $n_2 = 5223$ (schools)

*significant at the 95% CI

in parallel with a standardized metric and its squared form. As expected, both terms are highly significant. At one *SD* above the average score in RBEM, the log-odds of taking the EEM rise by 1.8; at 2 *SD*s, it is 4.4. Computing this for unstandardized metrics (i.e., exam points) shows that for students who achieved, say, 40 points in the BEM (12 points above the mean), the odds of taking the EEM rise about 5 times, which corresponds to going from 27 to 64% probability. For the total score (ceiling) of 50 points, it is as much as 91%.

With the RBEM effect roughly controlled, the difference between genders actually rises to −1.39 (Model 3), that is, female students with average RBEM scores are more than 3 times less prone than their male peers to choose mathematics (8% vs. 27%). This means that we observe the opposite of what we described earlier—the gap in pursuing mathematics is not explained by the difference in performance; in fact, it is concealed by it. We observe very different decision thresholds in taking the EEM for men and women (see Fig. 1).

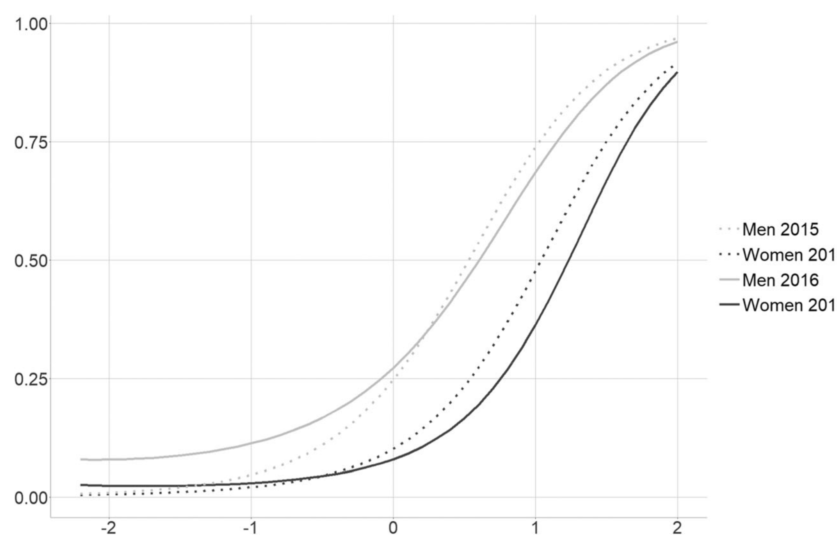
As Hypothesis 1 states, we expect the recorded magnitude of the difference between men and women to be wider at low levels of RBEM and close at higher levels. To explore this possibility, interaction terms between gender and skill have to be taken into account. Model 4 provides separate coefficients for effects in men and in women. It turns out that gender-specific effects are unexpectedly low. What is more, the skill immunization effect (i.e., narrowing gap at higher performance levels) disappears altogether when the school effects are introduced into the model (Model 5). A negative sign for the interaction between gender and squared RBEM means that among students with the highest scores, the gender difference in the propensity to take the EEM is even marginally higher.

Those results seem robust because they are supported by data on *Matura* results from previous years. We have conducted separate analyses (reported in the online supplement) which show that modelling the data from 2014 and 2015 exams produces gender gap coefficients ("Female") very close to this of 2016, while the interaction displays a pattern of random change around zero, further implying the substantive insignificance of the immunization effect. Those outcomes are largely coherent despite changes in the administration of *Matura* (up until 2015 extended exams were not obligatory). It suggests that main gender-related decision patterns hold across cohorts, tests, and rules governing the choice of extended exams.

We illustrate the net gender gap by plotting expected probabilities drawn from the analysis (see Fig. 1). For 2015 only, the new exam track was taken into account (for better comparability with 2016). Despite minor differences, the contrast between men and women is evident and stable. Whereas men cross the threshold of 50% probability at about 36 points (+.6 *SD*), for women, it is closer to 42 points (+1.2 *SD*). This means that for female students to exhibit the same level of readiness to pursue extended mathematics as their male counterparts, they need to present on average 15–20% higher mathematical performance in the standard curriculum (BEM score).

