The unequal effect of pollution exposure on labour supply across gender

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12th April 2023

WIDER Seminar Series

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Introduction

This Article

Q: **Does pollution have an effect on labor supply? Does it differ by gender and employment type?**

Setting: Mexico city, between 2005 and 2010

Data: Daily maxima from 20+ pollution measurement stations as well as information on extreme pollution events, these are matched to individual exposure at the census block level in a large, city-representative labour force survey.

Approach: RDD and fixed effects model of daily labor supply and pollution

Findings: Still work-in-progress, but more pollution seems to decrease working hours even in non-emergency times

1. Differential effect by gender: there is an unequal gendered response to pollution exposure. For female workers the income effect dominates, and thus labour supply increases at high levels of pollution;
2. Male workers have a different trajectory:their minutes worked trajectory reduce as pollution rises

Literature

Introduction

- Recent contributions from economists focus on identification of mortality and health effects employing natural experiments, administrative data and expand the attention to school and labour market outcomes:
  - **Identification:** Policy shocks (e.g., Chay and Greenstone (2003)), wind direction or temperature inversions (e.g., Deryugina et al. (2019))
  - **Outcomes:** School absenteeism and test scores (e.g., Lavy et al. (2014)); labour productivity of outdoor and indoor workers (e.g., Graff Zivin and Neidell (2012); Chang et al. (2016); He et al. (2019); hours worked (e.g. Aragón and Rud (2016)); Earnings (e.g. (Isen et al., 2017)); cognition, e.g. exam performance (e.g. Stafford (2015); Ebenstein et al. (2016); Zhang et al. (2018)); poverty (Persico, 2022);

Literature on labour market outcomes

- Graff Zivin and Neidell (2012); Chang et al. (2016, 2019): High pollution reduces labor supply through substitution effect.
- Leroutier and Ollivier (2022) for France finds that PM2.5 exposure increases workers' absenteeism and reduces firms' monthly sales
- Aragón et al. (2017) for Lima, Peru: Labor supply effect varies along pollution distribution and household structure. Households with more dependents in need of care are more sensitive to moderate pollution levels. There is no intra-household re-allocation of labor so that earnings decline.
- Hoffmann and Rud (2022) for Mexico City: Negative effect on same-day labor supply; effect larger on high-pollution days; workers compensate by working more later; informal workers reduce supply by less and compensate less leading to overall income loss. Interpretation: avoidance behaviour and income constraints matter.

Mechanisms and heterogeneity

- City "shut down" effect
- Direct health effect on workers with preconditions (e.g., asthma, vascular diseases)
- Direct and subtle health effects on "healthy" workers
- Increased demand for care-giving could differ by gender (Aragón et al., 2017)
- Work type (self-employed vs wage worker), informality status (Hoffmann and Rud, 2022) and employer (public *vs* private) imply differences in labor demand and supply decisions.

Theoretical framework

How should we think about pollution?

Lifting a model from Hanna and Oliva (2015). Partial Eq model where individuals maximise utility with respect to consumption c and hours worked e. Utility is given by

$$u = u(c, e; \alpha)$$

nb: e is 'bad' such that $u_e < 0$ and $u_c > 0$. Utility is assumed to be concave.

Air quality, α, is an argument of the utility function and affects consumption and hours worked.

Better air quality lowers disutility of work $u_{ea} > 0$ But effect can be ambiguous: better air quality may improve consumption ($u_{c\alpha} > 0$; think of amusement rides, or outdoor shopping). However, better air quality may also reduce marginal utility of consumption ($u_{c\alpha} < 0$; if say asthma medication or gym is substitute for clean air.)

Optimisation Problem

Using indirect utility approach one can write:

$$\max \nu(e) = \lambda(\alpha) \cdot we - g(e;\alpha)$$

Where w is wages in time t. NB: individuals are wage takers, and wages are assumed to be unaffected by pollution.

Marginal utility of lifetime income along optimal path is represented by $\lambda(\alpha)$

$g(e;\alpha)$ is disutility of hours for a given air quality

$$g(e;\alpha) = -\int_0^e u_e(x;\alpha)dx$$

The effect of pollution on hours worked

Solution to the FOC:

$$g_e(e;\alpha) = \lambda(\alpha)w$$

given the additive separability of hours and work, the change in hours worked as air quality increases is:

$$\frac{de}{d\alpha} = \frac{\overbrace{-g_{e\alpha}}^{\text{substitution effect}} + \overbrace{\frac{\partial\lambda}{\partial\alpha}w}^{\text{income effect}}}{g_{ee}}$$

Partial eq. model predicts that $\uparrow$ air quality should produce $\uparrow$ in hours worked, unless a negative income effect dominates.

