Prenatal exposure to pollution, parental behaviour and educational achievement

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Motivation: Background

Increasing evidence that prenatal pollution exposure affects educational achievement:

- Direct effects on cognitive development: finer pollutants (PM, CO) can cross placental barrier and harm fetal brain (e.g. Prado Bert et al., 2018)
- Indirect effects on health: harmful effects on lung functioning, respiratory diseases (Barone-Adesi et al., 2015; Alotaibi et al., 2019)
- Gestation most critical period in formation of brain and vital organs (Barker, 1990; Almond, Currie, and Duque, 2018)

Motivation: Socioeconomic Gradient

Lower SES children tend to be more vulnerable to pollution exposure (Jans, Johansson, and Nilsson, 2018; Bernardi and Keivabu, 2024), but limited causal evidence:

- High SES less exposed ex-ante (residential sorting)
- High SES better mitigates adverse exposure effects

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Need exogenous variations in exposure

Motivation: Role of parental investments

Differential parental investment is a possible mechanism explaining SES gradient, but it can be:

- Mediator
  - Reinforcing vs compensatory investments (e.g. Restrepo, 2016; Fan and Porter, 2020)
  - Response to prenatal pollution exposure (Zhang et al., 2024)
- Moderator

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Test directly role of parental investments in early childhood

Research Questions

- What is the effect of in utero exposure to air pollution on educational achievement?

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- What is the role of parental involvement in early childhood?

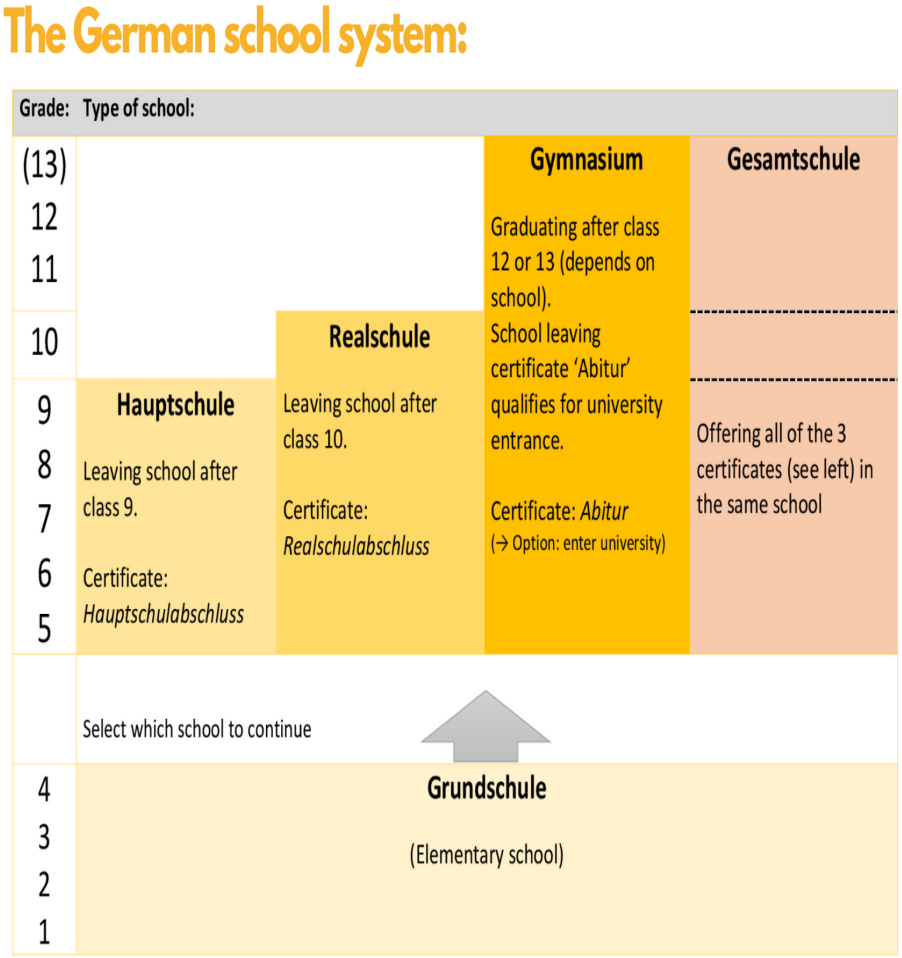
Data: Overview

- Setting: Germany, children born in 2000-2010
- Socioeconomic data from SOEP, large household panel survey (15000 HHs, 30000 individuals every year)
  - Information from individual, household and parent and child questionnaires
  - Frequency of activities of mother with child at ages 1, 3 and 6 (values ranging from 'Never' to 'Daily')
- Reanalysis data on weather and atmospheric conditions from European Centre for Medium-Range Weather Forecasts (ECMWF)
  - $0.25° \times 0.25°$ lat-long grid aggregated at the county (*Kreise*) level
  - Information on county of birth for around 2/3 of the sample

