

Online Appendix - Particulate matter and labor supply: the role
of caregiving and non-linearities

A Additional figures

Figure A.1: Distribution of weekly average PM₁₀ (in $\mu\text{g}/\text{m}^3$), years 2007-2011

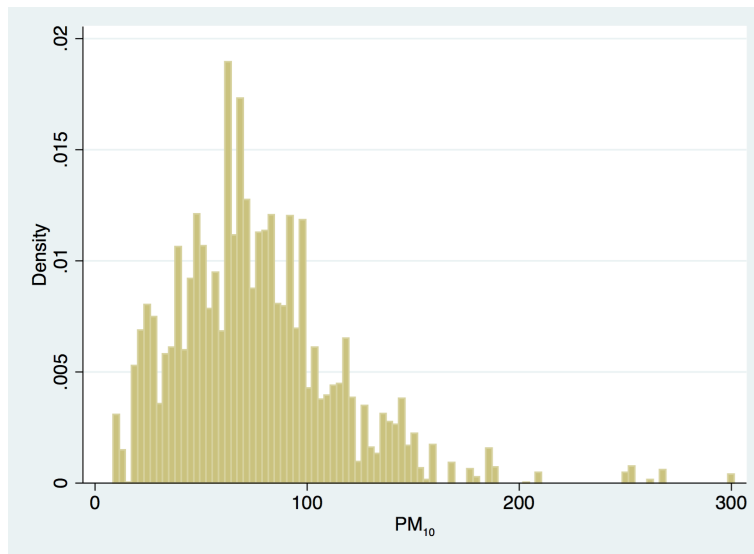


Figure A.2: Distribution of weekly average NO₂ (in $\mu\text{g}/\text{m}^3$), years 2007-2011

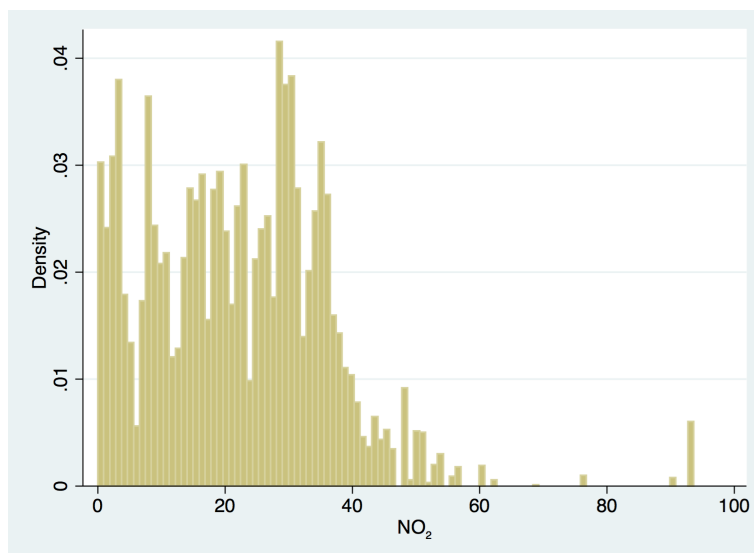


Figure A.3: Distribution of weekly average SO₂ (in $\mu\text{g}/\text{m}^3$), years 2007-2011

