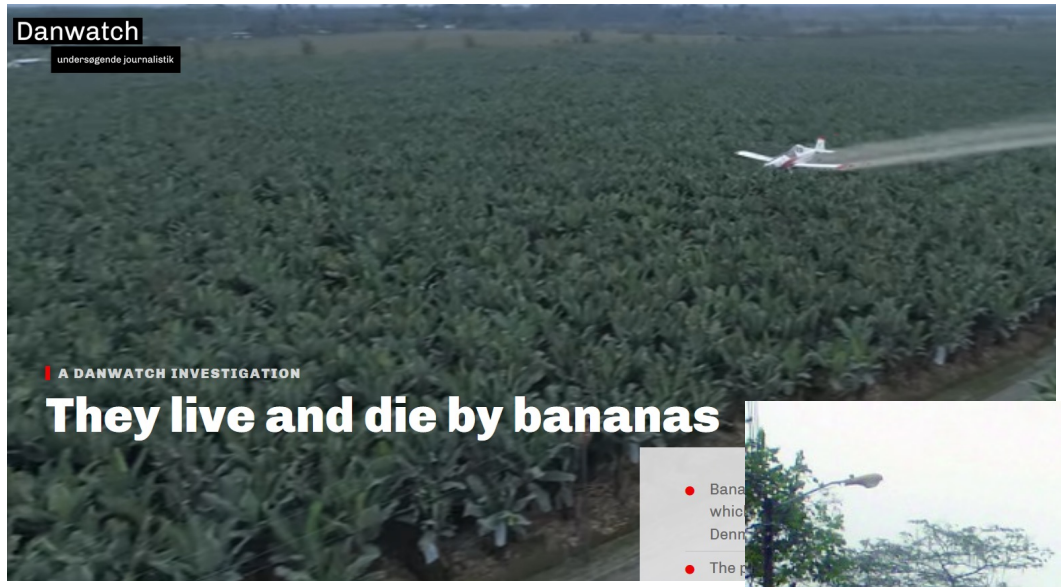
The hidden cost of bananas: The effects of pesticides on newborns' health

Joan Calzada Meritxell Gisbert

Bernard Moscoso

Center for Economic Research (CIEC) - ESPOL Polytechnic University

Research problem







- Does air fumigation in the banana plantations affect newborns' health at birth?

Outline

- Motivation
- Contribution to the literature
- Data
- Identification strategy
- Results
- Conclusion & public policy implication

Contribution to the literature

- **Pregnancy conditions affects fetal growth and potentially long-term socio-economic outcomes**
  - (Barker, 1990; Currie, 2011)
- **Environmental and air pollution affects health**
  - (Currie et al., 2009; Currie et al., 2015; Chen et al. 2013); glyphosate or atrazine use (Dias et al., 2019; Maertens, 2019); and the effectiveness of environmental regulation (Greenstone & Hannah, 2014)
- **Pesticides has negative effects on health**
  - (Harari, 2009; Del Bene et al. 2016; El-Baz et al. 2014, Wickerham et al. 2012; Marcdante & Kliegman, 2015)
- We suggest new evidence that the pesticides **pollution caused by aerial fumigation activities** in the agricultural industry have negative effect on newborns' health at birth
  - Birthweight, gestation weeks, likelihood of low birthweight (LBW) and preterm delivery

Take-away of the paper

- What are the effects of pesticides on newborns' health?
- We propose pesticides' exposure measure with spatial buffering: **distance & surrounding surface**
- We exploit three identification strategies to solve for endogeneity on pesticides exposure:
  - Seasonality analysis (main)
  - Mother fixed effects
  - Comparison with other crops
- Suggestive evidence of the effects of pesticides on newborns' birthweight:
  - Birthweight is reduced by around 80 to 150 grams when the newborn is in-utero exposed
  - Stronger effects during first and second trimester of gestation

Data

- We exploit 4 available datasets:
  - Newborns' yearly registry
  - Banana plantations census
  - Pesticides use from "Ecuadorian air activity registry"
  - Satellite map of other crops plantations