PM2.5

Hoy No Circula

Pollution in Mexico city is bad. In 1990 the city introduced it's flagship pollution abatement programme: Hoy no circula (HNC).

▸ HNC Detail

Did it work?

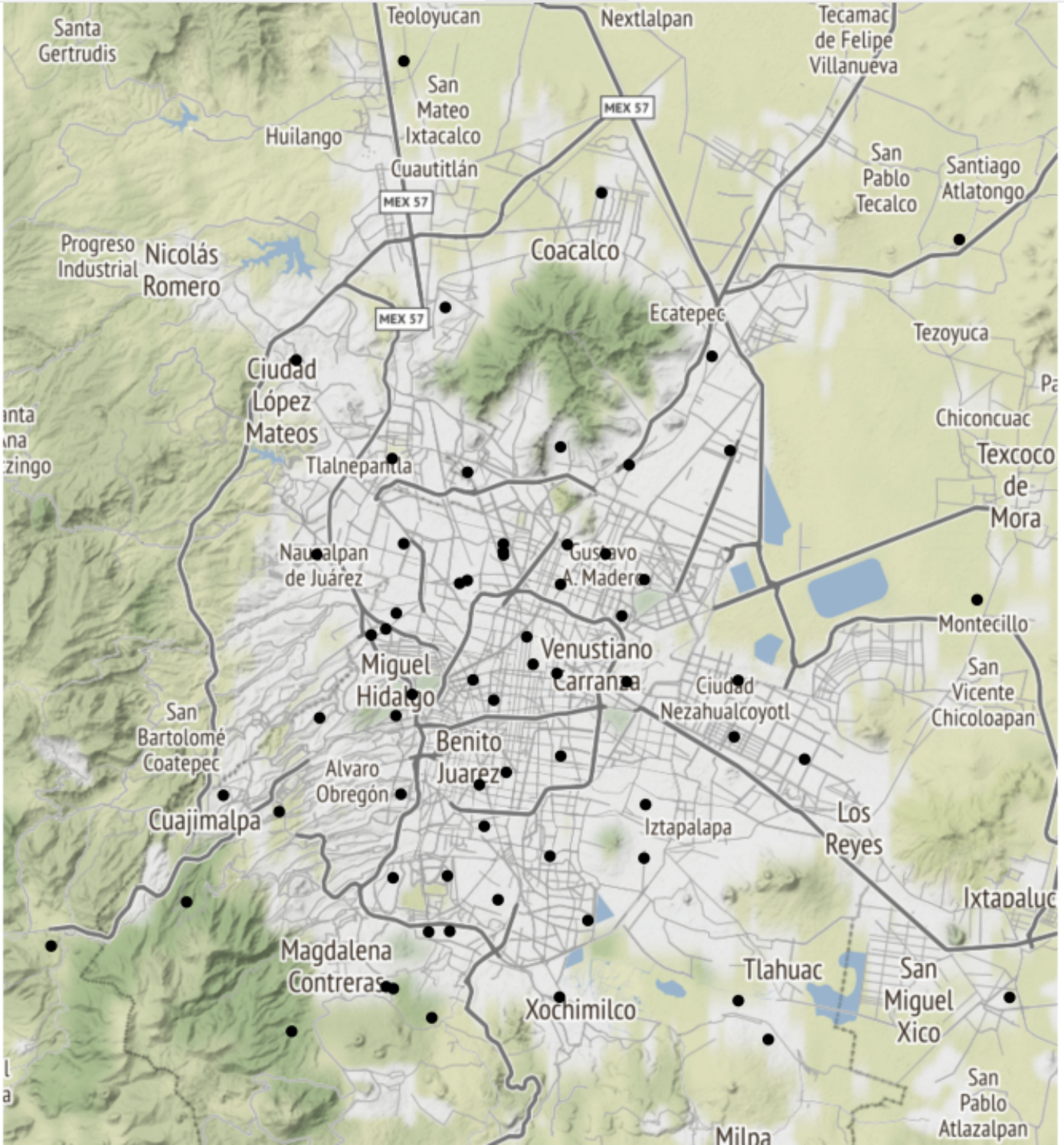
Not in the short-run for pollution: according to Davis (2008).

What about tweaks at the margin (Saturday restrictions)?

- Davis (2017) again finds nothing. Not even substitution to other forms of transport.
- Oliva (2015) finds that there is rife cheating in emissions testing. So even if it did work (it does not) it wouldn't reduce pollution by as much as promised.