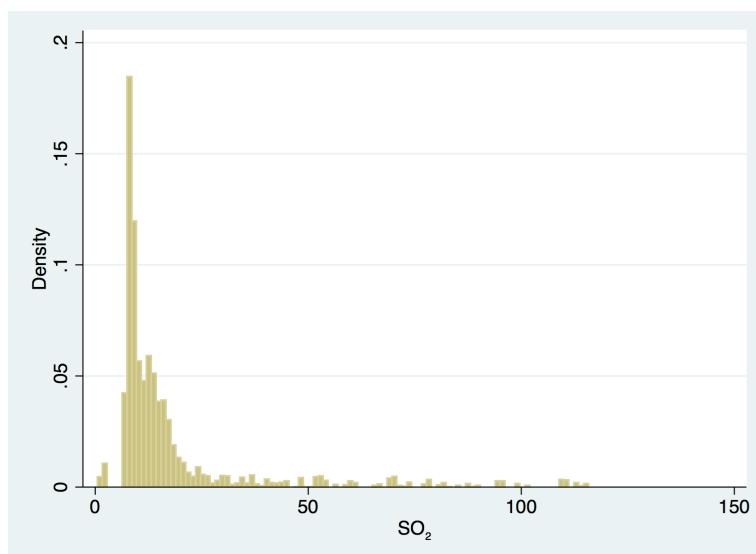


Figure A.4: Average PM_{2.5} (in $\mu\text{g}/\text{m}^3$), years 2007-2011, by monitoring station

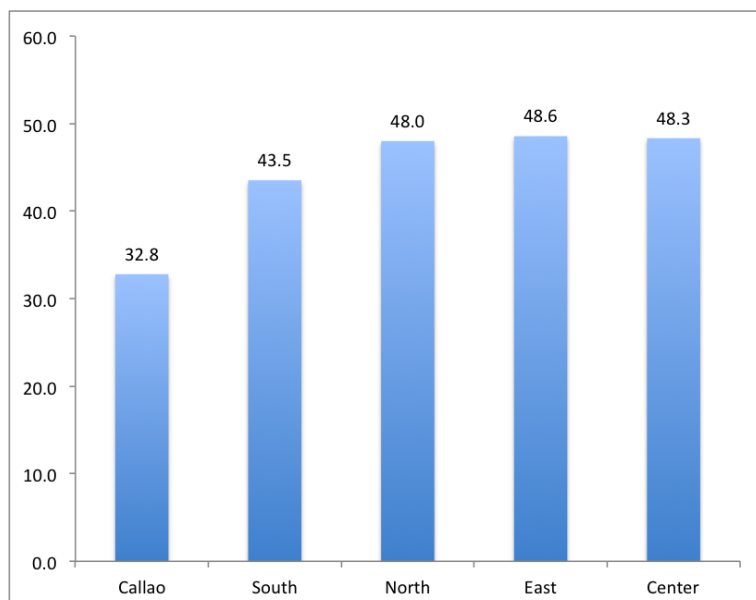
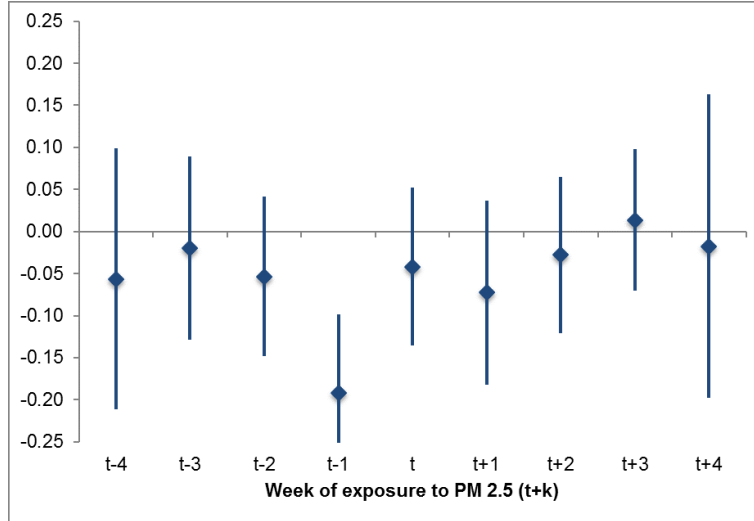
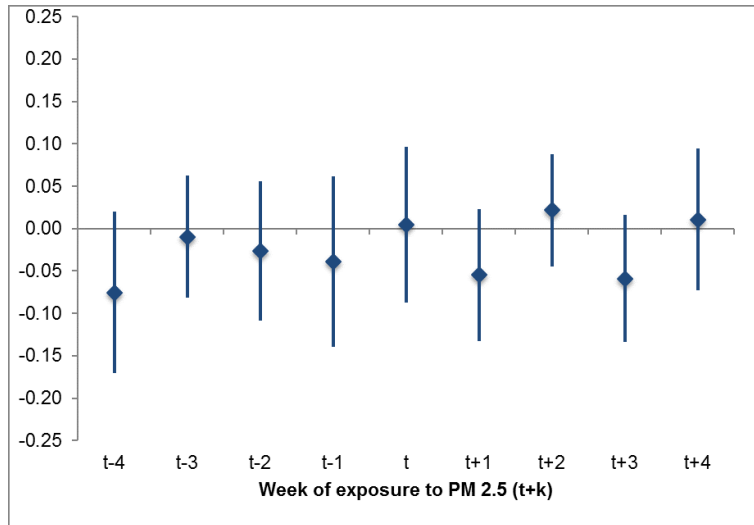


