The gender gap in mathematics self-assessment: evidence from twins

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Introduction

- Across a range of countries, contexts, and domains, men have been found to exhibit higher degrees of confidence in their ability than women (Briel et al. 2021; Reuben, Sapienza, and Zingales 2015).

- Especially true for STEM subjects and mathematics
  - Not only do girls assess their mathematics ability lower than boys, but this contributes to later gender gaps in math performance (Bharadwaj et al. 2016).

  - The confidence gap also contributes to the gender pay gap within STEM jobs (Sterling et al. 2020)

- The gender gap in math performance has received much scholarly attention
  - It emerges in school: zero when kids enter school, gradually grows (Fryer and Levitt 2010; Penner and Paret 2008) and stays relatively small on avg (0.05-0.11 SD) throughout high school (Kahn and Ginther 2017)

  - Cultural beliefs and gender (in)equality plays a large role (Nollenberger et al. 2016) in math performance, as well as preferences about competition (Niederle and Vesterlund 2010) and math anxiety (Zhang et al. 2019)

Self-assessed math ability (SAMA) and gender

- We know much less about why the gender gap in self-assessed math ability (SAMA) emerges
  - Students' attitudes toward mathematics are influenced substantially by their parents' perceptions of the difficulty and usefulness of math (Eccles and Jacob 1986)
  - Learning environment matters (Quinn, 2021): clarity of assessment criteria, teacher support, students involvement
  - Women assess their abilities below men's because of stereotyped gender identities, "stereotype threat" (Steele and Aronson 1995).

Our contribution to the literature

- First, we show that the gender gap in SAMA persists even after controlling for math grades given by teachers, math test scores, measures of verbal and non-verbal cognitive abilities, birth order, birth weight and twin fixed effects, i.e. shared genetic and environmental background. Objective skills only explain 14-26% of the gender gap in SAMA.

- Second, we show that the gender gap in SAMA is even higher among opposite-sex twins than among non-related boys and girls.

- Third, we test three potential channels
  - parental assessments (explains a further 23% of the gender gap)
  - gender roles in the home (no effect)
  - within-twin peer effects (no effect)

Data

- We use data on twins born in the UK from the Twins Early Development Study (TEDS) (Rimfeld at al. 1998)
- Born in 1994-1996 in England and Wales
- TEDS collects rich longitudinal information on cognitive and non-cognitive skills, parental background and educational outcomes.
- Using data of twins allows us to control for shared genetic and parental backgrounds of boys and girls.
- Twin samples are not representative of the population, which might hinder the external validity of our results.
- (Usual problems: attrition, non-response)
- Our estimation sample includes those who have non-missing data for the variables we use at age 9 (4,309) and age 12 (3,923) (overlap: 899 obs)

Self-assessed math abilities

- Three survey questions taken at age 9 and 12. How good you think you are at
  - solving number and money problems.
  - doing Maths in your head.
  - multiplying and dividing.

- There are five ordinal answers to each: very good; quite good; doing OK; not so good; not good at all, coded from 1 to 5. The average of the three answers is provided in the data.

- Age 9: parental and teachers' assessment

- Math liking scale ("How much do you like...")

Objective math abilities

- Math levels. Teachers provided evaluations of students at age 9 and 12 according to National Curriculum levels (1 to 5) for three aspects of math: using and applying mathematics; number and algebra; shapes, space and Measures. Thus, the overall score goes from 3 to 15 and its standardized value is provided in the data.

- Math test scores. At age 12, study members also completed an Internet-based math test.

Control variables and potential channels

- Cognitive abilities: verbal skills and non-verbal cognitive skills at age 9 and 12.
- Whether individual i is the elder twin; whether individual i was born with higher weight; birth weight in grams.
- Having a male co-twin
- Having not-twin brothers, sisters
- Highest parental education in four categories
- Twin peer effects: whether individual had higher math level than their twin
- Measures of gender roles in the home: (1) whether mother worked in managerial position; (2) whether mother needed special qualification for her job; (3) whether mother had A-levels or above.