$\rightarrow$ Switching to newer cars = targeted pollutants reduction not associated with HNC

Data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Santiago Atlatongo
Progreso Industrial
Nicolás Romero
Coacalco
Ecatepec
Tezoyuca
Ciudad López Mateos
Chiconcuac
Texcoco de Mora
Tlalnepantla
Naucalpan de Juárez
Gustavo A. Madero
Montecillo
Venustiano Carranza
Miguel Hidalgo
Ciudad Nezahualcoyotl
San Vicente Chicoloapan
San Bartolomé Coatepec
Benito Juarez
Alvaro Obregón
Cuajimalpa
Iztapalapa
Los Reyes
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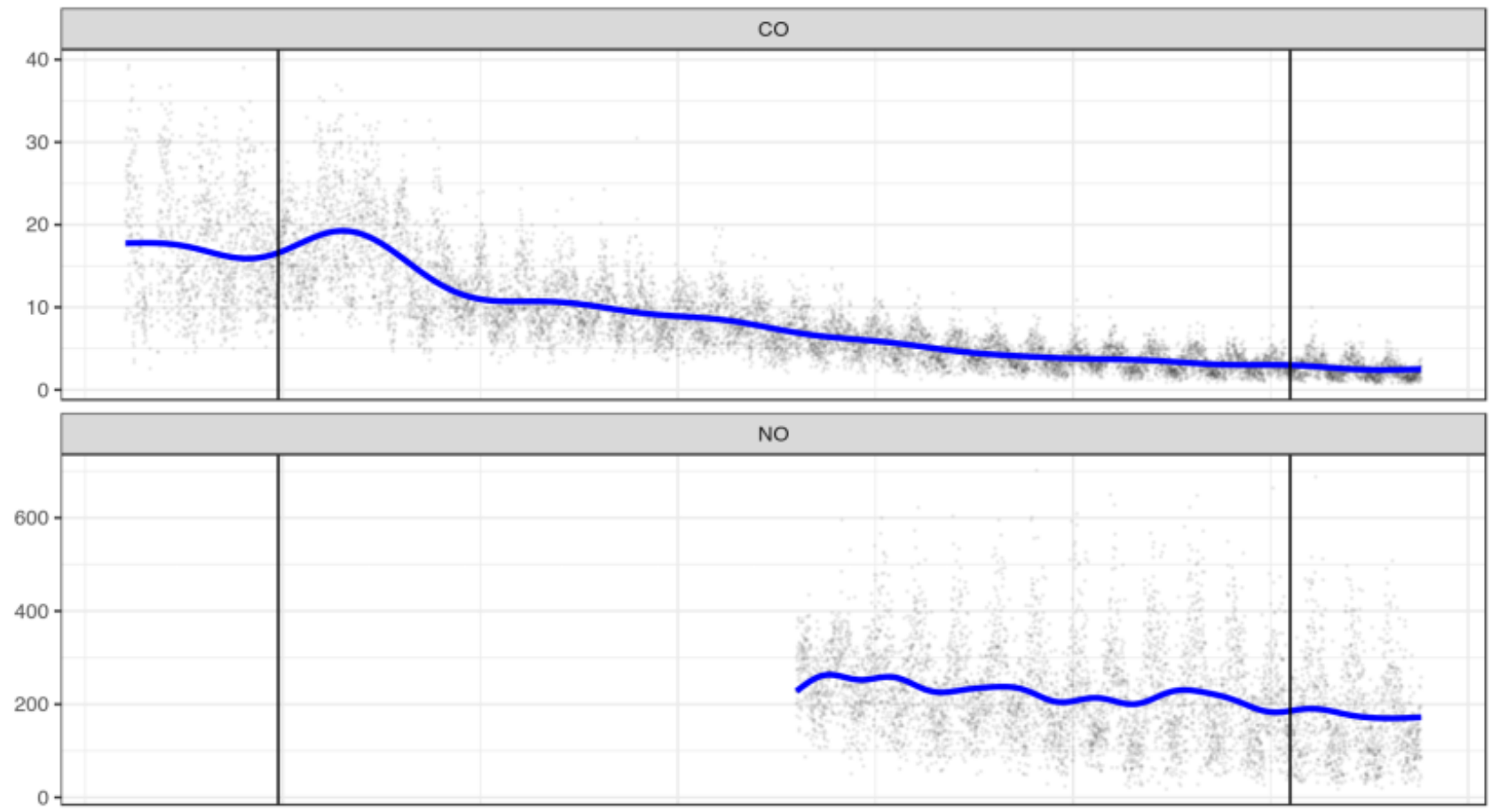
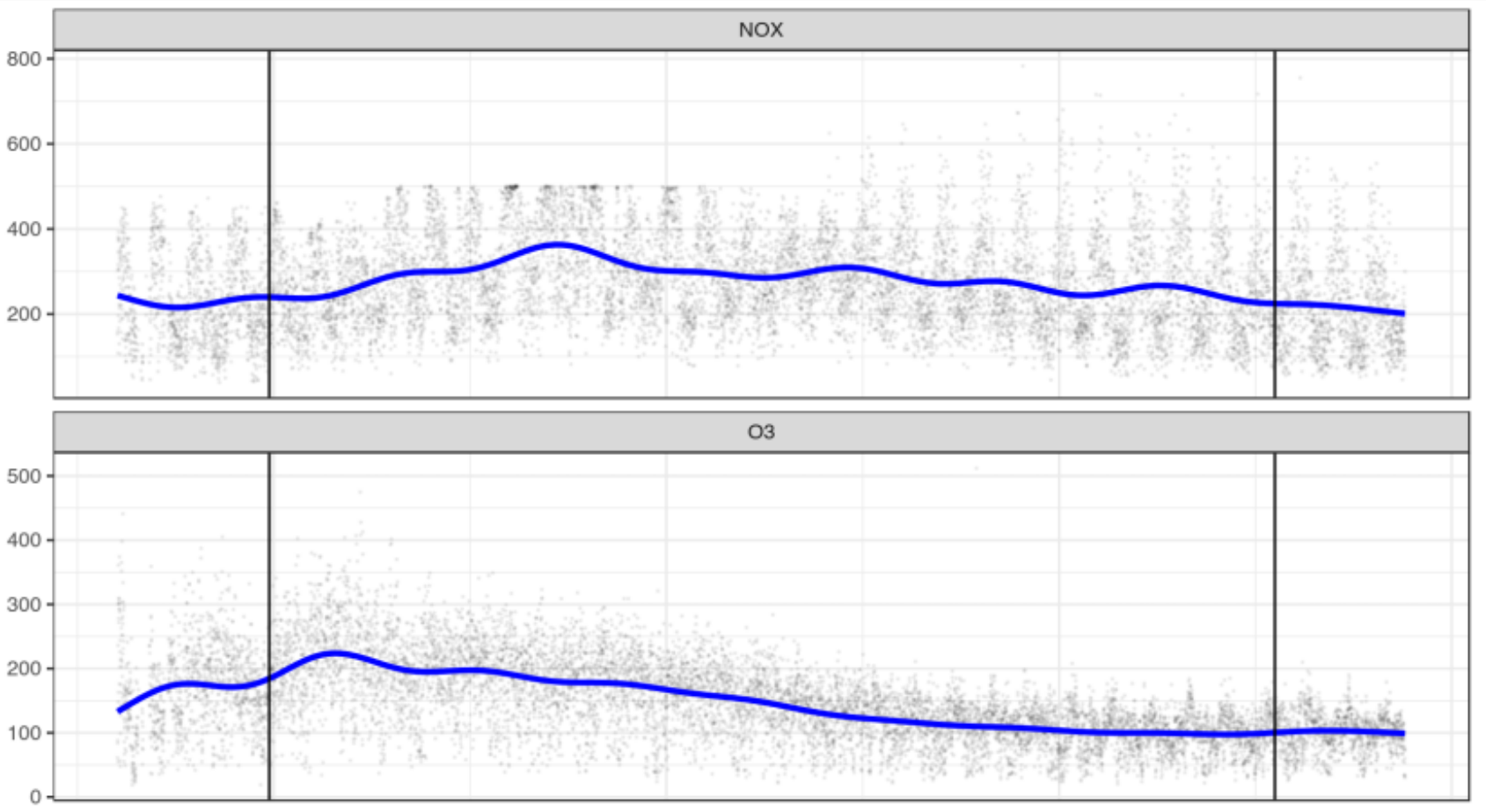
San Miguel Xico
Xochimilco
San Pablo Atlazalpan
Milpa