Figure A.5: Effect of $PM_{2.5}$ in week $t + k$ on hours worked in week t



(a) Households with susceptible individuals



(b) Households without susceptible individuals

Diamonds represent point estimates, vertical lines are 95% confidence intervals. Each estimate is obtained from a different regression and represents the effect of exposure to $PM_{2.5}$ in week $t+k$ on hours worked in week t , where t is reference week of labor outcomes and $k \in (-4, 4)$. The baseline regressions in Table 2 use $k = -1$.

B Additional tables

Table B.1: Mean of children's health indicators

Variable	Mean
PM _{2.5}	53.9
PM _{2.5} > 35 $\mu\text{g}/\text{m}^3$ (%)	83.8
Has cough and short breath (%)	19.9
Has fever (%)	22.4
Has diarrhea (%)	12.3
Has anemia (%)	32.1
Nr. observations	712

Notes: Reference period for morbidity variables is weeks $t - 1$ and $t - 2$, where t is the date of survey. Reference period for measures of pollution is weeks $t - 2$ and $t - 3$.

Table B.2: Baseline results using sample of households with no change in susceptible individual status

	Hours worked			
	(1)	(2)	(3)	(4)
PM 2.5	-0.227*** (0.065)	-0.069 (0.054)		
PM 2.5 above 35 $\mu\text{g}/\text{m}^3$			-8.243** (3.165)	-0.613 (1.705)
Household has susceptible individuals	Yes	No	Yes	No
Observations	1,514	2,514	1,514	2,514
R-squared	0.435	0.438	0.434	0.437

Notes: Robust standard errors in parentheses. Standard errors are clustered at the municipality level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. Baseline specification includes household, week and municipality-by-year fixed effects, characteristics of individual (gender, age, age², schooling, schooling², type of household member, indicator for having a second job, indicator of being independent worker), and monthly temperature and humidity. PM 2.5 is average PM_{2.5} in week $t - 1$, where t is the week of reference of labor outcomes. PM 2.5 above 35 $\mu\text{g}/\text{m}^3$ is an indicator equal to 1 if average PM_{2.5} in week $t - 1$ exceeded the U.S. standard. Sample includes only households with no time variation in variable “has susceptible individual”.

Table B.3: Non-linear relation of PM_{2.5} and children’s health

	Cough and short breath	Fever	Diarrhea	Anemia
PM 2.5 between 35-45 $\mu\text{g}/\text{m}^3$	0.061 (0.061)	0.080 (0.065)	0.025 (0.042)	0.045 (0.087)
PM 2.5 between 45-55 $\mu\text{g}/\text{m}^3$	0.101* (0.055)	-0.005 (0.062)	0.046 (0.045)	-0.026 (0.079)
PM 2.5 between 55-75 $\mu\text{g}/\text{m}^3$	0.144** (0.058)	-0.001 (0.065)	0.030 (0.042)	0.040 (0.091)
PM 2.5 above 75 $\mu\text{g}/\text{m}^3$	0.078 (0.060)	0.074 (0.069)	-0.010 (0.050)	-0.071 (0.094)
Observations	712	712	712	492
R-squared	0.057	0.065	0.069	0.244

Notes: Robust standard errors in parentheses. Standard errors are clustered at the survey block level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions are estimated using OLS and include the same control variables as in Table 3. The omitted category is PM 2.5 lower than 35 $\mu\text{g}/\text{m}^3$.

