

Air Pollution, Weather, and Agricultural Worker Productivity

Alexandra E. Hill, J. Burkhardt, J. Bayham, K., O'Dell, B. Ford, E.V. Fischer, & J. Pierce
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Assistant Professor of Agricultural Economics
Colorado State University

Why pollution and ag worker productivity?

1. Employees

2. Employers

Why pollution and ag worker productivity?



Health effects of air pollution

short-term effects

exacerbation
of asthma

cough, wheezing
and shortness
of breath

episodes of high air
pollution increase
respiratory and
cardiovascular hospital
admissions and mortality

long-term effects

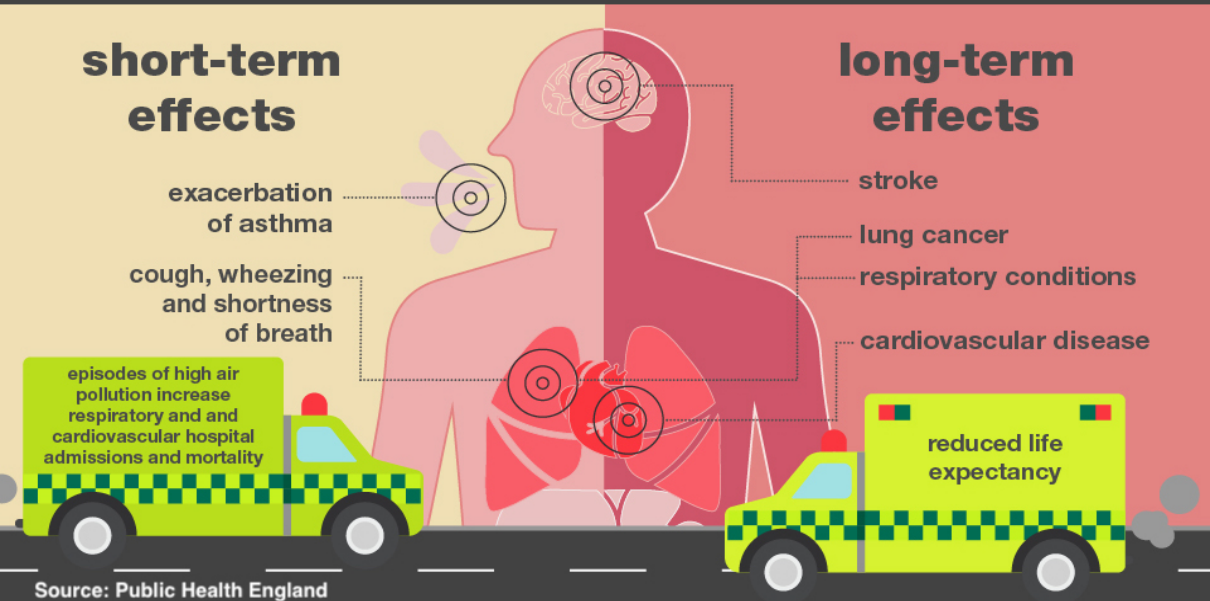
stroke

lung cancer

respiratory conditions

cardiovascular disease

reduced life
expectancy



Why pollution and ag worker productivity?



2. Employers

Pollution can Influence Employee Income through Two Mechanisms

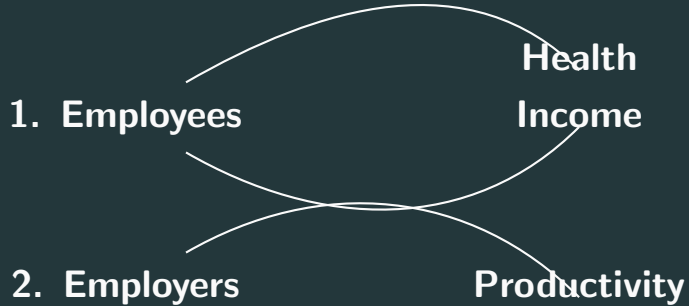
1. Piece rate pay $\Rightarrow$ $\downarrow$ Productivity = $\downarrow$ Pay

- 43% of harvesters in NZ are paid by the piece
- 50% of winter pruning tasks in NZ are paid by the piece
(NZ Kiwifruit Growers Incorporated 2020 RSE Survey)

2. Pollution can increase absenteeism

- Pollution increases illness-related school absences
(Currie et al. 2009; Gilland et al. 2001; Park et al. 2002; Mendoza et al. 2020)
- Pollution increases workplace absenteeism
(Bruyneel et al. 2022; Leroutier & Ollivier working paper)

Why pollution and ag worker productivity?