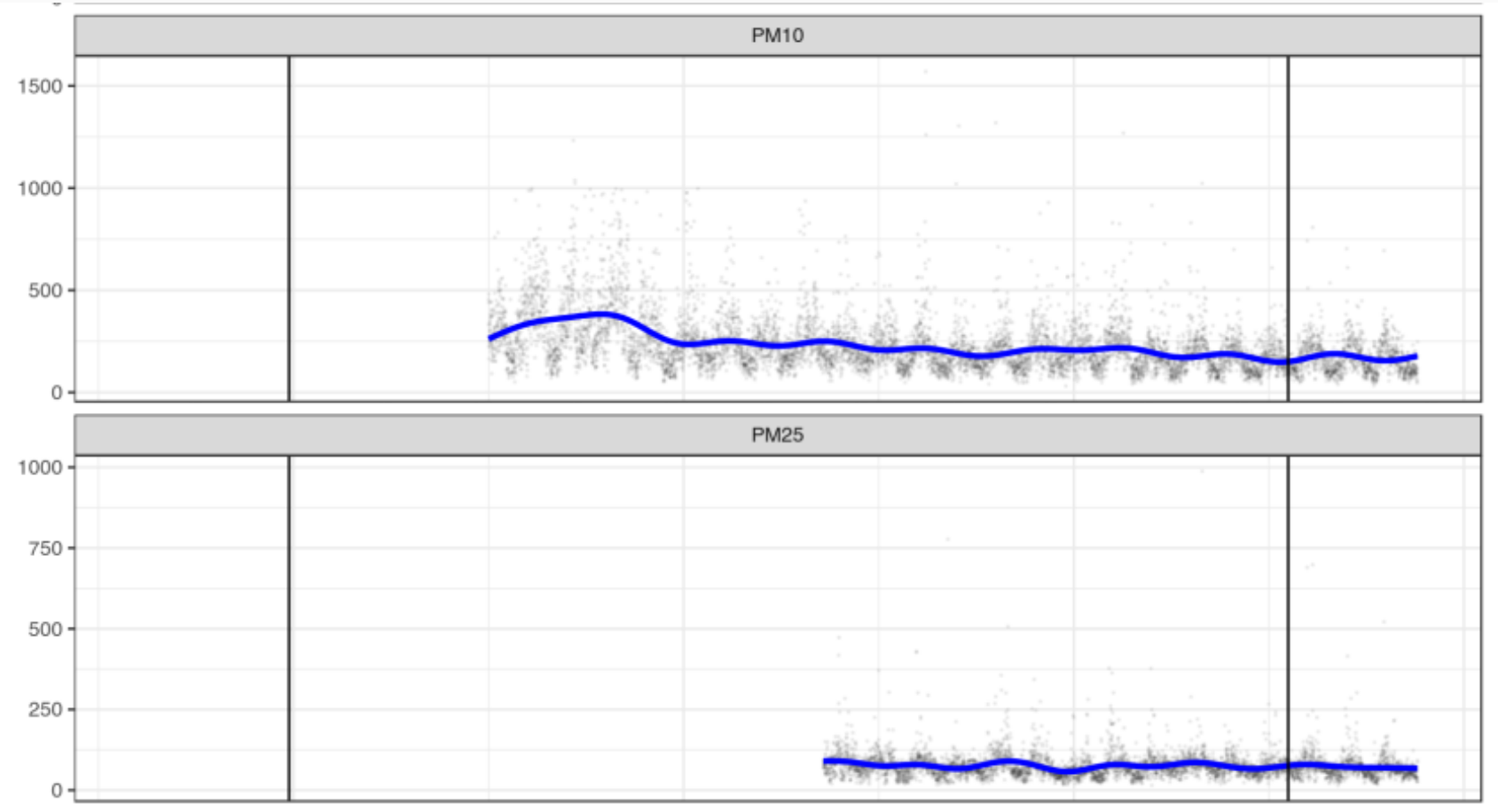
Did pollution decrease with HNC? Daily Maxima I



