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Gender and socioeconomic dimensions of relative age effects on ADHD prescriptions: Evidence from Denmark ☆

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ABSTRACT

This paper examines the impact of relative age on Attention Deficit Hyperactivity Disorder (ADHD) prescriptions among school-aged children. Using a regression discontinuity design, we leverage the quasi-experimental variation in school starting age. We use administrative data for all children aged 6–16 from 2010 to 2019 in Denmark. We find a significant decrease in ADHD prescription rates for girls who are relatively old compared to their class mates. We do not find any significant results for boys. We further test the social gradient in relative age on ADHD prescriptions and find that the effect is entirely driven by girls from low income families.

1. Introduction

In this paper, we ask, does relative age within grades affect the ADHD prescription rates for children in Danish schools? The aim is to obtain an indication of the degree of misdiagnosis of children who are mainly just relatively less mature than their classmates. To answer this, we exploit the exogenous variation in school starting age induced by Danish law. In Denmark, children should start school in the calendar year they turn six years old. Thus, children born on December 31 should enter school a full year earlier than children born one day later, on January 1. Consequently, the former will be the youngest in their class, while the latter will be the oldest, despite being born one day apart.

Thus, if relative age within class affects ADHD, we would expect a discontinuity in ADHD around January 1. To estimate this, we use a regression discontinuity (RD) design. Furthermore, to examine whether the relative age effect is heterogeneous across income groups, we run these estimations based on whether the parent's income is above the median or not.

We use Danish administrative data for all children between 6 and 16 years old from 2010 to 2019. Our dataset can identify various prescription purchases at the individual level, including all the typical medications used for ADHD. Furthermore, we can add socio-economic factors for both children and parents.

We find a noticeable decrease in ADHD prescription rates at the cut-off, with statistical significance evident only among girls. Specifically for girls, we estimate that being born one day later than December 31 results in the share of ADHD prescription rates dropping by 0.33 percentage points from a level of around 1.1%.

Given the strong genetic component of ADHD, we would have expected stable prescription rates over birth dates. However, as younger students are relatively less mature compared to their classmates, they are more likely to be diagnosed with ADHD. Therefore, the observed drop could be attributed to changes in relative age, and can thus be interpreted as misdiagnosis.

We study the effect by socio-economic family background and find that the discontinuity stems for girls with low-income parents. This could suggest that parents from the high-income group might be better at offsetting the effect of being relative young in a class.

Previous studies have found evidence of relative age affecting ADHD in many western countries, such as the US and Germany, see Elder (2010) and Schwandt and Wuppermann (2016). However, for Denmark, previous studies have found no evidence, see Dalsgaard et al. (2012) and Pottegård et al. (2014). Some reasons could be that they do not separate genders in their research, have fewer observations or use diagnoses instead of prescriptions. Evidence from Schwandt and Wuppermann (2016) suggests that the latter is not the case, as they find a larger share of misdiagnoses when ADHD is based on a diagnosis rather than a prescription. The difference might also be driven by the simple fact that our data is more recent. The last year of observation was 2010 and 2012 for Dalsgaard et al. (2012) and Pottegård et al. (2014), respectively. This would indicate that the degree of misdiagnosis has increased over time in Denmark, as our latest year of observation is 2019. Furthermore, as far as we are aware, no study has explored the income heterogeneity regarding how relative age affects ADHD.

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2. Method

We follow the approach of Dalsgaard et al. (2012). We estimate the following reduced form of a fuzzy RD design:

$$ADHD_{it} = \alpha_1 I(days_i \geq 0) + f(days_i) + \gamma X_{it} + u_{it}. \quad (1)$$

$ADHD_{it}$ is 1 if individual i has a prescription for ADHD medicine at time t. $days_i$ is the difference in days between birth date and the cutoff. For instance, if $days_i$ is equal to $-1, 0$ or 1, then that individual was born on December 31, January 1 or January 2. We will only consider those children who are born within 100 days of January 1. The function $f(\cdot)$ is a polynomial fit of second degree, separately on either side of the cutoff.[1] This allows the use of ADHD medication to depend on time of birth. X_{it} is a vector of observable characteristics and includes the parents' personal income, the child's home region, type of household, and ancestry. The coefficient of interest, α_1, estimates the discontinuity in ADHD prescription rates at the cutoff.