Technology and automation

These pages provides information on what the technology does and whether it may be of benefit in your situation. This is relevant for new dairies or retrofitting to existing dairies.



Feeding Systems

Automatic feeding systems provide a lot of flexibility, find out more here.



Electronic ID

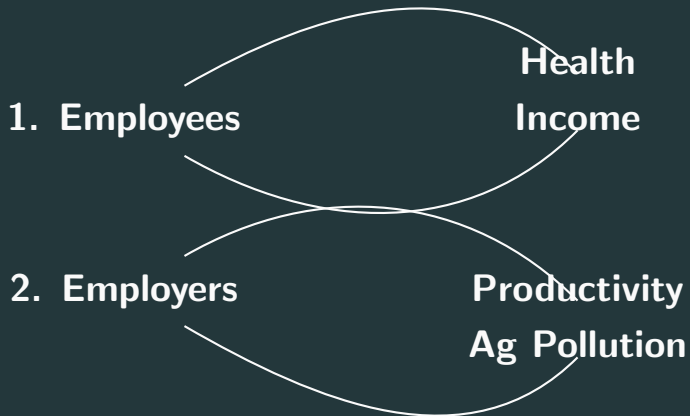
Find out how EID systems can improve efficiency, simplify data collection and produce valuable information.



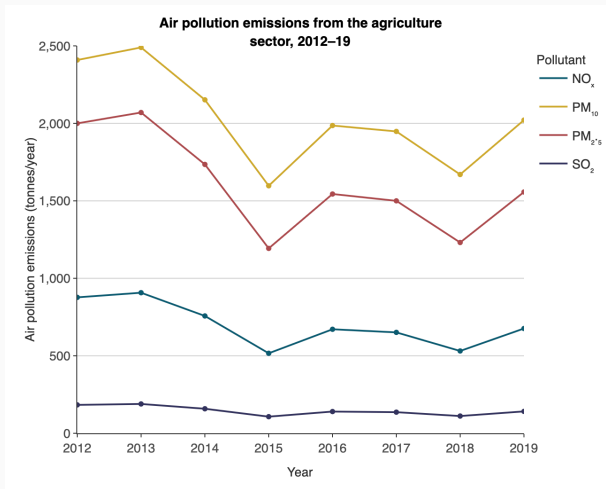
Drafting Systems

Well designed and accurate drafting systems are becoming more important as herd sizes expand.

Why pollution and ag worker productivity?



Agricultural Production Contributes to Air Pollution



This Study: Research Question and Results Preview

How does pollution impact worker productivity?

- **Fine Particulate Matter** (PM_{2.5}): a 10 $\mu\text{g}/\text{m}^3$ increase in PM_{2.5} is associated with a 2.9% decrease in productivity.
- **Surface-level Ozone** (O₃): a 10 ppb increase in O₃ is associated with a 2.4% decrease in worker productivity.

What are these pollutants and why can they impact worker productivity?

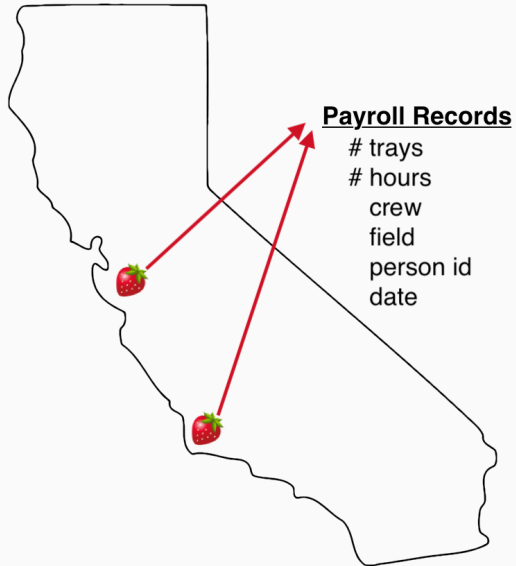
- PM_{2.5} are tiny particles in the air that can cause the air to appear hazy when levels are elevated.
- O₃ a colorless, reactive oxidant gas that is a major constituent of smog.