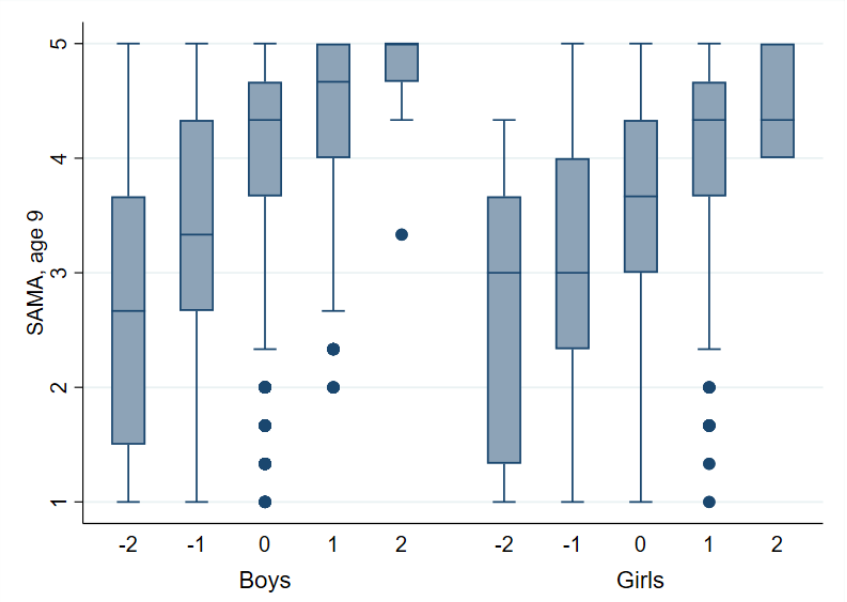
Descriptive, age 9 Descriptive, age 12

Empirical methods

- OLS regressions
  $sama_{i,j} = \alpha + \beta_{OLS} * female_{i,j} + \beta * X_{i,j} + \nu_i + u_{i,j}$, where
  i represents twin pairs
  j stands for the individual within a twin pair
  $female_{i,j}$ captures whether individual i is female
  $X_{i,j}$ is a matrix of control variables
  $u_{i,j}$ is the usual error term, robust and clustered within twins.

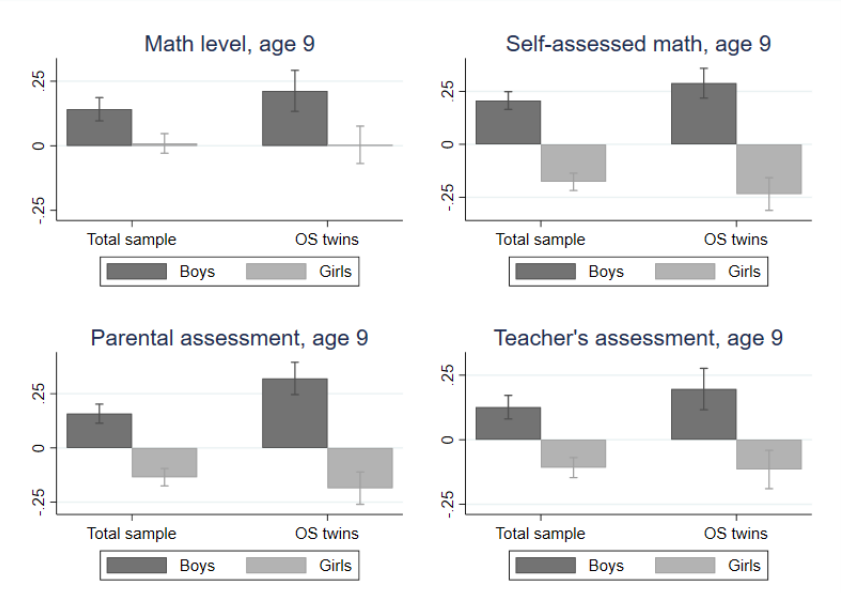
- Twin FE models
  $sama_{i,j} = \alpha + \beta_{FE} * female_{i,j} + \beta * X_{i,j} + \nu_i + u_{i,j}$, where
  ν_i is the twin-pair fixed effect.