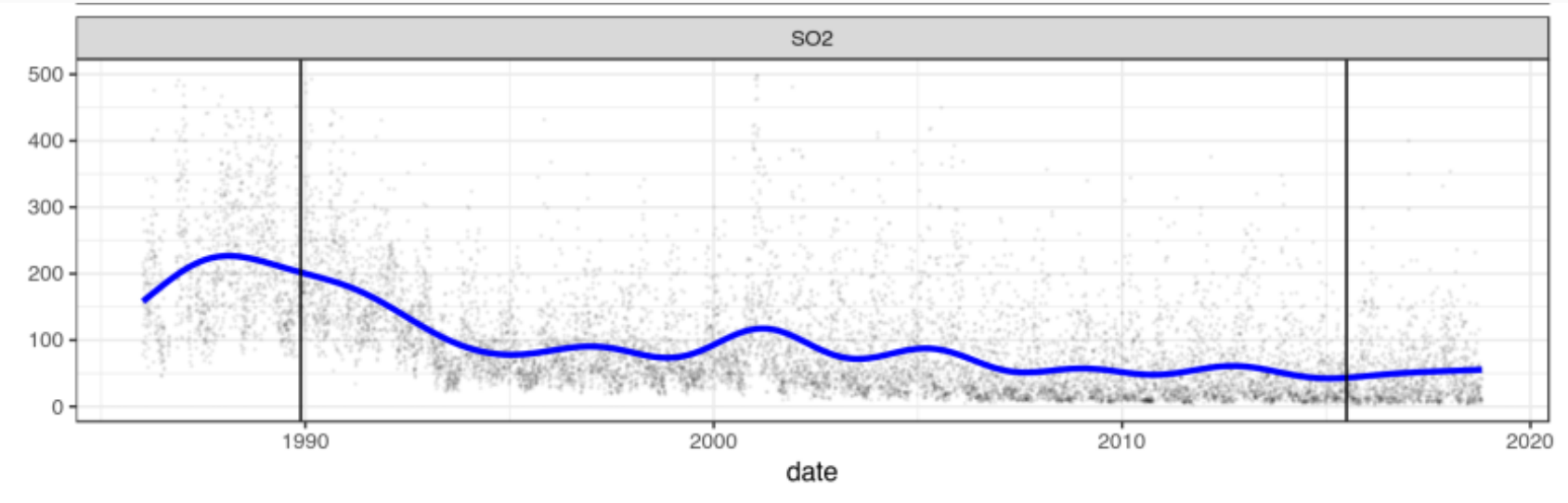
Did pollution decrease with HNC? Daily Maxima II