⇒ Both have been linked with reductions in respiratory, cardiovascular, and cognitive function.

Setting: Strawberry Harvesters in California



Data from the Farms

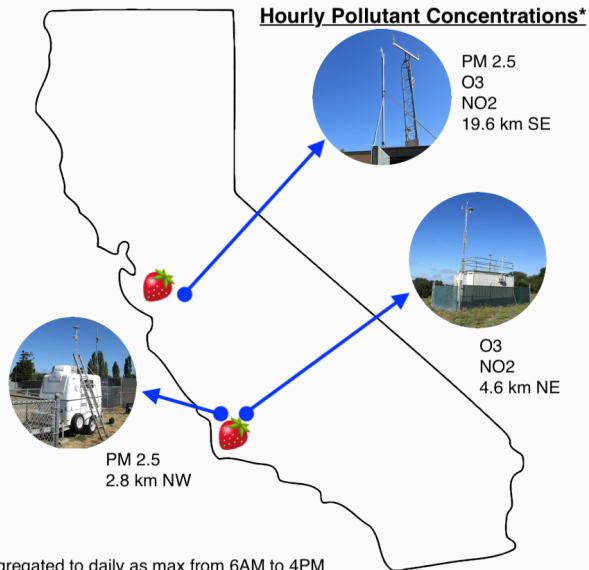


Payroll Summary Statistics

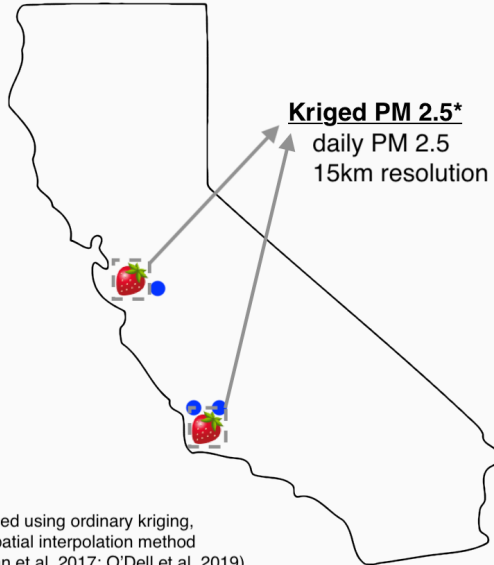
Variable	Mean	Std. Dev.	Min.	Max.	N
Productivity (trays/hr)	6.853	3.269	1	20	630652
Number of workers	28.931	7.843	1	63	630652
Experience	60.436	45.123	1	209	630652
Male	0.691	0.462	0	1	630652
Age	29.17	7.868	15	71	629324

Notes: All variables summarized at the worker-day observation level. We drop observations with productivities at the lower and upper one percent of the productivity distribution (below 1 tray per hour and above 20 trays per hour).

Data from Nearest EPA Air Quality Monitors



Kriged PM_{2.5}

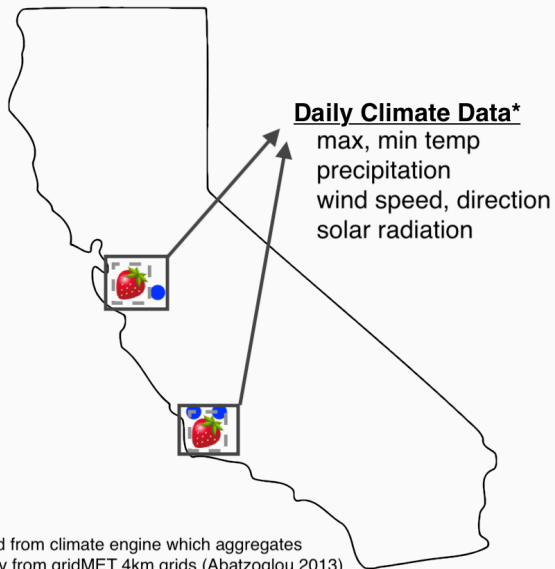


*produced using ordinary kriging,
a geospatial interpolation method
(lassman et al. 2017; O'Dell et al. 2019)