To interpret estimates of α_1 as misdiagnosis, we rely on the identifying assumption that individuals near the cutoff should have the same overall characteristics, both observable and unobservable. In relation to our design, we have to assume that people born close to the cutoff, e.g., December 31, should have an equal likelihood of receiving an ADHD prescription as those born the following day, e.g., January 1.

3. Data

The population of our analysis is all Danish children aged 6–16 from 2010 to 2019. Our choice of population includes some individuals not in school and excludes some individual still in school. We argue, that this is a rather small part of our population, and thus is necessary to keep a simplified population for our analysis.

We combine several Danish population wide registers to create our dataset. The following itemization shows the title for each registry and what they have been used for:

- The Danish National Population Registry is used most importantly to determine the date of birth and gender. It contains further information on what household type the child lives in, e.g., with a single woman or a married couple, what geographical region they live in, and their ancestry, e.g., immigrant or descendant of an immigrant. Moreover, it is used to identify the children's parents.
- The Income Statistic is used to determine the parents' yearly taxable income.
- The Danish National Prescription Registry is used to determine whether an individual was prescribed any ADHD medicine.

Our definition of ADHD medicine follows a recent analysis made by Statistics Denmark (2023).[2] Thus, our definition does not take into consideration how many prescriptions a given individual has used or how much of the active drug is prescribed.

4. Results

In this section we present our results. We start with a graphical presentation of the estimation of Eq. (1) for girls and boys. Then, we present the table containing the results of estimating Eq. (1). Lastly, we split our estimated results for girls based on parental income.

Fig. 1 presents a graphical illustration of the estimation of (1) for boys and girls. The horizontal axis marks the running variable, $days_i$, ± 100 days around the cutoff, such that $days_i$ equals zero for people born on January 1. The vertical axis marks the ADHD prescription rate. We plot the mean ADHD prescription rate by five-day intervals of $days_i$. The vertical red line marks the cutoff, while the orange and green lines are the polynomial fits, $f(days_i)$, on each side of the cutoff. $\hat{\alpha}_1$ correspond exactly to the vertical distance between the two polynomial fits at the cutoff.

Table 1
Regression results by gender.

	(1) Males	(2) Females	(3) Males	(4) Females
$\hat{\alpha}_1$	−0.0015	−0.0033**	−0.0007	−0.0029**
	(0.0020)	(0.0011)	(0.0018)	(0.0010)
Constant	0.0287***	0.0106***	0.0447***	0.0160***
	(0.0015)	(0.0008)	(0.0018)	(0.0009)
2nd degree polynomial fit	X	X	X	X
Covariates, X_{it}			X	X
Observations	1 579 596	1 504 509	1 579 596	1504509

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. The dependent variable is $ADHD_{it}$. The columns are estimations of Eq. (1) for boys and girls, where $f(days_i)$ is defined as a 2nd degree polynomial. Standard errors (in parenthesis) are clustered at the days level.

From Fig. 1, we can see that there is a clear difference in levels of prescription rates on each side of the cutoff for both genders. We can see that for boys born before the cutoff, approximately 3% are prescribed ADHD medicine, whereas the overall level drops to 2.5–2.6% after the cutoff. For girls the level drops from around 1.1% to 0.8% after the cutoff. Hence, the jump in ADHD prescriptions at the cutoff is more distinct for girls than for boys.