Table B.4: Heterogeneous effects of PM_{2.5} on hours worked

	Hours worked			
	(1)	(2)	(3)	(4)
Air pollution	-0.039 (0.050)	-0.043 (0.110)	-0.107 (1.637)	2.317 (4.187)
Air pollution × household has susceptible individuals	-0.153** (0.074)	-0.160* (0.083)	-6.711** (2.912)	-7.204** (3.369)
Air pollution × household is poor		0.072 (0.070)		2.145 (3.827)
Air pollution × age		0.001 (0.002)		-0.082 (0.092)
Air pollution × number of income earners		-0.008 (0.026)		0.175 (0.677)
Measure of air pollution		PM 2.5	PM 2.5 above 35 $\mu\text{g}/\text{m}^3$	
Observations	5,218	5,218	5,218	5,218
R-squared	0.440	0.440	0.440	0.440

Notes: Robust standard errors in parentheses. Standard errors are clustered at the municipality level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. Regressions include the same controls as the baseline specification (see notes of Table 2 plus full interactions with an indicator of a household having a susceptible individual. Columns 2 and 4 also add interactions of air pollution with an indicator for poor household, individual's age, and number of income earners. Columns 1 and 2 use PM 2.5 as measure of air pollution, while columns 3 and 4 use an indicator of PM 2.5 exceeding the U.S. standard.

Table B.5: Robustness of main results to alternative S.E. clustering

	Hours worked			
	(1)	(2)	(3)	(4)
PM 2.5	-0.192 (0.046)*** [0.060]** {0.047} * **	-0.039 (0.050) [0.037] {0.036}		
PM 2.5 above 35 $\mu\text{g}/\text{m}^3$			-6.817 (2.279)*** [2.170]*** {1.957} * **	-0.107 (1.635) [1.442] {1.312}
Household has susceptible individuals	Yes	No	Yes	No
Observations	2,167	3,051	2,167	3,051
R-squared	0.429	0.447	0.429	0.447

Notes: This table replicates results in Table 2 using alternative S.E. clustering approaches. The baseline results using clustering at the municipality level are shown in parenthesis (no. of clusters = 35). In brackets, we cluster S.E at block-week-year levels (no. clusters \sim 790). I braces, we use a two-way clustering by block and week-year (no. clusters \sim 540 and \sim 310, respectively). * denotes significant at 10%, ** significant at 5% and *** significant at 1%. See notes of Table 2 for specification details.

Table B.6: Testing for attrition bias

	Hours worked			
	(1)	(2)	(3)	(4)
Drops from sample next year	-2.812 (2.122)	2.814 (2.537)	-3.206 (2.309)	2.799 (2.571)
PM 2.5	-0.194*** (0.045)	-0.040 (0.048)		
PM 2.5 above 35 $\mu\text{g}/\text{m}^3$			-7.081*** (2.390)	-0.199 (1.576)
Household has susceptible individuals	Yes	No	Yes	No
Observations	2,167	3,049	2,167	3,049
R-squared	0.430	0.446	0.429	0.446

Notes: Robust standard errors in parentheses. Standard errors are clustered at the municipality level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. Regressions include the same controls as the baseline specification (see notes of Table 2. "Drops from sample next year" is an indicator equal to 1 if household drops from panel sample the following year, and 0 otherwise.