Did pollution decrease with HNC? Daily Maxima III



Did pollution decrease with HNC? Daily Maxima IV



Pollution Alerts

Pollution alerts (contingencies) are called when Ozone or PM10 reach a given threshold in terms of an air quality index. Crucially for the present analysis PM2.5 cannot trigger a pollution alert though it is highly likely that pollution alerts are correlated with higher than average levels of PM2.5.

There's different levels of Pollution alerts (Alerts, Amber Alerts and Red Alerts).

An Alert entails public notifications of poor air quality with voluntary action advised. Amber alert (Phase 1) traffic restrictions and limited circulation of cars. Amber alert (phase 2) all motorcycles plus all newer cars follow the HNC regime, closure of schools, some industries shut. At red alert 50% of cars called off the road and in addition all public sector work places close, school closures, all industrial activity shut down, no cars on the road except essential vehicles.

Between 2005-2010 there were no Red or Amber Alerts.

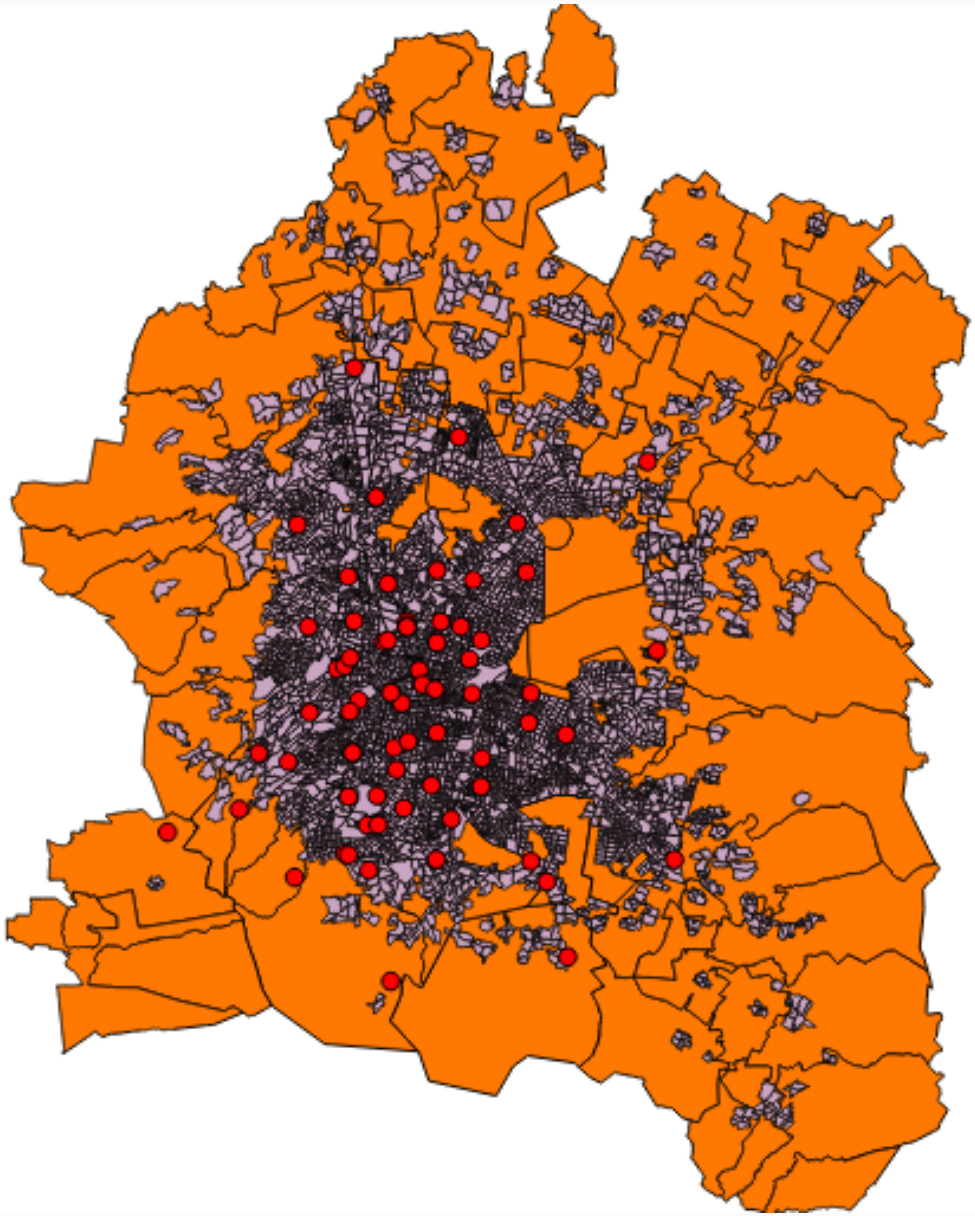
Cutpoints of AQI