Pollution Summary Statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
PM _{2.5} (kriged, $\mu\text{g}/\text{m}^3$)	6.654	2.732	0.691	21.342	633163
Max Ozone (ppm)	0.038	0.009	0.014	0.083	633163
Max NO ₂ (ppb)	6.111	5.084	0	36	633163

Notes: All variables summarized at the worker-day observation level. Max PM_{2.5} (monitor) indicates the measure of PM_{2.5} from the nearest pollution monitor and PM_{2.5} (kriged) is our 15km grid cell-level measure of PM_{2.5}.



*sourced from climate engine which aggregates to county from gridMET 4km grids (Abatzoglou 2013)

Empirical Model

$$\ln(Y_{ifct}) = \mathbf{X}'\boldsymbol{\beta} + \beta_N N_{ct} + \beta_E E_{it} + \gamma_{fw_t} + \theta_i + \phi_c + \text{dow}_t + \varepsilon_{ifct}$$

Y_{ifct} is productivity.

of trays harvested per hour by person i on field f , crew c , and day t

$\mathbf{X}$ are the variables of interest.

a vector of farm-specific daily measures of pollutants and weather conditions

N_{ct} and E_{it} are controls.

the number of workers on a crew and the experience of each worker

γ_{fw_t} , θ_i , ϕ_c , dow_t are fixed effects.

field-by-week, person, crew, and day of week

Identification Concern 1: Pollutant Correlation

Concentrations of individual pollutants can be correlated

► Correlation Matrix

► O₃ and NO₂ Scatter

► PM_{2.5} and NO₂ Scatter

► PM_{2.5} and O₃ Scatter

Identification Concern 1: Pollutant Correlation

Concentrations of individual pollutants can be correlated

▸ Correlation Matrix

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▸ PM_{2.5} and NO₂ Scatter

▸ PM_{2.5} and O₃ Scatter

⇒ Include all pollutants in regression to isolate effects

Identification Concern 2: Functional Form

Are relationships between pollutants and productivity linear?

▸ O_3 Concentration Response

▸ $PM_{2.5}$ Concentration Response

▸ $PM_{2.5}$ Concentration Response

▸ $PM_{2.5}$ Nearest Monitor

Identification Concern 2: Functional Form

Are relationships between pollutants and productivity linear?

▸ O_3 Concentration Response

▸ $PM_{2.5}$ Concentration Response

▸ $PM_{2.5}$ Concentration Response

▸ $PM_{2.5}$ Nearest Monitor

⇒ Include quadratic and cubic terms where appropriate

Main Specification: All Pollutants, Non-linear

► Nearest Monitor PM_{2.5} Results

► More Identification

	(1)	(2)	(3)
Kriged PM _{2.5}	-0.0029* (0.0015)	-0.0029* (0.0015)	-0.0029* (0.0015)
Max Ozone	23.1505*** (8.5267)	24.7213*** (8.5103)	25.0092*** (8.5151)
Max Ozone Squared	-596.6356*** (191.5308)	-627.8553*** (190.9163)	-630.4232*** (191.2896)
Max Ozone Cubed	4546.8954*** (1356.5162)	4756.2100*** (1352.7855)	4742.9321*** (1356.4326)
Observations	633163	633163	633163
Adjusted R ²	0.8507	0.8513	0.8512
All Controls & FE	Y	Y	Y
Weather Splines	N	Y	N
Quadratic Weather	N	N	Y

Concluding Remarks

Increases in $\text{PM}_{2.5}$ and O_3 **decrease** worker productivity.

- Despite that levels of both pollutants in our data are largely well below the EPA's National Ambient Air Quality Standards
- A 1 standard deviation increase in $\text{O}_3 \rightarrow 2.2\%$ decrease in prod
- A 1 standard deviation increase in $\text{PM}_{2.5} \rightarrow 0.8\%$ decrease in prod

Increases in pollutant concentrations **do not** impact worker income.

- Workers are expected to continue working until fields are completely harvested, and indeed we find that increases in pollution increase work hours
- This increases worker exposure to pollutants, potentially amplifying health effects

Higher productivity days on the farm are correlated with **higher** PM_{2.5} concentrations according to nearby pollution monitors.