Data: Outcome variables

Measures of early educational achievement:

- Rate of transition to *Gymnasium*
  - Teacher's recommendation in elementary school
  - Very low cross-track mobility
  - Only track granting access to university
- School grades in Maths and German age 12-14



Data: Parental involvement

Construct measures of maternal involvement in early childhood from frequency of activities using PCA (Del Bono et al., 2016)

Table: Maternal Activities: Factor Loadings

	Factor 1 (E_a)	Factor 2 (P_a)
Ages 1, 3, 6:		
Singing	*0.76*	-0.18
Painting	*0.72*	0.17
Watching tv	0.06	*0.76*
Reading	*0.70*	-0.33
Age 6:		
Playing cards	*0.59*	0.28
Computer games	0.00	*0.77*
Cultural trips	*0.32*	0.09
Obervations	2473	
Correlation	0.11	

The table reports factor loadings of the maternal activities of interest obtained from a principal component analysis and an oblique rotation. Values in italics indicate the factor with the higher loading for the activity.

Baseline Model

$$Y_{iymc} = \beta_1 Pol_{ymc} + \beta_2 W_{ycm} + \beta_3 X_i + \alpha_c + \alpha_m + \alpha_y + \epsilon_{iymc} \quad (1)$$

- Y_{iymc} rate of transition to *Gymnasium* or school grades
- Pol_{ymc} air pollution exposure
- W_{ymc} weather conditions (e.g. ground-level temperature, wind speed, precipitation)
- X_i individual and family background characteristics
- α county, month of birth and year of birth fixed effects

Causal Effect?

Pollution exposure may be endogenous:

- Residential sorting
- Avoidance behaviour
- Measurement error
- Other unobservables

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Exogenous variations in pollution $\rightarrow$ Planetary boundary layer height (PBLH)

The instrument

- PBLH: height of lowest part of atmosphere directly influenced by earth's surface, where pollutants disperse
  - Strong seasonal patterns, influenced by wind and weather conditions
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- Higher PBLH $\rightarrow$ lower concentration of pollutants on the ground (e.g. Levi et al., 2020; Godzinski and Castillo, 2021) figure
- PBLH affects multiple pollutants $\rightarrow$ exclusion restriction not fully satisfied
- Reduced form specification (Molina, 2021):

$$Y_{iymc} = \beta_1 BLH_{ymc} + \beta_2 W_{ycm} + \beta_3 X_i + \alpha_c + \alpha_m + \alpha_y + \epsilon_{iymc} \quad (2)$$

Summary Statistics

Table: Summary Statistics

	Mean	SD	N
Gymnasium	0.43	0.495	5902
German	4.34	0.85	3286
Maths	4.27	0.99	3285
BLH (m)	574.66	62.08	5902
PM2.5 ($\mu g/m^3$)	14.88	2.13	5902
Age at Birth	30.3	5.53	5902
Birth order	1.93	1.09	5902
Migration Background	0.29	0.45	5902
Female	0.49	0.5	5902
Single Parent HH	0.19	0.39	5883
Mother: No high school	0.15	0.36	5885
Mother: High school	0.58	0.49	5885
Mother: University	0.27	0.44	5885
Father: No high school	0.11	0.32	4786
Father: High school	0.5	0.5	4786
Father: University	0.39	0.49	4786