IMECA AQI	Description to public	Ozone ppm	PM10 $\mu g/m^3$
0–50	Good	0.000-0.055	0–60
51–100	Normal	0.056–0.110	61–120
101–150	Bad	0.111–0.165	121–220
150–200	Very Bad	0.166–0.220	221–320
>200	Extremely Bad	>0.220	>320

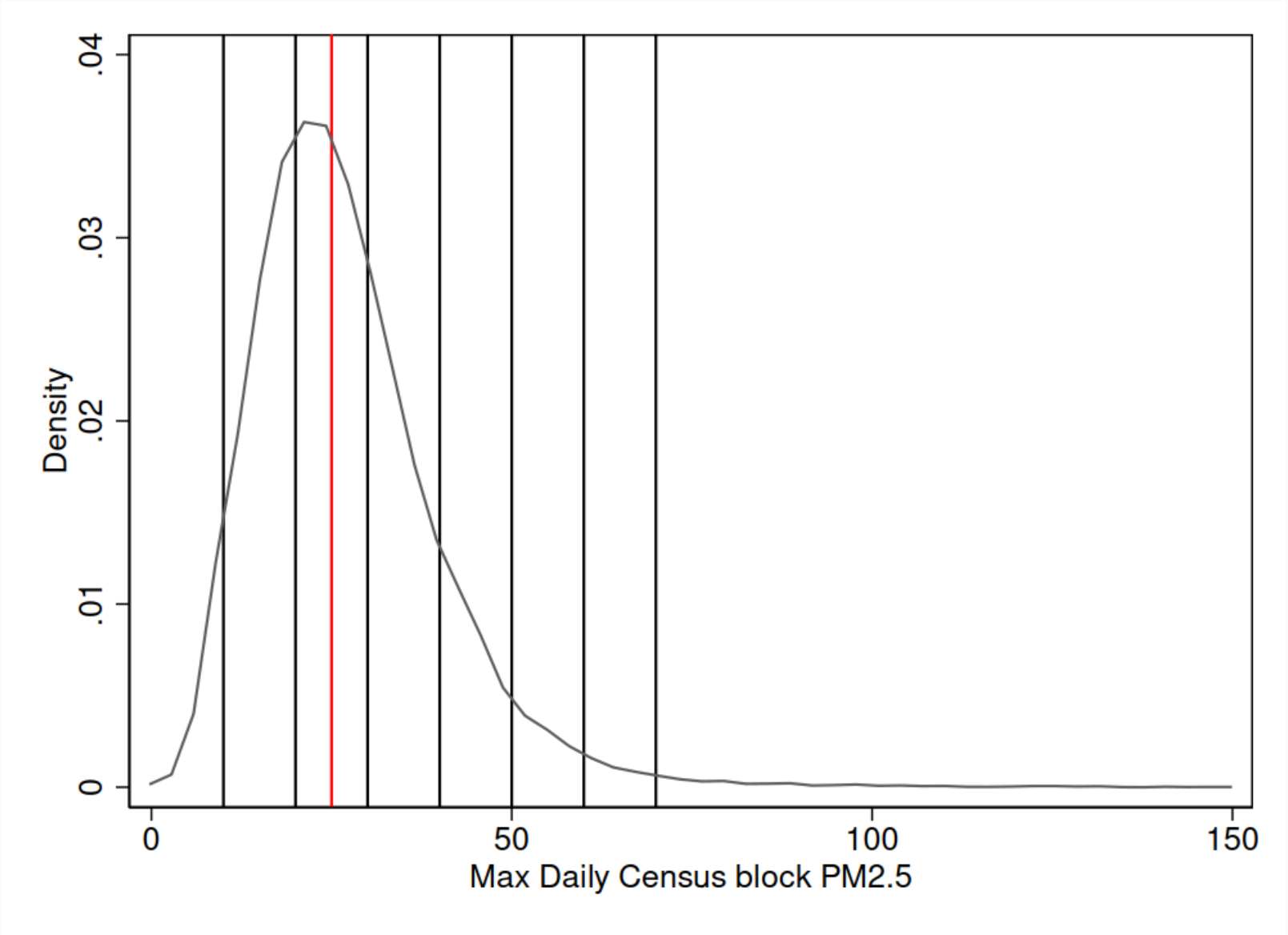
Notes: The cutpoints in this table derive from the public policy in effect during our time period of analysis and derive from Mexico city environmental norm NADF-009-AIRE-2006. Note that the cutpoints are only reported for Ozone and PM10 the two pollutants over which pollution alerts may be called. Though there exist cut points for PM2.5 for the air quality index, but these are not relevant for the activation of public policy. So for example, should PM2.5 thresholds exceed the 150 threshold there would not be a pollution amber alert called. It is worth noting that the PM10 standard used for a precontingency exceeds the Interim target 1 measure of WHO outdoor air quality standards, which is the loosest air quality standard. The Standard for bad outdoor air quality in PM10 is 20, thus for some levels described to the public as good the actual pollution level is actually harmful to public.