Newborns data

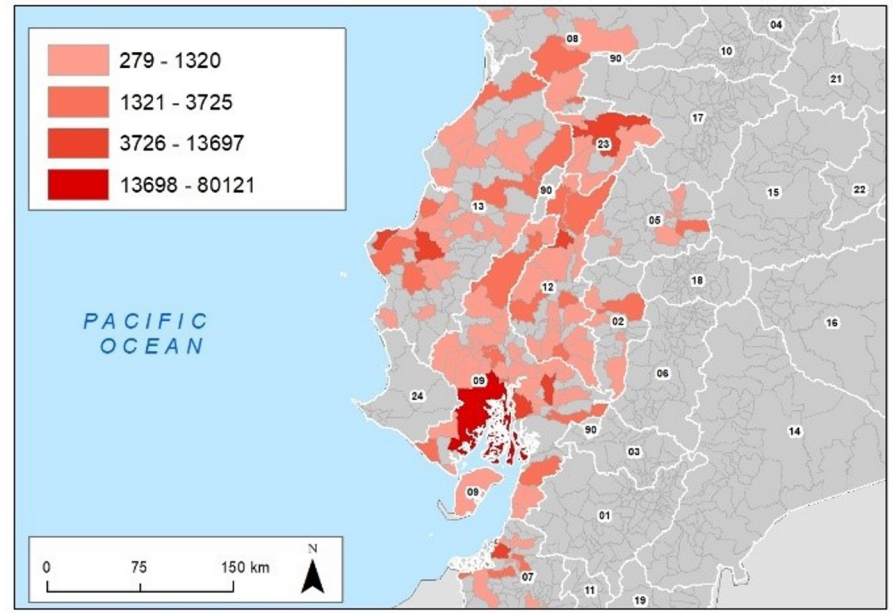
- Information of the mother: marital status, ethnic group, education, where labor took place, prenatal controls, c-section dummy.
- Newborns' characteristics: birthweight, gestation weeks, preterm, LBW
- From 2015 the registry includes the exact address of mother's place of residence during pregnancy: X,Y coordinates
- We study the pesticides effects on newborns' birthweight from years 2015 to 2017