Table B.7: Non-linear effect of PM_{2.5} on hours worked

	Hours worked		p-value
	(1)	(2)	H ₀ : (1)=(2) (3)
PM 2.5 between 35-45 $\mu\text{g}/\text{m}^3$	-4.940* (2.758)	-0.944 (1.585)	0.168
PM 2.5 between 45-55 $\mu\text{g}/\text{m}^3$	-7.318** (2.801)	0.737 (1.782)	0.047
PM 2.5 between 55-75 $\mu\text{g}/\text{m}^3$	-9.685*** (3.090)	-0.445 (3.175)	0.081
PM 2.5 above 75 $\mu\text{g}/\text{m}^3$	-10.635*** (3.036)	-6.941** (3.001)	0.439
Household has susceptible individual	Yes	No	
Observations	2,167	3,051	
R-squared	0.430	0.448	

Notes: Robust standard errors in parentheses. Standard errors are clustered at the municipality level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions include the same controls as the baseline specification (see notes of Table 2). The omitted category is PM 2.5 lower than 35 $\mu\text{g}/\text{m}^3$. Column 3 reports the p-value of a test that the estimates in column 1 and 2 are the same. This is obtained from estimating equation (2) and including full interactions with dummies of the household having a susceptible individual. The p-values correspond to the estimated interaction terms.

Table B.8: Exploring attenuation behavior in households without susceptible individuals

	Hours worked					
	(1)	(2)	(3)	(4)	(5)	(6)
PM 2.5	-0.034 (0.051)	-0.032 (0.058)	-0.031 (0.050)	-0.046 (0.059)	-0.079 (0.065)	-0.017 (0.049)
PM 2.5 \times worker characteristic	0.003 (0.037)	-0.001 (0.049)	-0.011 (0.067)	0.015 (0.070)	0.127* (0.074)	-0.012 (0.045)
Worker characteristic	Is house- hold head	Is female	Under 25 years	Complete secondary	Indep. worker	Has job contract
Household has susceptible indiv.	yes	yes	yes	yes	yes	yes
Observations	3,051	3,051	3,051	3,051	3,051	3,051
R-squared	0.444	0.444	0.444	0.446	0.449	0.449

Notes: Robust standard errors in parentheses. Standard errors are clustered at the municipality level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions include household, week and municipality-by-year fixed effect, and the same individual and household controls as the baseline specification (see notes of Table 2) plus interactions of PM 2.5 with workers' characteristics. Sample includes only workers in households without susceptible individuals.

Table B.9: PM_{2.5} and earnings adding municipality-by-year fixed effects

	ln(earnings in last month)			
	(1)	(2)	(3)	(4)
A. % weeks PM 2.5 above 35 $\mu\text{g}/\text{m}^3$	-0.135 (0.111)	-0.174 (0.139)	-0.093 (0.092)	-0.066 (0.100)
B. % weeks PM 2.5 above 35 $\mu\text{g}/\text{m}^3 \times$ has job contract		0.109 (0.149)		-0.077 (0.108)
C. p-value $H_0: A+B=0$		0.628		0.214
Household has susceptible individuals		yes	yes	no no
Observations		2,274	2,274	3,240 3,240
R-squared		0.600	0.603	0.625 0.631

Notes: Robust standard errors in parentheses. Standard errors are clustered at the municipality level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions include household, month and municipality-by-year fixed effects, and the same individual and household controls as the baseline specification (see notes of Table 2). The reference period for explanatory variable “% weeks PM 2.5 above 35 $\mu\text{g}/\text{m}^3$ ” is weeks $t-1$ to $t-4$. Row C displays the p-value of the test $A+B=0$, where A and B refer to the estimates in first two rows.

Table B.10: PM_{2.5} and average household earnings

	ln(average household earnings)					
	(1)	(2)	(3)	(4)	(5)	(6)
% weeks PM 2.5 above 35 $\mu\text{g}/\text{m}^3$	-0.206* (0.102)	-0.135 (0.151)	-0.082 (0.172)	0.011 (0.046)	0.008 (0.072)	-0.016 (0.113)
Household F.E.	No	Yes	Yes	No	Yes	Yes
Municipality-by-year FE	No	No	Yes	No	No	Yes
Household has susceptible individuals	Yes	Yes	Yes	No	No	No
Observations	1,122	1,122	1,122	1,716	1,716	1,716
R-squared	0.304	0.815	0.858	0.337	0.822	0.847

Notes: Robust standard errors in parentheses. Standard errors are clustered at the municipality level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. Regressions use observations aggregated at the household level by taking the average of income earners, and are estimated using a panel data model with fixed effects and no sample weights. All regressions include municipality, month and year fixed effects, average temperate and humidity, and characteristics of the average income earner: age, age², schooling, schooling², share of females, share of earners having a second job, and share of independent workers. Columns 2 and 4 add household fixed effects, while columns 3 and 6 also add municipality-by-year fixed effects. Reference period for household earnings is weeks t to $t-3$. Reference period for explanatory variable “% weeks PM 2.5 above 35 $\mu\text{g}/\text{m}^3$ ” is weeks $t-1$ to $t-4$.