Table 1 presents the underlying estimations for the plot. Columns (1) and (2) are for boys and girls, respectively. Columns (3) and (4) are similar, but also include covariates given by X_{it}. The covariates are parents' personal income and dummies for the child's home region, household type and ancestry. We see a drop in ADHD prescription rates at the cutoff for both genders. More specifically, in columns (1) and (2), we estimate α as −0.0015 for boys and −0.0033 for girls. Our estimates are only significant for girls. In other words, when we compare girls born on December 31 with those born on January 1, we see a decrease in the ADHD prescription rate of 0.33%-points. The introduction of the covariates in columns (3) and (4) slightly reduces the estimated discontinuity to −0.07%-points and −0.29%-points for boys and girls, respectively. The estimates are still only significant for girls after the introduction of covariates.

In Table 3 (see Appendix), we repeat the estimation for girls, but for the subperiods 2010–2014 and 2015–2019. The estimates are −0.0032 for 2010–2014 and −0.0033 for 2015–2019, which indicate that the effect is fairly constant over the entire period, 2010–2019.

The reason why we only get significant results for girls might be that a larger share of girls enter school the year they turn 6. The more compliers, the higher is the change in relative age within grades at the cutoff, and the more likely it is that we find a discontinuity in ADHD. Fig. 2 (see Appendix) shows school starting age of our population from 2010 to 2013 by gender. We observe that the jump at the cutoff is larger for girls than for boys. For boys there is an average jump of just below 0.2 years, while for girls it is just above 0.2 years.

It should be noted that our definition of school starting age is biased, as it is based on the time that the children graduated 6th grade. Thus, for children who retook a grade prior to 6th grade, our school starting age variable would be higher than the true value. A recent report from the Ministry of Children and Education (2022) finds that around 2.5% were retakers in 0th grade in 2019. Thus, we will consider this bias to be negligible.

Fig. 3 (see Appendix) shows the ADHD rate by age and gender for children in school from 2010 to 2019. Evidently, there are signs of discontinuities for boys, starting already at age 7. However, the pattern is far less consistent across the full age span compared to that of girls, and there are no visible discontinuities at the cutoffs after age 11.

[1] A 2nd degree polynomial fit is:
$f(days_i) = \phi_0 + \phi_1 days_i + \phi_2 days_i^2 + \phi_3[days_i \cdot I(days_i \geq 0)] + \phi_4[days_i^2 \cdot I(days_i \geq 0)]$.

[2] Statistics Denmark base their definition of ADHD medicine on the following 5 ATC-codes: C02AC02, N06BA02, N06BA04, N06BA09 and N06BA12.