Main Results: Reduced form effect

Table: Pollution exposure and educational achievement

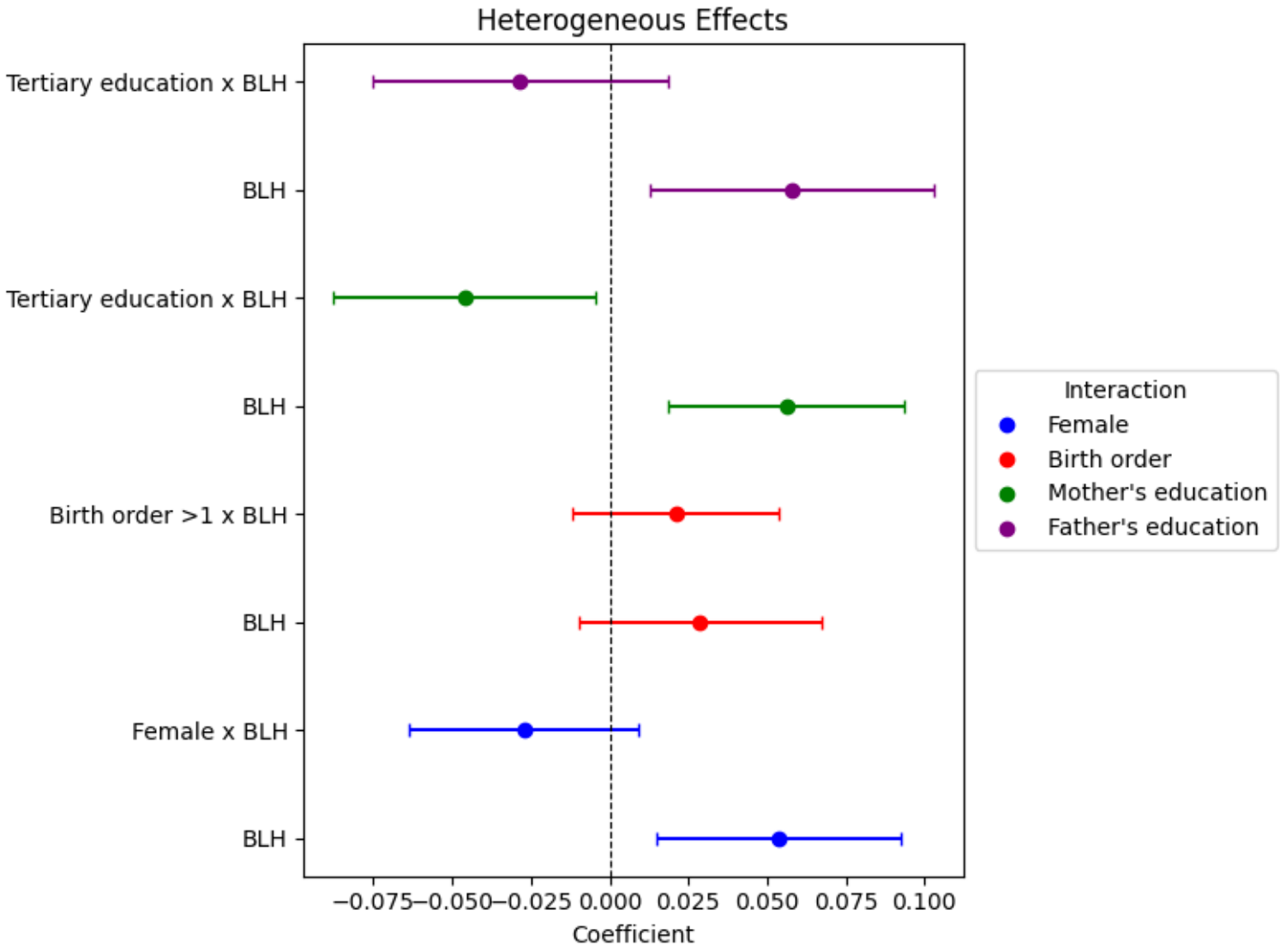
	School track	School grades: age 12-14	
Dep. Var.	Gymnasium	German	Maths
BLH in-utero	0.0371**	0.0703	0.0630
	(.0179)	(.05)	(.0594)
Mean Dep. Var.	0.43	4.34	4.27
Counties	373	346	346
Observations	5902	3286	3285

SE clustered at county level. *** p<0.01, ** p<0.05, * p<0.1

1 s.d. decrease in BLH $\rightarrow$ 3.7 p.p. decrease in enrolment in Gymnasium

Main Results: Education gradient

Figure: Heterogeneity by sociodemographic characteristics



Main Results: Mediation of parental involvement?

Table: Maternal activities and BLH

High Frequency of:	(1) E_a	(2) P_a	(3) Singing	(4) Painting & Crafts	(5) Watching TV	(6) Reading
BLH in-utero	0.0209	-0.0338	-0.0177	0.0397	-0.044	0.003
	(.0393)	(.0351)	(.0376)	(.0344)	(.039)	(.0377)
Mother: Tertiary	0.0264	-0.0985***	0.0413	-0.0517*	-0.0618**	0.1327***
	(.0296)	(.027)	(.0272)	(.03)	(.0294)	(.0269)
Tertiary x BLH	0.0253	-0.0086	0.015	-0.0019	-0.0233	0.0044
	(.022)	(.0228)	(.0267)	(.0246)	(.0255)	(.0226)
Mean Dep. Var.	0.54	0.45	0.58	0.53	0.56	0.61
Counties	291	291	301	302	301	302
Observations	2365	2365	2577	2578	2579	2581

SE clustered at county level. *** p<0.01, ** p<0.05, * p<0.1.