Table B.11: PM_{2.5} and total hours worked by household members

	Total hours worked	
	(1)	(2)
PM 2.5	-0.203* (0.105)	-0.076 (0.135)
Household has susceptible individuals	Yes	No
Observations	984	1,480
R-squared	0.671	0.605

Notes: Robust standard errors in parentheses. Standard errors are clustered at the municipality level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. Regressions use observations aggregated at the household level, and are estimated using a panel data model with fixed effects and no sample weights. The outcome “total hours worked” is the sum of hours worked by all household members. All regressions include household, municipality-by-year, and week fixed effects, average temperate and humidity, share of females, share of workers having a second job, share of independent workers and characteristics of the average worker: age, age², schooling, and schooling².

C Ancillary results

This section presents additional results of the effect of pollution on labor supply.

Table C.1 examines the effect on hours worked of other air pollutants, such as PM_{10} , SO_2 , and NO_2 . These air pollutants are highly, but not perfectly, correlated to $\text{PM}_{2.5}$ (see table C.2). Our preferred specifications (columns 1 to 6) include only one measure of air pollutant at the time, while columns 7 and 8 includes all of them. These last regressions may be less precise due to multicollinearity.

Similar to the results using fine particulate matter ($\text{PM}_{2.5}$) we find a negative relationship between hours worked and air pollutants. The magnitude is larger for individuals in households with susceptible dependents. However, except in the case of NO_2 , the estimates are not statistically significant. This result may be due to $\text{PM}_{2.5}$ effectively being more harmful than other pollutants. For example, U.S. EPA (2009) reports that there is causal evidence linking $\text{PM}_{2.5}$ to health problems, but the evidence is less conclusive for other air pollutants. We cannot, however, reject the possibility that this insignificant result is due to noisy data and lack of statistical power.

Table C.1: Effect of other air pollutants on hours worked

	Hours worked							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PM ₁₀	-0.042 (0.043)	0.002 (0.024)					-0.031 (0.065)	0.012 (0.034)
NO ₂			-0.095** (0.040)	-0.009 (0.051)			0.030 (0.097)	0.029 (0.063)
SO ₂					-0.045 (0.032)	-0.008 (0.039)	0.069 (0.089)	-0.029 (0.076)
PM _{2.5}							-0.124 (0.111)	-0.041 (0.043)
Household has suscept. indiv.	Yes	No	Yes	No	Yes	No	Yes	No
Observations	2,084	2,981	2,337	3,326	2,412	3,441	1,637	2,390
R-squared	0.434	0.446	0.422	0.443	0.416	0.432	0.464	0.480

Notes: Robust standard errors in parentheses. Standard errors are clustered at the municipality level. * denotes significant at 10%, ** significant at 5% and *** significant at 1%. All regressions include the same controls as the baseline specification (see notes of Table 2). Similarly, the measures of air pollution (PM₁₀, NO₂, SO₂ and PM_{2.5}) are the average in week $t - 1$, where t is the reference week for labor outcomes.

Table C.2: Correlation matrix of main air pollutants

	PM _{2.5}	PM ₁₀	NO ₂	SO ₂
PM _{2.5}	1			
PM ₁₀	0.4698	1		
NO ₂	0.2969	0.2441	1	
SO ₂	0.2771	0.201	0.0173	1

References

U.S. EPA, “Final Report: Integrated science assessment for particulate matter,” U.S. Environmental Protection Agency (EPA). Washington, DC, 2009.