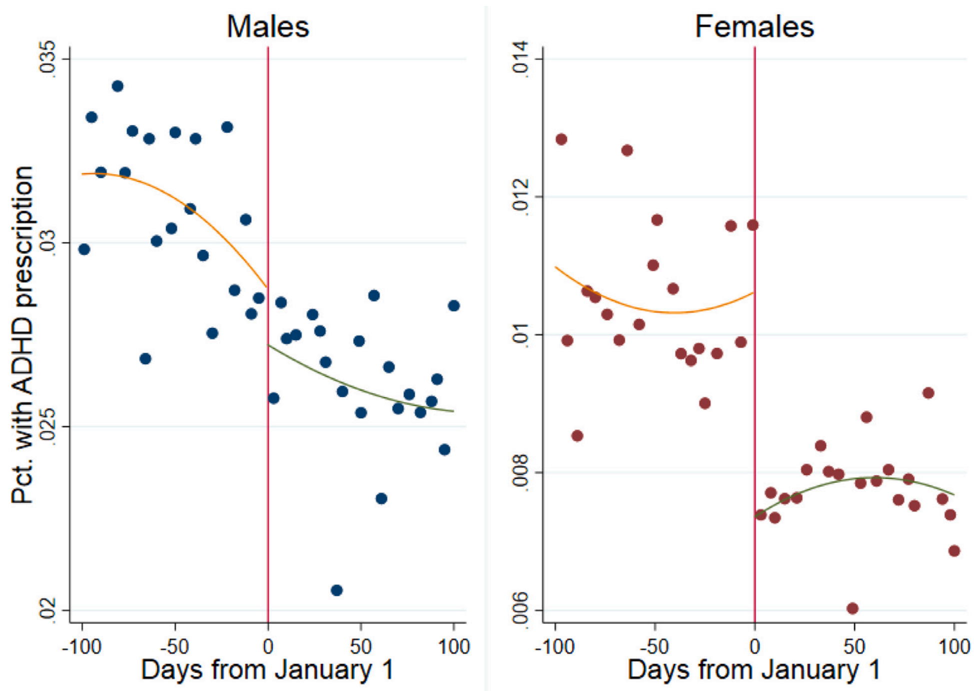

Fig. 1. ADHD prescription rates by birth date for children, 2010–2019. **Note:** This figure shows ADHD prescription rates by date of birth relative to January 1 for observations in 2010–2019. One observation is a five-day average of ADHD prescription rates. The red vertical line indicates the cutoff. Orange and green lines are the fitted values on each side of the cutoff, using a 2nd degree polynomial fit. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 2
Regression result for girls by parental income.

	Mother's income Below/above median		Father's income Below/above median	
$\hat{\alpha}_1$	−0.0036*	−0.0021	−0.0043**	−0.0014
	(0.0016)	(0.0013)	(0.0015)	(0.0013)
Constant	0.0213***	0.0100***	0.0239***	0.0105***
	(0.0016)	(0.0011)	(0.0016)	(0.0011)
2nd degree polynomial fit	X	X	X	X
Covariates, X_{it}	X	X	X	X
Observations	752 250	752 259	749 880	754 629

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. The dependent variable is $ADHD_{it}$. The columns are estimations of Eq. (1) for girls, where $f(days_i)$ is defined as a 2nd degree polynomial. The covariates are parents' personal income and dummies for the child's home region, household type and ancestry. Standard errors (in parenthesis) are clustered at the days level.

Table 3
Regression results for girls by subperiods.

	2010–2014 Females	2015–2019 Females
$\hat{\alpha}_1$	−0.0032**	−0.0033**
	(0.0011)	(0.0012)
Constant	0.0101***	0.0112***
	(0.0009)	(0.0008)
2nd degree polynomial fit	X	X
Covariates, X_{it}		
Observations	754 451	750 058

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. The dependent variable is $ADHD_{it}$. The columns are estimations of Eq. (1) for girls for the periods 2010–2014 and 2015–2019. $f(days_i)$ is defined as a 2nd degree polynomial. Standard errors (in parenthesis) are clustered at the days level.

4.1. Heterogenous effects

In addition to our main analysis, we want to investigate whether certain groups from different economic backgrounds are more likely to be misdiagnosed with ADHD. Thus, we split our reduced form regression based on the parent's personal income. More specifically, for girls we investigate whether there are any discontinuities in ADHD prescription rates at the cutoff depending on whether their mother or father has a personal annual income above or below the sample-median. Table 2 shows these results. The first two columns are for groups with mothers with a personal income above or below the observed median income, respectively. The last two columns show the corresponding estimations for fathers.

We only estimate a significant discontinuity in ADHD prescription rates when the father's or mother's income is less than the median. More specifically, we estimate α_1 at −0.36 percentage-point for mothers and −0.43 percentage-point for fathers with a below-median income. For parents with an income higher than the median, we find no significant discontinuities. These results suggest that the discontinuity we estimated in Table 1, column (4) are driven by girls whose parents have a lower income.

Appendix

See Figs. 2, 3 and Table 3.

Data availability

The authors do not have permission to share data.