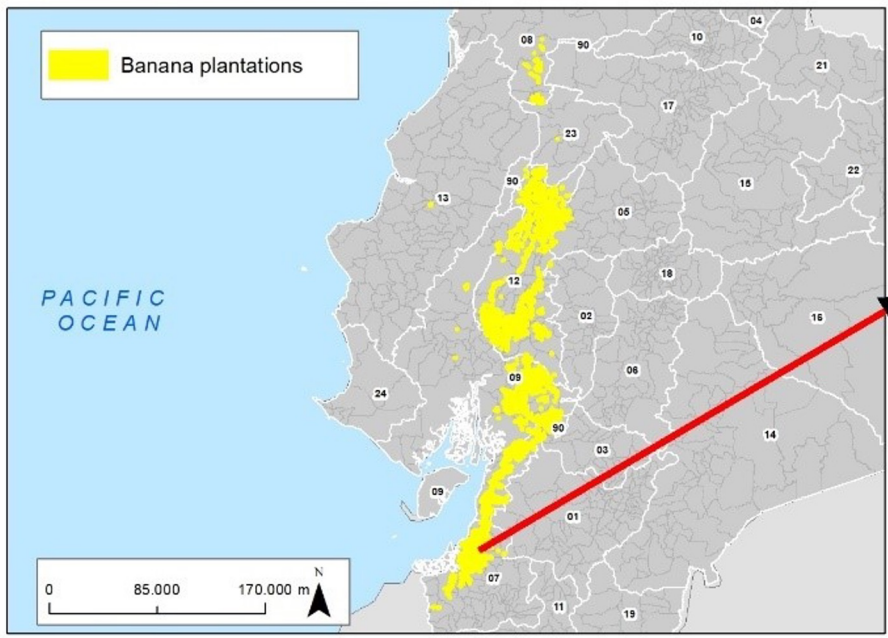
Plantations data

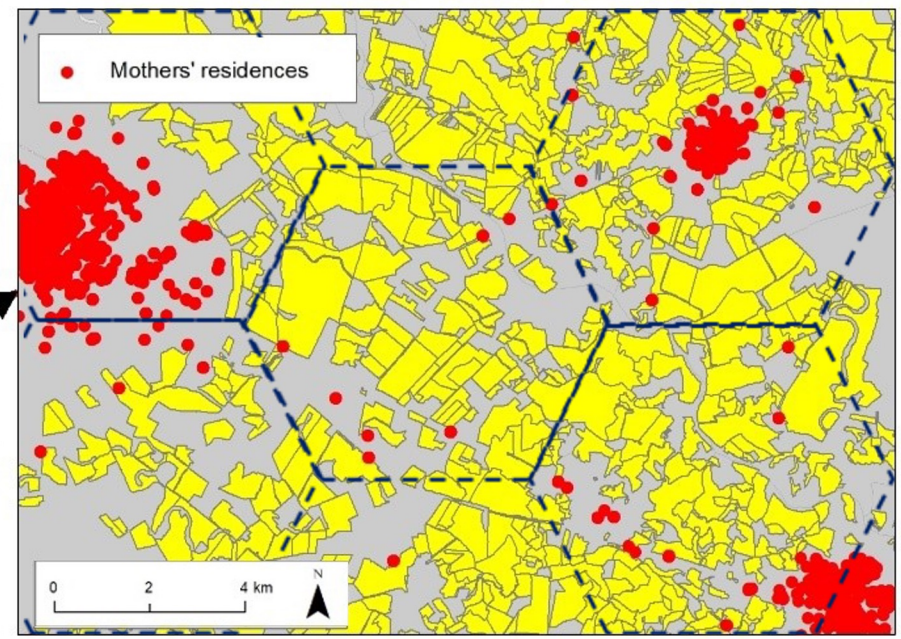
- 2013 Census of banana plantations from MAGAP:
  - Highest demand of agrochemicals
  - Nearly 7,400 banana plantations in total
  - Around 70% of the plantations uses aerial fumigation (using airplanes or helicopters)
  - Exact location (polygon maps) of plantations

- 2016 satellite map of other crops
  - Rice, corn and cocoa
  - Manual fumigation (not intensive)


Nicaragua
Costa Rica
Panama
Colombia
Venezuela
Guyana
Suriname
French Guiana
Ecuador
Peru
Brazil
Bolivia
Chile
Argentina
Uruguay
PACIFIC OCEAN
ATLANTIC OCEAN
0
1.375
2.750 km
N