- Farm activities are likely contributing to PM_{2.5} (dust)
- This is associated with productivity losses and other expenses that are economically meaningful for the farm.

Employers might consider mechanisms for **reducing pollution** (reducing vehicles, efficient fertilizer application) and **reducing worker exposure** to pollution (timing of harvest)

THANK YOU!
for welcoming me
to such a wonderful country



alexandra.e.hill@colostate.edu

<https://alexandraehill.github.io>

Extra Slides

Variable	Mean	Std. Dev.	Min.	Max.	N
Max Temp (C)	27.394	4.974	9.300	39.19	630652
Min Temp (C)	10.712	3.495	-3.44	19.06	630652
Precipitation (mm)	0.139	0.918	0	16.05	630652
Wind Speed (mph)	9.763	4.742	2.908	27.514	630652
Solar Radiation (w/m^2)	284.45	58.012	38.9	366.5	630652
NE	0.017	0.128	0	1	630652
SE	0.016	0.124	0	1	630652
SW	0.166	0.372	0	1	630652
NW	0.802	0.399	0	1	630652

Notes: All variables summarized at the worker-day observation level.

Individual Pollutants – Linear Full Results

[▶ Back to Abbrv. Results](#)

	O ₃	NO ₂	kriged PM _{2.5}	nearest PM _{2.5}
Pollutant	-1.0659*	0.0012	-0.0034**	0.0002
	(0.5620)	(0.0008)	(0.0015)	(0.0002)
Max Temp (C)	0.0040**	0.0032*	0.0037**	0.0032*
	(0.0017)	(0.0017)	(0.0016)	(0.0016)
Min Temp (C)	0.0109***	0.0125***	0.0118***	0.0125***
	(0.0028)	(0.0028)	(0.0027)	(0.0027)
Precipitation (mm)	-0.0204***	-0.0211***	-0.0205***	-0.0211***
	(0.0059)	(0.0059)	(0.0059)	(0.0059)
Number of workers	-0.0303***	-0.0301***	-0.0303***	-0.0304***
	(0.0038)	(0.0039)	(0.0039)	(0.0039)
Experience	0.0474**	0.0478**	0.0457**	0.0471**
	(0.0206)	(0.0206)	(0.0206)	(0.0208)
Wind Speed	-0.0025**	-0.0021*	-0.0022*	-0.0029**
	(0.0012)	(0.0011)	(0.0011)	(0.0012)
1 Week Lag Radiation	0.0035***	0.0035***	0.0034***	0.0035***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Observations	633163	633163	633163	625080
Adjusted R ²	0.8502	0.8502	0.8503	0.8525
All Controls & FE	Y	Y	Y	Y

Notes: table omits variables with coefficients that are not statistically significantly different from 0: Contemporaneous solar radiation and indicators for wind direction. Fixed effects include: field-by-week, individual-by-year, day of week, and crew. Standard errors are two-way clustered at the individual level and the farm-day level.

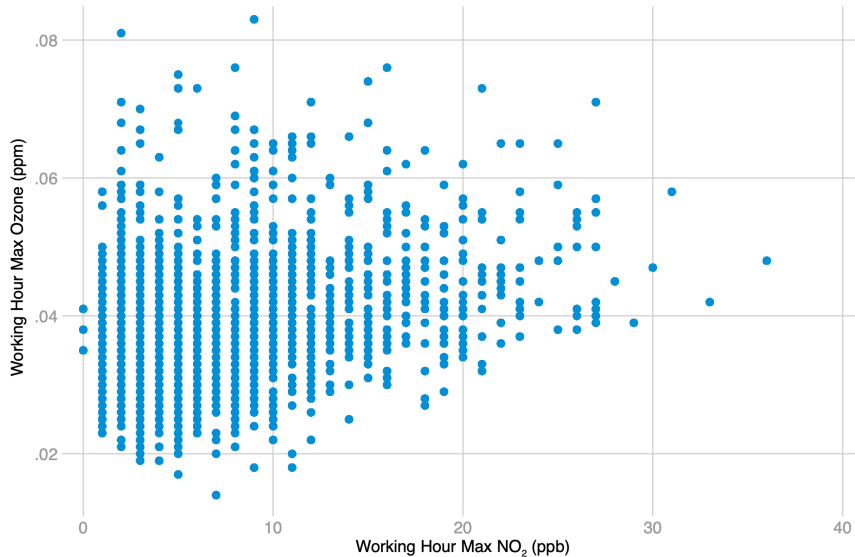
Pollutant Correlation Matrix

[▶ Back to identification](#)