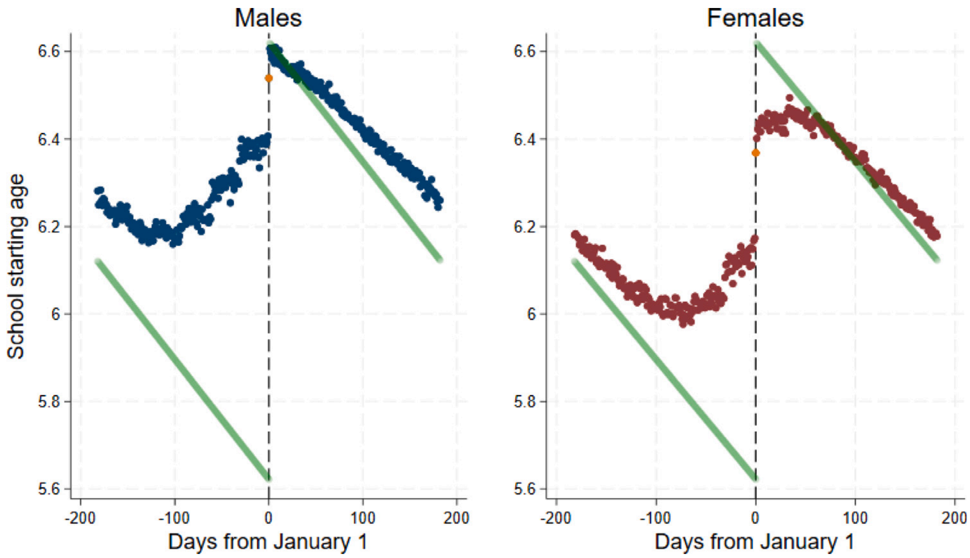

Fig. 2. School starting age by birth date, 2010–2013. **Note:** This figure shows the average school starting age by date of birth relative to January 1 for children in 2010–2013. School starting age is an approximation based on when a person graduated 6th grade. The green lines depict the school starting age if all children started the year they turned six. The orange dot is the observation exactly at the cutoff.

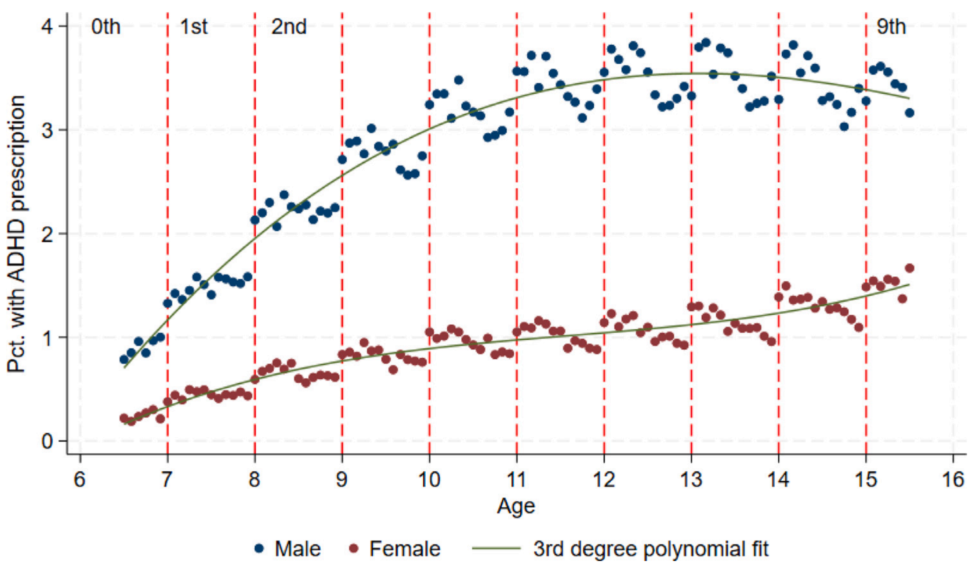

Fig. 3. ADHD rate by age, 2010–2019. **Note:** This figure shows the ADHD prescription rate as a percentage by the children's age measured in months for the period 2010–2019. The vertical red lines indicate school grades from 0th to 9th grade for those who comply. The green lines are 3rd degree polynomials to capture the overall trend.

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