279 - 1320
1321 - 3725
3726 - 13697
13698 - 80121
PACIFIC OCEAN
0
75
150 km
N

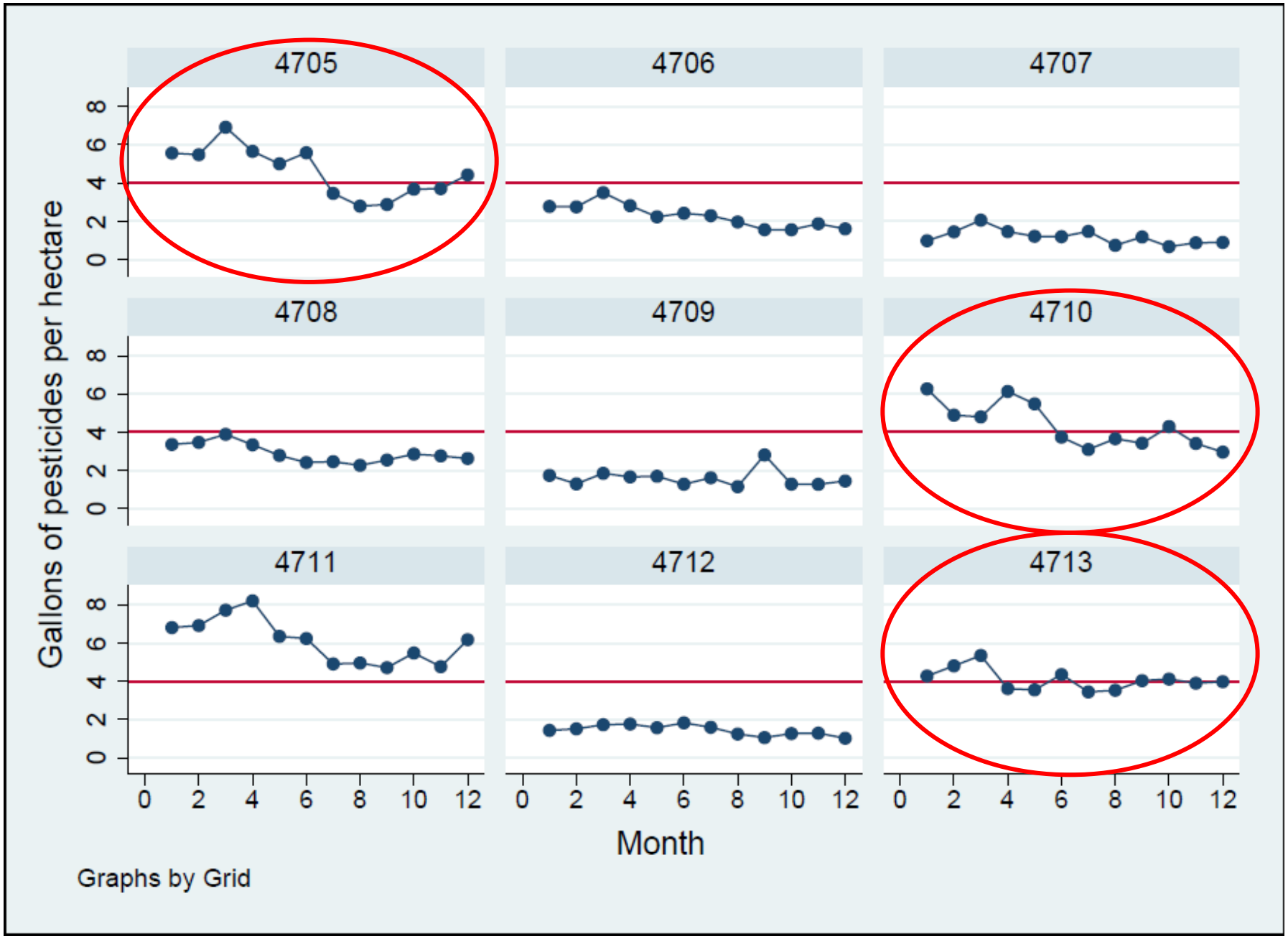

Banana plantations
PACIFIC OCEAN
0
85.000
170.000 m
N


Mothers' residences
0
2
4 km
N

Air fumigation registry

- 2016-2018 registry of pesticides use from the "Ecuadorian aerial activity registry"
  - X,Y coordinates of the application of pesticides
  - Type of pesticides, toxicity and quantity in gallons: 6.7 to 7.8 Millions gallons per year.
  - Nearly 90% are organophosphorus pesticides (moderate to high toxic)

- We compute pesticides dosage profiles (Gal/Ha) at the grid cell level


4705
4706
4707
4708
4709
4710
4711
4712
4713
Gallons of pesticides per hectare
0
2
4
6
8
0
2
4
6
8
10
12
Month
Graphs by Grid

Empirical strategy: Seasonality analysis

- $BananaExposure_i = \begin{cases} 1\ if\ Exposure\ Buffer_{b_i} \geq \frac{Exposure\ Buffer_{b_i}}{n_{b_i}}\ s.t.\ distance_i \leq 150 \\ 0\ if Exposure\ Buffer_{b_i} < \frac{Exposure\ Buffer_{b_i}}{n_{b_i}}\ s.t.\ distance_i \geq 150 \end{cases}$

- $Intense\ Fumigation_i = \begin{cases} 1\ if\ Gestation\ months\ matches\ intense\ fumigations \\ 0\ Otherwise \end{cases}$

- Sample to analyze

$$S = \{\, i : 1\,[0 \leq Distance \leq 2500]_i = 1 \,\}$$

- Compare the difference between newborns, whose gestation stages matches the months with intense fumigations, relative to the exposed newborns whose gestation stages occurs during months with normal levels of fumigations, and the rest of newborns.