The distribution of SAMA over math levels (age 9)

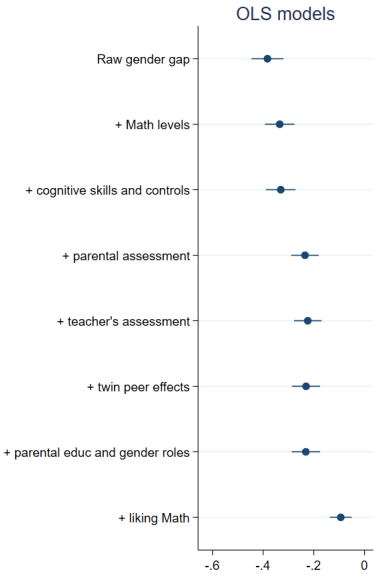


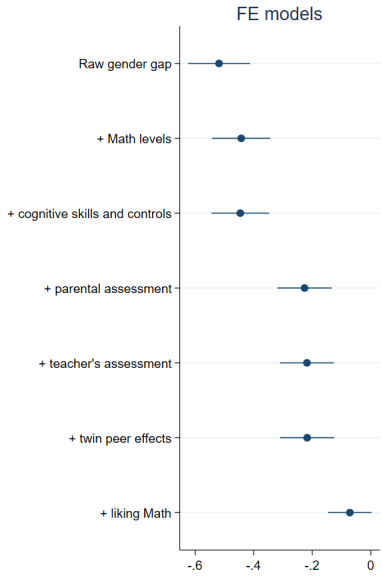
Age 12

The gender gap in Math (standardized measures)



Estimation results (age 9)





Age 12

Conclusions and discussion

- We find that objective skills only explain 14-26% of the gender gap in SAMA.
- Parental assessments (conditional on objective skills) explain a further 23%
- We do not find evidence for the role of gender roles or peer effects
- Interestingly, parental education does not raise SAMA Math outcomes and parental education
- The gender gap in SAMA is even larger among opposite sex twins than among non-related boys and girls (Potential explanation: in-utero testosterone exposure (Gielen and Zwiers 2018). But, the gender in parental assessment is also larger...)

How to go on?

- We need to understand more what we are measuring exactly with parental assessment and liking math
- Handling non-response and attrition
- Thinking about how to capture gender roles in the home better (proxy for preference for boys: firstborn is a girl a la Dossi et al 2019)
- To try female*parental assessment interactions - parental assessment might matter for girls more (Hildebrand et al 2022)
- To try female*math level interactions - objective skills might matter less for girls (Cho 2017)

Thanks for your attention!