Main Results: Parental involvement as moderator

Table: Heterogeneity by maternal involvement and activities

Gymnasium	(1)	(2)	(3)	(4)	(5)	(6)
BLH in-utero	.107***	.0577	.0624*	.0715**	.0494	.1052***
	(.0408)	(.037)	(.0352)	(.0341)	(.0381)	(.0405)
E_a	.0482**					
	(.0228)					
E_a x BLH	-.0637**					
	(.0323)					
P_a		-.0334				
		(.0221)				
P_a x BLH		.0157				
		(.0301)				
Singing			.0594***			
			(.0212)			
Singing x BLH			.0152			
			(.0274)			
Painting				.0283		
				(.0207)		
Painting x BLH				-.0163		
				(.0249)		
Watching tv					-.0303	
					(.0195)	
Watching tv x BLH					0.0124	
					(.0315)	
Reading						.0575***
						(.0215)
Reading x BLH						-.068**
						(.0317)
Mean Dep. Var.	0.46	0.46	0.46	0.46	0.46	0.46
Counties	291	291	301	302	301	302
Observations	2373	2373	2585	2586	2587	2589

SE clustered at county level. *** p<0.01, ** p<0.05, * p<0.1

Robustness Checks

Alternative samples Robustness I

- Lower bound obs per county
- Restrict to three classical tracks

Alternative specifications Robustness II

- Alternative baseline and weather controls
- BLH lead and lag
- Extended fixed effects

Conclusions

Summing up:

- Significant negative effects of prenatal pollution exposure on the rate of transition to *gymnasium*, especially for lower SES children
- High maternal involvement with child can mitigate adverse effects of pollution

Policy implications:

- Socially equitable policies to limit vulnerability of lower SES children
- Importance of quality of parental involvement in early childhood, independent of parental background

Thank you!!