	Kriged PM _{2.5}	Monitor PM _{2.5}	Max O ₃	Max NO ₂
Kriged PM _{2.5}	1			
Monitor PM _{2.5}	0.2118	1		
Max O ₃	0.2980	0.2414	1	
Max NO ₂	0.0850	-0.0577	0.2907	1

O₃ and NO₂ Scatterplot

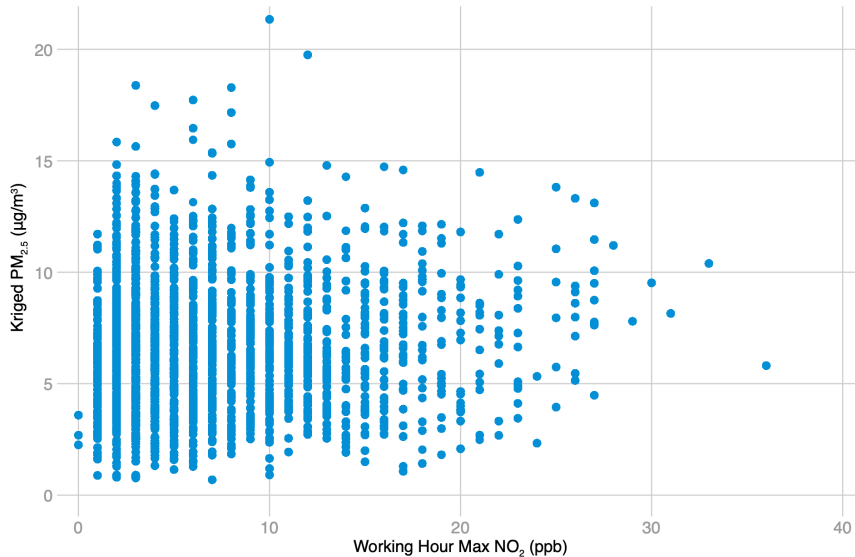
► [Back to identification](#)



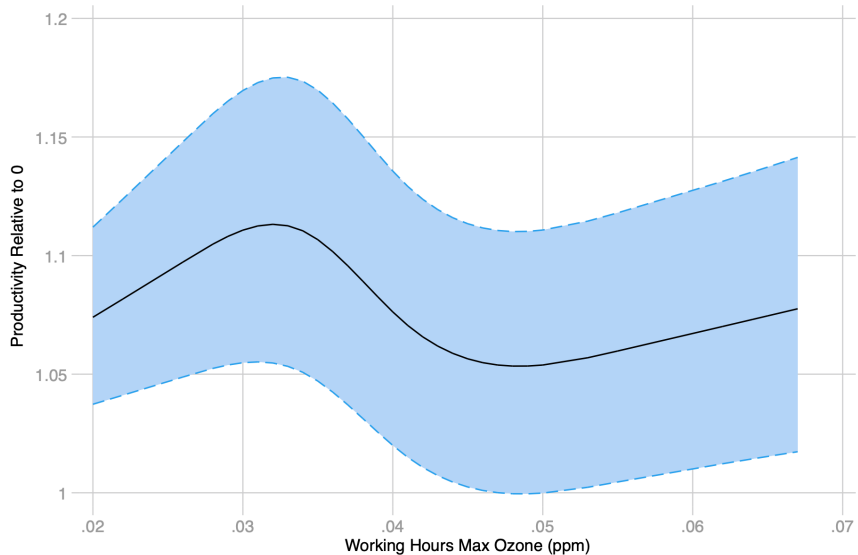
Kriged PM_{2.5} and NO₂ Scatterplot

[▸ Back to identification](#)