Appendix

Descriptive statistics, age 9

	Mean	SD	Min	Max	N
SAMA, age 9	3.83	0.99	1.00	5.00	4,309
SAMA, age 9, std	0.00	1.00	-2.84	1.18	4,309
Math level, age 9	0.07	0.98	-2.94	2.99	4,309
Verbal abilities, age 9	0.05	0.97	-3.54	2.61	4,309
Non-verbal abilities, age 9	0.05	0.97	-3.72	1.39	4,309
Parental assessment of Math	3.93	0.93	1.00	5.00	4,309
Parental assessment of Math, std	0.00	1.00	-3.14	1.14	4,309
Teachers' assessment of Math	3.36	0.83	1.00	5.00	4,309
Teachers' assessment of Math, std	0.00	1.00	-2.83	1.97	4,309
Better at Math than twin, age 9	0.23	0.42	0.00	1.00	4,309
Maths liking scale, age 9	3.52	1.16	1.00	5.00	4,287
Likes math, age 9, std	-0.00	1.00	-2.16	1.27	4,287
Heavier twin at birth	0.47	0.50	0.00	1.00	4,309
Elder twin	0.50	0.50	0.00	1.00	4,309
Birthweight, gramms	2,539.45	552.29	595.88	6,320.00	4,309
Female	0.54	0.50	0.00	1.00	4,309
Has a male twin	0.47	0.50	0.00	1.00	4,309
Has brother	0.32	0.47	0.00	1.00	4,309
Has sister	0.29	0.45	0.00	1.00	4,309
Female*male twin	0.16	0.36	0.00	1.00	4,309
Mother has A-levels or above	0.42	0.49	0.00	1.00	4,309
Mother has managerial job	0.11	0.31	0.00	1.00	4,309
Mother needs qualification	0.25	0.43	0.00	1.00	4,309
No qual or low-grade CSE/GCSE	0.11	0.31	0.00	1.00	4,292
High-grade CSE/GCSE	0.31	0.46	0.00	1.00	4,292
A-level or below degree	0.28	0.45	0.00	1.00	4,292
Degree	0.30	0.46	0.00	1.00	4,292

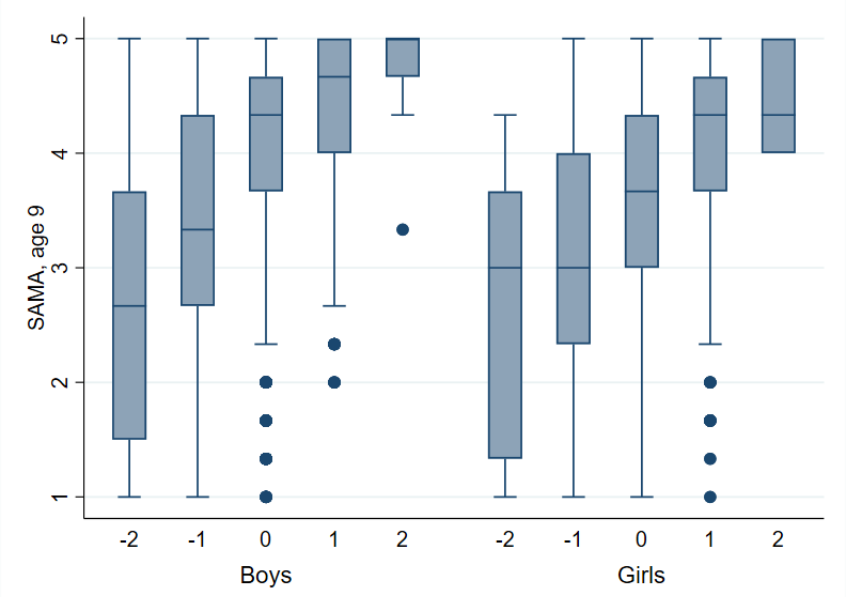
Back

Descriptive statistics, age 12

	Mean	SD	Min	Max	N
SAMA, age 12	3.89	0.89	1.00	5.00	3,923
SAMA, age 12, std	-0.00	1.00	-3.24	1.24	3,923
Math level, age 12	0.09	0.97	-3.36	4.62	3,923
Verbal abilities, age 12	0.00	1.00	-3.20	2.58	3,923
Non-verbal abilities, age 12	-0.04	1.00	-3.87	3.06	3,923
Math test scores, age 12	68.39	13.49	12.25	94.00	3,923
Math test scores, age 12, std	-0.00	1.00	-4.16	1.90	3,923
Better at Math than twin, age 12	0.23	0.42	0.00	1.00	3,923
Maths liking scale, age 12	3.40	1.03	1.00	5.00	3,922
Likes math, age 12, std	-0.00	1.00	-2.33	1.55	3,922
Heavier twin at birth	0.47	0.50	0.00	1.00	3,923
Elder twin	0.50	0.50	0.00	1.00	3,923
Birthweight, gramms	2,516.62	531.52	595.88	5,900.00	3,923
Female	0.57	0.50	0.00	1.00	3,923
Has a male twin	0.44	0.50	0.00	1.00	3,923
Has brother	0.29	0.46	0.00	1.00	3,923
Has sister	0.29	0.45	0.00	1.00	3,923
Female*male twin	0.15	0.35	0.00	1.00	3,923
Mother has A-levels or above	0.48	0.50	0.00	1.00	3,923
Mother has managerial job	0.11	0.31	0.00	1.00	3,923
Mother needs qualification	0.25	0.43	0.00	1.00	3,923
No qual or low-grade CSE/GCSE	0.08	0.28	0.00	1.00	3,917
High-grade CSE/GCSE	0.27	0.44	0.00	1.00	3,917
A-level or below degree	0.29	0.46	0.00	1.00	3,917
Degree	0.35	0.48	0.00	1.00	3,917