Empirical strategy: Seasonality analysis

$$Y_{ijmy} = \beta_0 + \beta_1 Banana\ Exposure_{ijmy} + \sum_{z=1}^{3} \beta_z\, Z^{th}\ Intense\ Fumigations_{ijmy}$$

$$+ \sum_{z=1}^{3} \boldsymbol{\theta_z}\, Banana\ Exposure_{ijmy} * Z^{th}\ Intense\ Fumigations_{ijmy} + \delta X_i + \mu_j + \psi_m + \phi_y + \varepsilon_{ijmy}$$

- Coefficient of interest θ capture the net effect of the increase in the intensity of fumigations on the newborns gestated in the exposure area during the Z^{th} gestation trimester.
- X_i represents mothers and newborns' characteristics.
- Fixed Effects: Birth cohort (m, y), grid cell (j).
- Bootstrapped S.E. (1000 reps), clustered at the grid cell level.

Table 2 - Effects of the seasonal intensification of fumigations on birth weight and gestation weeks

	Birthweight					
	(1)	(2)	(3)	(4)	(5)	(6)
Banana Exposure	-48.58	0.998	-37.59	-33.93	-49.38	-5.965
	(39.57)	(50.21)	(47.72)	(43.96)	(51.55)	(47.67)
Intense fumigation during pregnancy		29.64***				
		(10.09)				
Banana Exposure x Intense fumigation during pregnancy		-80.02***				
		(30.81)				
Intense fumigation during 1st Trimester			17.58			24.19*
			(14.23)			(14.03)
Intense fumigation during 2nd Trimester				14.34		20.09
				(15.04)		(15.65)
Intense fumigation during 3rd Trimester					8.135	18.26
					(17.88)	(16.27)
Banana Exposure x Intense fumigation during 1st Trimester			-47.44**			-74.29**
			(20.58)			(32.61)
Banana Exposure x Intense fumigation during 2nd Trimester				-63.09***		-75.40***
				(20.40)		(24.44)
Banana Exposure x Intense fumigation during 3rd Trimester					4.933	-43.17
					(23.54)	(37.84)
Mother's controls	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X
Grid F.E.	X	X	X	X	X	X
Observations	21,393	21,393	21,393	21,393	21,393	21,393
R2	0.1096	0.1102	0.1098	0.1100	0.1096	0.1104
Number of Clusters	151	151	151	151	151	151

Table 3 - Effects of the seasonal intensification of fumigations on birth weight and gestation weeks

	OLS fixed effects		Logit fixed effects			
	Gestation weeks		Preterm		Low birth weight	
	(1)	(2)	(3)	(4)	(5)	(6)
Banana Exposure	0.0482	0.106	1.250	1.252	1.304	1.249
	(0.153)	(0.154)	(0.360)	(0.281)	(0.287)	(0.248)
Intense fumigation during pregnancy	0.0125		0.829**		0.791***	
	(0.0385)		(0.0710)		(0.0648)	
Banana Exposure x Intense fumigation during pregnancy	-0.0183		1.426		1.429**	
	(0.105)		(0.400)		(0.259)	
Intense fumigation during 1st Trimester		0.0631*		0.747**		0.714***
		(0.0366)		(0.106)		(0.0902)
Intense fumigation during 2nd Trimester		-0.0417		1.029		0.849*
		(0.0580)		(0.155)		(0.0822)
Intense fumigation during 3rd Trimester		-0.00557		0.989		0.869*
		(0.0375)		(0.103)		(0.0668)
Banana Exposure x Intense fumigation during 1st Trimester		-0.142**		1.470**		1.568***
		(0.0677)		(0.269)		(0.221)
Banana Exposure x Intense fumigation during 2nd Trimester		-0.121*		1.461*		1.799***
		(0.0728)		(0.293)		(0.246)
Banana Exposure x Intense fumigation during 3rd Trimester		-0.0594		1.319		1.204
		(0.0686)		(0.229)		(0.176)
Mother's controls	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X
Grid F.E.	X	X	X	X	X	X
Observations	21,393	21,393	20,871	20,871	21,086	21,086
R2	0.0842	0.0850	-	-	-	-
Pseudo-R2	-	-	0.1161	0.1170	0.1170	0.1180
Number of Clusters	151	151	91	91	99	99