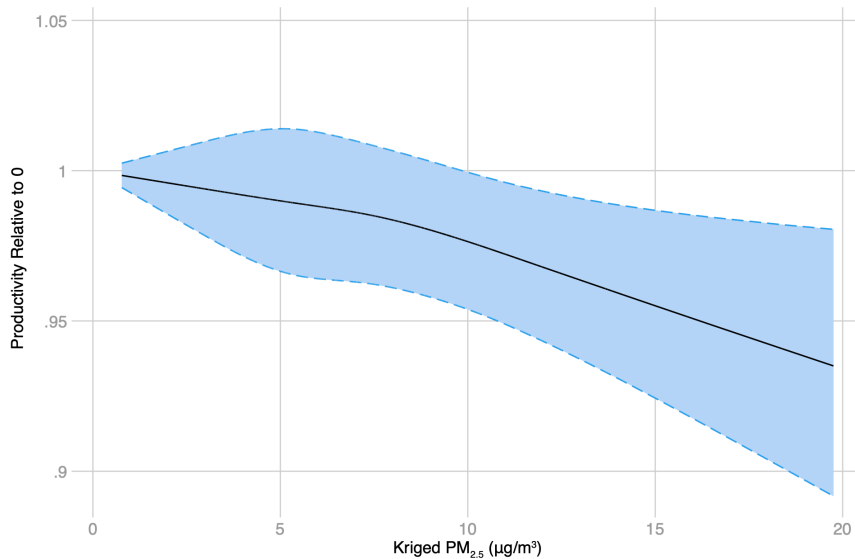
Kriged PM_{2.5} and O₃ Scatterplot

[► Back to identification](#)

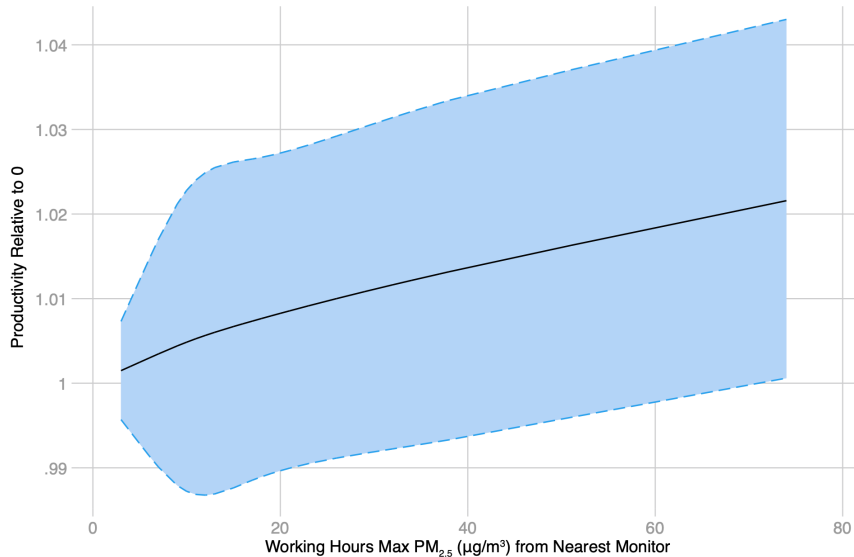
O₃ Concentration Response Function

[► Back to identification](#)

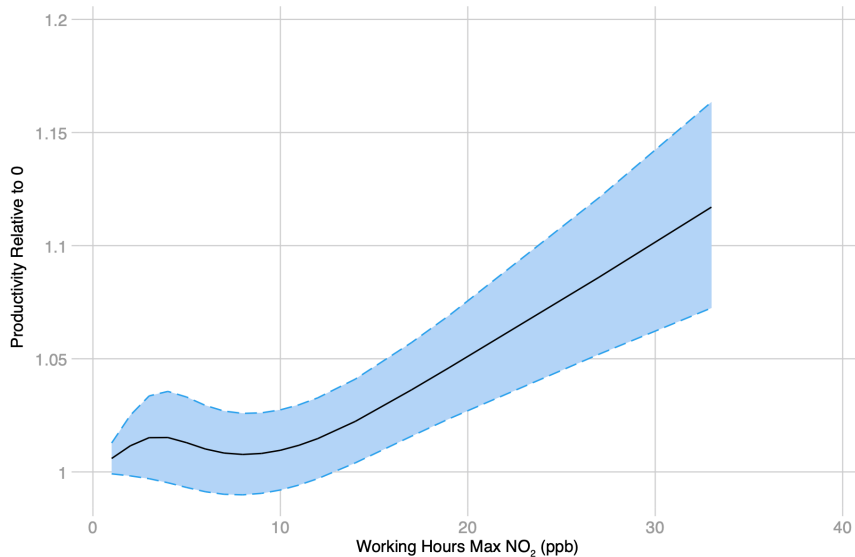
Kriged PM_{2.5} Concentration Response Function