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BLH and PM2.5

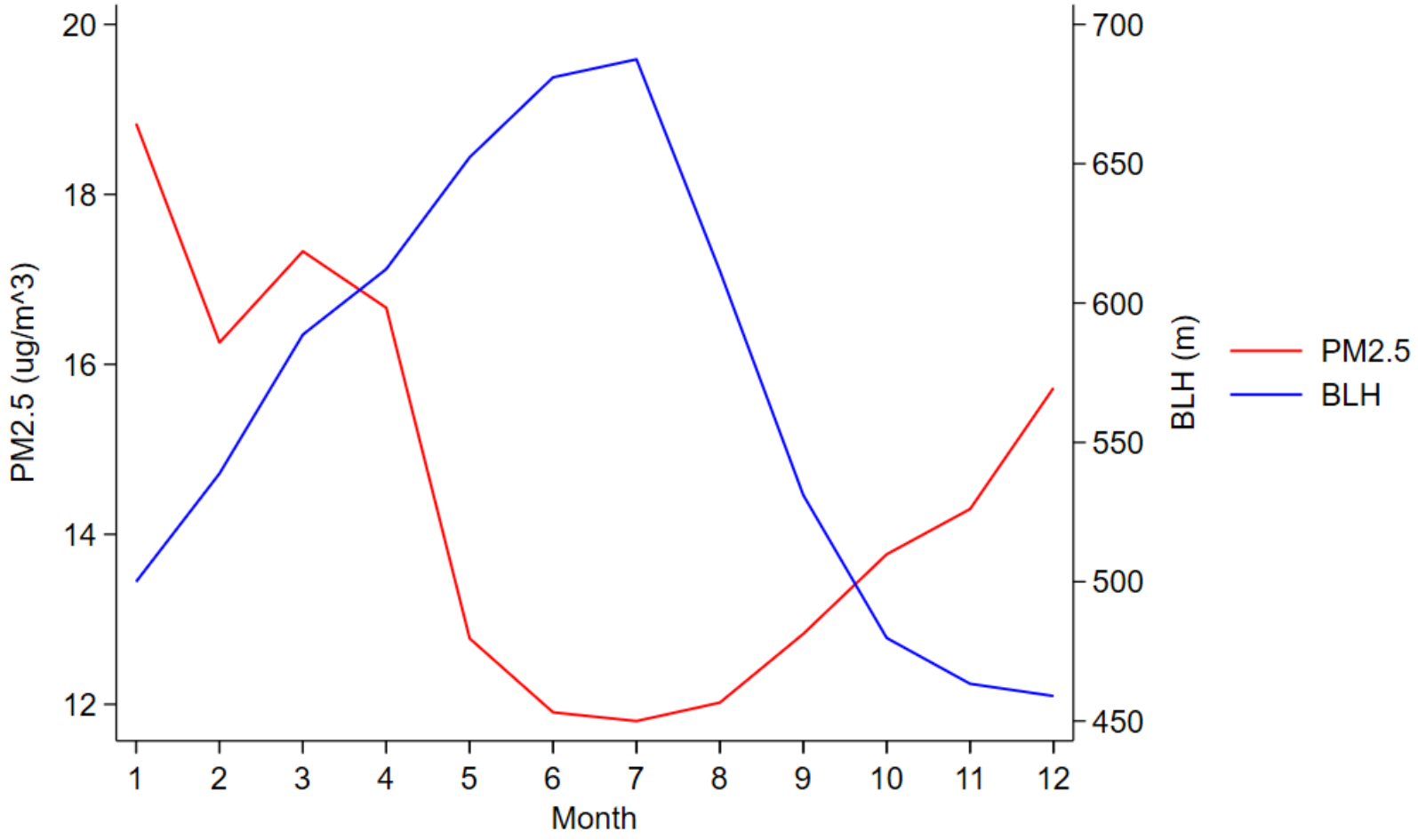

Figure: Correlation between BLH and PM2.5 over time: years 2000-2010

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Falsification checks

Table: Falsification checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep.Var	MAB	Migration Background	Mother: No HS	Mother: HS	Mother: Tertiary	Father: No HS	Father: HS	Father: Tertiary
				Panel A: Gymnasium Sample				
BLH in-utero	-0.287	-0.011	-0.014	0.021	-0.008	-0.015	-0.027	0.042*
	(.224)	(.018)	(.015)	(.02)	(.018)	(.014)	(.026)	(.025)
Observations	5828	5828	5812	5812	5812	4709	4709	4709

The table shows the effects of BLH in-utero (in standard deviations) on a set of household and child characteristics. MAB (Mother's age at birth) is measured in years. All regressions include county, month and year of birth fixed effects, child gender and period-specific weather controls as described in equation 2. SE are clustered at the county level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Robustness Checks I

Table: Alternative Samples

Gymnasium	(1)	(2)	(3)	(4)
BLH in-utero	0.0469**	0.0497**	0.0301*	0.038*
	(.0184)	(.0199)	(.0181)	(.0198)
Minimum Obs. per county	10	20	All	All
Years	All	All	No 2020	All
Mean Dep. Var.	0.43	0.44	0.42	0.56
Counties	245	140	373	357
Observations	5305	4143	5453	4500

The table shows the effects of BLH in-utero (in standard deviations) on the likelihood of transition to *gymnasium*, using different samples from the baseline sample of equation 2. Columns 1 and 2 restrict the sample to counties with at least 10 and 20 observations, respectively. Column 3 excludes survey year 2020 from the analysis. Column 4 restricts the sample to children who enrolled in one of the three classic tracks (no *gesamtschule*, vocational or other). All regressions include county, month and year of birth fixed effects, parental and child characteristics and period-specific weather controls as described in equation 2. SE are clustered at the county level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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Robustness Checks II

Table: Alternative Specifications

Gymnasium	(1)	(2)	(3)	(4)	(5)	(6)
BLH in-utero	0.0444**	0.0373**	0.0471**		0.0389*	0.0471**
	(.0206)	(.0175)	(.0236)		(.0213)	(.0187)
BLH prenatal			-0.0027	-0.0079		
			(.0209)	(.0182)		
BLH postnatal			-0.0198			
			(.023)			
Mean Dep. Var.	0.43	0.43	0.43	0.43	0.43	0.43
Counties	373	373	368	369	373	373
Observations	5902	5902	5542	5642	5895	5900
Specification	No SES controls	Linear weather	Ext. Weather controls	1 Lag BLH	Year*region FE	Month*region FE

The table shows the effects of BLH in-utero (in standard deviations) on the likelihood of transition to *gymnasium*, using different specifications from the baseline regression in equation 2. In column 1 we do not include the set of child and household background characteristics X. In column 2 we do not include weather controls in quadratic form. In column 3 we add one lead and one lag (nine months average) of the instrument and of second order weather controls. In column 4 we run the same regression as column 3 but only keeping the lag of the instrument and the correspondent weather controls. In column 5 and 6 we expand the set of fixed effects by including year of birth by state and month of birth by state fixed effects, respectively. SE are clustered at the county level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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