Additional light on the propensity to pursue extended mathematics is shed by adding the results of another obligatory *Matura* exam. As proposed in the Hypothesis 2, people can be drawn to alternative options by their other skills. To test this possibility, we used the results of another obligatory *Matura* exam (Basic Exam in Polish or BEP), which can serve as a proxy measure of verbal skills. As Model 6 shows, there is a negative correlation between the results of BEP and the probability to sit the EEM, with other factors (prominently mathematical performance) controlled. Both men and women are less prone to sit the EEM when they achieve better results at BEP. However, women are drawn away from mathematics by their Polish language abilities much more strongly than men are (coefficient of −.54 vs. −.38). A comparison of coefficients between Models 5 and 6 clearly shows that in explaining the gender gap at the EEM, the "drawing away"

Fig. 1 Predicted probabilities for men and women of taking Extended Exam in Mathematics (EEM) in 2015 and 2016 by standardized results of Basic Exam in Mathematics (BEM)



effect connected with verbal skills is much more evident than the effect connected with skill in the standard mathematical curriculum.

School Effects

Model 5 includes both the fixed effect of general secondary schools (*Liceum*), separately for men and women, and the random effects, that is, those connected with particular schools. Because many technical schools (*Technikum*) offer educational tracks involving extended mathematics courses, the odds in general schools are on average much lower. There are relatively smaller groups of students who are interested in pursuing further technical education. In the case of female students, this difference is even larger. The variation in individual decisions concerning the extended mathematics exam is also contingent on a specific school context. The variance of the intercept is 1.46, relatively high compared to the constant term. All in all, the addition of school effects (fixed and random) gives a substantial boost to the model's fit, further reducing the deviance by 11%.

It is worth noting that when the unique effect of each school is taken into account, the ability premium becomes substantially more pronounced. Apparently, there are particular schools that draw students away from extended mathematics regardless of their skill. General high schools, on average, fall into this category, while at the same time they widen the gender gap. In the light of this result, it would be invalid to argue that *Liceum* offers more gender-masked education, at least in terms of producing homogenous mathematics-pursuing incentives (no matter whether by means of substantial encouragement, lack of attractive alternatives, or merely by the specific selection of pupils). Thus Hypothesis 3 was not confirmed.

As we can see, the between-school standard deviation for the gender effect is .39, so for the large majority of schools the coefficient representing the gap (i.e., dummy variable 'Female") is negative. Decomposing the variance further by the type of school (Model 7) shows, as expected, that there is much more variance in decisions concerning extended mathematics in *Technikums* than in *Liceums*. What is important is that it makes the average difference between those types of schools substantially less pronounced for men, while at the same time renders the adverse effect of *Liceum* on pursuing mathematics by women insignificant. Variance computed separately for the interactions between type of school and genders proves to be high, especially for *Technikums*. Because they offer occupationally profiled education, the result implies that it is certain vocational tracks that widen or narrow the gender gap in making mathematics-related career choices. It is those tracks that account for much of the variance in the propensity to pursue the EEM.

Discussion

We have analyzed the gender gap in the probability of taking the Extended Exam in Mathematics (EEM), which in the Polish educational system stands as an important filter for STEM majors. As it turned out, with the statistical control of mathematical skill—as measured by the results of the concurrent high stakes test (BEM)—the average difference between women and men became even more pronounced, signifying that the gap in pursuing mathematics is not a simple derivative of the skill gap. Contrary to what we hypothesized (Hypothesis 1), the interaction of skill and gender proved to be negligible when school effects are taken into account. The difference between men and women in the propensity to take the EEM does not diminish with rising level of ability. This finding is robust because it is confirmed by the results of *Matura* exams from 2014 and 2015. Although the expected immunization effect in women did not occur, there was a significant, negative interaction between gender and results of the Polish language exam testing verbal skills. It shows that women are substantially more strongly "pulled away" from taking the EEM by their verbal abilities than men are (Hypothesis 2). Evidently, there is no uniform comparative advantage effect in men and women (see Jonsson 1999), and with the ability profile held constant, men are still much more likely to pursue mathematics (see Coyle et al. 2015).