Robustness & tests

- **Mother fixed effects: All mothers and sub-sample of mothers that stay**

Empirical strategy: Seasonality analysis

$$Y_{ijkmy} = \beta_0 + \beta_1 Banana\ Exposure_{ijkmy} + \sum_{z=1}^{3} \beta_z\, Z^{th}\ Intense\ Fumigations_{ijkmy}$$

$$+ \sum_{z=1}^{3} \boldsymbol{\theta_z}\, Banana\ Exposure_{ijkmy} * Z^{th}\ Intense\ Fumigations_{ijkmy} + \delta X_i + \mu_j + \varphi_k + \psi_m + \phi_y + \varepsilon_{ijkmy}$$

- Coefficient of interest θ capture the net effect of the increase in the intensity of fumigations on the newborns gestated in the exposure area during the Z^{th} gestation trimester.
- X_i represents mothers and newborns' characteristics, and birth order and intervals.
- Fixed Effects: Birth cohort (m, y), grid cell (j), mother (k).
- Bootstrapped S.E. (1000 reps), clustered at the grid cell level.

Table 5 - Effects of the seasonal intensification of fumigations on birth weight and gestation weeks – Maternal fixed effects

	Birth weight					Gestation weeks				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Banana Exposure	38.04		77.94	109.5		-0.711		-0.643	-0.346	
	(154.9)		(176.5)	(186.2)		(0.679)		(0.727)	(0.815)	
Intense fumigation during pregnancy		-10.72	13.04				0.479**	0.535**		
		(59.25)	(66.84)				(0.231)	(0.252)		
Banana Exposure x Intense fumigation during pregnancy			-122.4					-0.268		
			(129.1)					(0.438)		
Intense fumigation during 1st Trimester				121.2	90.25				0.574	0.396
				(97.20)	(101.2)				(0.365)	(0.323)
Intense fumigation during 2nd Trimester				-94.10	-130.5				0.146	0.322
				(111.2)	(100.6)				(0.429)	(0.545)
Intense fumigation during 3rd Trimester				64.10	74.84				0.702*	0.674*
				(103.7)	(121.5)				(0.399)	(0.398)
Banana Exposure x Intense fumigation during 1st Trimester				-327.0*	-319.0***				-1.539*	-1.614***
				(175.2)	(108.2)				(0.795)	(0.406)
Banana Exposure x Intense fumigation during 2nd Trimester				92.60	163.8				-0.156	-0.439
				(135.0)	(141.4)				(0.540)	(0.492)
Banana Exposure x Intense fumigation during 3rd Trimester				-246.2	-239.3				-1.407**	-1.508***
				(179.4)	(147.6)				(0.647)	(0.511)
Mother's controls	X	X	X	X	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X	X	X	X	X
Maternal to Grid F.E.	X	X	X	X	X	X	X	X	X	X
Observations	1,961	1,961	1,961	1,961	1,567	1,961	1,961	1,961	1,961	1,567
R2	0.861	0.861	0.861	0.862	0.873	0.848	0.848	0.849	0.850	0.879
Number of mothers	970	970	970	970	777	970	970	970	970	777

Conclusion

- We contribute to the literature that analyzes the effect of environmental pollution through the effect of pesticides on newborns health

- We suggest new evidence from pollution caused by air fumigation industry
  - In-utero exposed newborns' birthweight is reduced by around 80 to 150 grams
  - Pesticides have a stronger effect when exposure occurs in the first and second gestation trimester
  - The results are robust when considering other specifications

- Distance matters, but the surrounding area and the length of exposure matters much more!

Public policy implications

- Results suggest that the regulations, if any, have not generated the expected results on birth weight:
  - Review, control and enforce regulation on traded agrochemicals
  - Non-compliance – There's a need to enforce it and to make it effective
  - Reconsider and redesign the protection distance
  - Introduction of protection protocol targeted to pregnant woman living or working close to plantations

Thank you

Contact: hmoscoso@espol.edu.ec

@henry_bernard

Robustness & tests

- **Mother fixed effects: All mothers and sub-sample of mothers that stay**
  - Learning effect? → No learning effect when exposed to interaction term
- Selection into gestation timing
- Variation in the exposure thresholds → Shorter/larger threshold denotes a lower/higher effect, respectively.
- Direct measure of pesticide pollution: Buffers with data on aerial fumigation of pesticides → Same results
- Dognut design (excluding those between 150 to 250 meters from plantations) → Results enhancement
- Placebo test with other crops → No significant results
- Falsification tests → No significant results