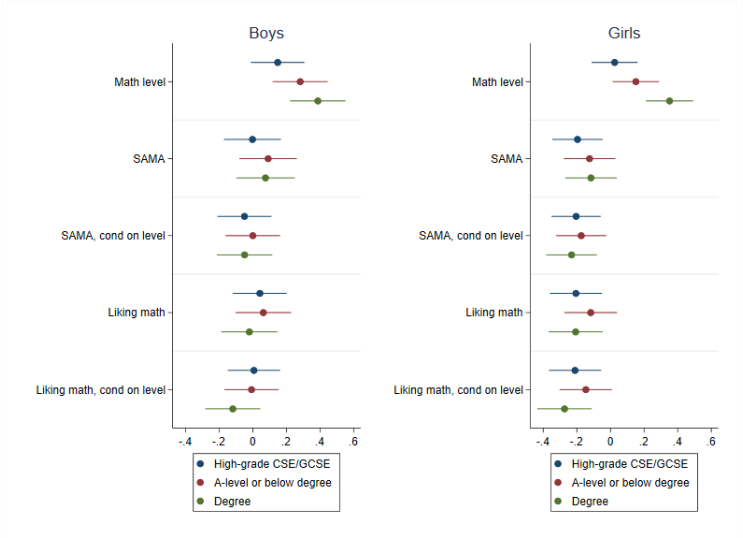
Back

The distribution of SAMA over math levels (age 12)



Age 9

The role of parental education in Math outcomes, age 9



Back

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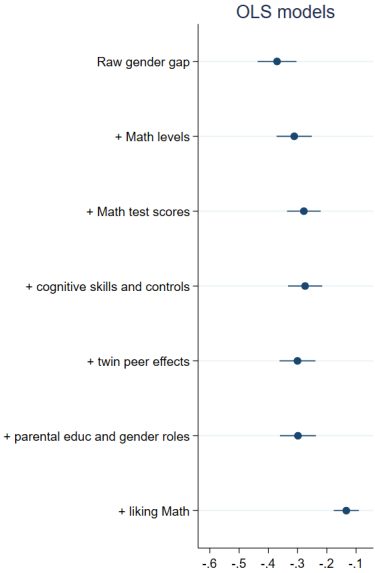

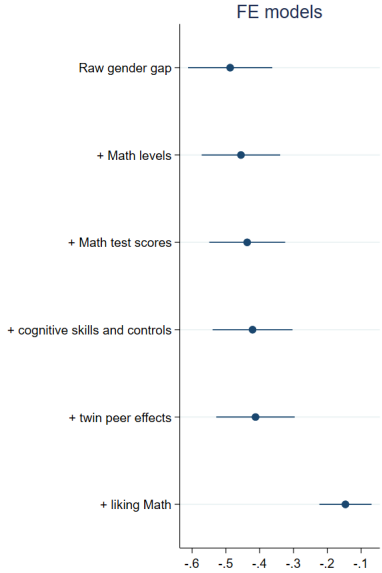

Age 9