Hypothesis 3 (concerning school effects) was not confirmed as well: General high schools do *not* diminish the gender gap. In fact, *Liceums* put a slight "penalty" on women's propensity to sit EEM, although it becomes insignificant with decomposition of variance between types of schools. The between-school variance is relatively larger in *Technikums*, which indicates that occupational tracks are instrumental in keeping women in mathematics-related educational paths.

Perhaps the most striking result is that the net gender difference in the propensity to choose the EEM—that is, with mathematical skills, verbal skills, and school effects held constant—roughly equals the gross gender difference (−1.00 vs. −.96). None of the three factors explains why the propensity of men and women differ that substantially, making way for alternative explanations—mostly in terms of cultural and attitudinal causes.

Limitations and Future Research Directions

Our study was based on data covering the full cohort taking high stakes matriculation exams, yet it has certain limitations, and further studies are required to corroborate its general conclusions. The key limitation is a lack of attitudinal variables which could ascertain that non-cognitive factors are indeed the *tertium quid*. Future analyses should also incorporate information on the subject tracks that each student followed in high school because there is variety offered in both *Liceums* and

Technikums. The official *Matura* results do not cover such data, whereas its addition would allow us to further attribute the variance (deviance) and allow us to look below the school level in more detail. It is possible that decisions on taking the EEM and to further pursue STEM majors are contingent on decisions made at the end of primary and at the start of secondary education. Following the availability and actual choice of subject tracks at each educational threshold could show how the actual options for tertiary education gradually narrow down. *Matura* is simply the final threshold (or filter) before tertiary education. Finally, without analyses involving comparable design made in other countries, it is hard to reliably argue whether Polish results are typical or distinctive.

Practice Implications

The underrepresentation of women in many technical and engineering majors in Poland might be attributed, at least in part, to their relative aversion to pursuing extended mathematics in matriculation exams. EEM scores are crucial for entering STEM in Poland because they are taken into account during admittance to most STEM majors. For example, it has the highest weight in the admission algorithm for all but one major at the Warsaw University of Technology, a leading Polish technical university.

The institutional design of the Polish educational system creates two crucial self-selection moments for pursuing STEM at tertiary level—at the entrance to high school and at *Matura*. In the first case, choosing an occupationally profiled track (*Technikum*) in large part determines subsequent choices because the core curriculum is focused on upgrading certain vocational skills. *Liceum* is usually perceived as the school leaving the future career choice more open. However, our study shows that women are significantly more strongly pulled away to other options by their verbal abilities such that the higher availability of options in fact creates more opportunities to defect. Because women constitute the majority of students in *Liceums*, where a relatively broad choices of humanities and social science subjects are offered, they are effectively diverted from choosing mathematics-oriented tracks.

Our study implies that the sheer structure of the system of education is an important factor in self-selection mechanisms. Some recent changes in the organization of *Liceums* may considerably change these situations because many schools have now established engineering profiles. It might reshape the structure of actual options concerning career paths and lower the probability that women are already lost to STEM-related education already at the entrance to secondary education.

Conclusions

Our study showed that the gender gap in pursuing mathematics is not founded on the underlying difference in standard-curriculum mathematical skill. This means that the relatively low probability of women entering engineering and technology majors has to be explained mostly in terms of non-cognitive and institutional causes. In our study, the latter were recorded directly as the variance explained by school effects. We also showed that women are being diverted from mathematics-related careers by relatively low probability of failure in alternative tracks (as shown by the negative correlation with verbal abilities). The interpretation of our results can, therefore, be regarded both in terms of "negative choice" concerning mathematics and in terms of "positive choice" concerning other fields. In any case, STEM majors are more likely to be losing mathematically-gifted women than mathematically-gifted men.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Human Participants and/or Animals The research did not involve Human Participants or Animals. Only official and publically available data was analyzed.

Informed Consent The study did not require informed consent.

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