[▶ Back to identification](#)

PM_{2.5} Concentration Response Function, Nearest Monitor

[► Back to identification](#)

NO₂ Concentration Response Function

[▶ Back to identification](#)

Main Specification, Nearest Monitor PM_{2.5}

► Main Results

	(1)	(2)	(3)
Max PM _{2.5} Nearest Monitor	0.0003 (0.0002)	0.0002 (0.0002)	0.0002 (0.0002)
Max Ozone	20.9741** (8.6146)	22.4712*** (8.6117)	22.9335*** (8.6153)
Max Ozone Squared	-551.9999*** (191.9809)	-581.7347*** (191.6664)	-587.6546*** (191.9796)
Max Ozone Cubed	4242.8751*** (1351.5015)	4443.9334*** (1350.0195)	4451.2892*** (1352.9149)
Max NO ₂	-0.0020 (0.0021)	-0.0017 (0.0021)	-0.0013 (0.0021)
Max NO ₂ Squared	0.0002** (0.0001)	0.0002** (0.0001)	0.0002* (0.0001)
Observations	625080	625080	625080
Adjusted R ²	0.8530	0.8535	0.8534
All Controls & FE	Y	Y	Y
Weather Splines	N	Y	N
Quadratic Weather	N	N	Y

Identification Concern 3: Measurement Error

Are nearby pollution monitors accurate for the farms?

▸ Monitor directions & distance

Identification Concern 3: Measurement Error

Are nearby pollution monitors accurate for the farms?

▸ Monitor directions & distance

⇒ Interactions with wind speed and direction do not change results

Identification Concern 4: Simultaneity

Does the farm have higher contributions to air pollution concentrations on high productivity days?

Identification Concern 4: Simultaneity

Does the farm have higher contributions to air pollution concentrations on high productivity days?

⇒ Comparison of kriged and nearest monitor $PM_{2.5}$

Main Specification: Comparison of Kriged and Nearest Monitor

	Kriged PM _{2.5}	Nearest Monitor PM _{2.5}
PM _{2.5}	-0.0029* (0.0015)	0.0003 (0.0002)
Max Ozone	23.1505*** (8.5267)	20.9741** (8.6117)
Max Ozone Squared	-596.6356*** (191.5308)	-551.9999*** (191.9809)
Max Ozone Cubed	4546.8954*** (1356.5162)	4242.8751*** (1351.5015)
Max NO ₂	-0.0017 (0.0020)	-0.0020 (0.0021)
Max NO ₂ Squared	0.0002* (0.0001)	0.0002** (0.0001)
Observations	633163	633163
Adjusted R^2	0.8507	0.8513
All Controls & FE	Y	Y
Weather Splines	N	Y
Quadratic Weather	N	Y

Identification Concern 4: Simultaneity

Does the farm have higher contributions to air pollution concentrations on high productivity days?

⇒ Comparison of kriged and nearest monitor $PM_{2.5}$

⇒ Yes, but only for $PM_{2.5}$

Nearest Monitors Distance and Direction [▶ Back to identification](#)

Farm	Pollutant	Distance (KM)	Direction	% Upwind	% Downwind
North	PM _{2.5}	19.6	SE	2.0	11.3
South	PM _{2.5}	2.8	NW	86.8	2.3
North	NO ₂	19.6	SE	2.0	11.3
South	NO ₂	4.6	NE	2.3	9.2
North	O ₃	19.6	SE	2.0	11.3
South	O ₃	4.6	NE	2.3	9.2

When a farm is downwind $\Rightarrow$ pollution transported to the farms

When a farm is upwind $\Rightarrow$ pollution produced upwind of the farm and transported over the farm, pollution produced downwind from the farm, or emissions from the farm itself