Mexican Employment and Occupation Survey (ENOE)

- 2005q1–2010q2
- Quarterly Household survey
- 5 qtr Rotating Panel
- Representative at city level for Mexico City
- Employed are asked about working in reference week
- For those working we have daily hours worked and normal hours
- We end up with 60,535 individuals across 18 quarters
- 423,745 individual-days
- 3k obs per quarter



Distribution of maxima PM2.5 hourly-census block



▸ Bins yearly frequency ▸ Pollution regression

Distribution of pollution in bins

bin	PM2.5 $\mu g/m^3$	Hours-census block (%)	Days-census block (%)
0	0–10	58.87	60.04
1	11–20	13.25	11.76
2	21–30	12.08	13.78
3	31–40	7.5	8.99
4	41–50	4.08	3.88
5	51–60	2.00	1.17
6	61–70	0.83	0.27
7	70+	0.67	0.12

Descriptive stats

Descriptive stats: individual characteristics by gender

	N	Total	Female	Male	t-test / χ^2
Female	60,535	0.420			
Age	60,535	39.152	38.934	39.309	-8.929
Informal (social protection)	60,535	0.574	0.565	0.581	-10.094
Informal in the informal sector	60,535	0.288	0.252	0.313	-43.555
Self-Employed	60,535	0.191	0.182	0.197	-11.881
Wage Worker	60,535	0.729	0.738	0.723	11.164
Worked Reference Week	60,535	0.450	0.456	0.445	7.512
Professional occupations	60,535	0.192	0.209	0.180	32,338.934
Managers, directors and senior officials	60,535	0.036	0.028	0.041	
Skilled trades occupations	60,535	0.252	0.120	0.348	
Administrative and secretarial occupations	60,535	0.152	0.196	0.120	
Sales and customer service occupations	60,535	0.208	0.235	0.188	
Caring, leisure and other service occupations	60,535	0.160	0.213	0.123	

Note: All t-test & χ^2 test are stat. different by gender.

Descriptive stats: individual characteristics by gender

	N	Total	Female	Male	χ^2
Manufacturing	60,535	0.144	0.128	0.157	36,243.955
Construction	60,535	0.054	0.009	0.086	
Trade	60,535	0.222	0.240	0.208	
Restaurants & Accommodation Services	60,535	0.064	0.079	0.053	
Transport, Communications, Post & Storage	60,535	0.083	0.031	0.120	
Professional, Financial & Corporate Services	60,535	0.125	0.120	0.129	
Social Services	60,535	0.113	0.175	0.068	
Diverse Services	60,535	0.119	0.148	0.098	
Government & International Organisations	60,535	0.077	0.071	0.081	

Note: All χ^2 tests are stat. different by gender.

Informality status by gender & employment

Employment Modality	Male	Female	All
Wage employment	.478	.468	.47
Self-Employment	.997	.998	.99
Private Sector	.657	.668	.66
Public Sector	.113	.104	.108

Note: All t-test stat. different by gender.

Labor supply by work status: Daily minutes worked, by gender

Employment Modality	Male	Female	All
Wage employment	404.96	340.55	377.84
Self-Employment	396.40	282.99	350.91
Private Sector	407.00	331.96	377.12
Public Sector	373.31	320.79	348.10

Note: All t-test stat. different by gender.

Person-days of pollution exposure in each bin, by gender

PM2.5 $\mu g/m^3$	Male	Female	Total
0-10	141,651	105,513	247,164
11-20	30,653	20,998	51,651
21-30	35,326	25,189	60,515
31-40	23,490	16,352	39,842
41-50	10,406	7,024	17,430
51-60	3,134	2,208	5,342
61-70	782	491	1,273
70+	314	214	528
Total	245,756	177,989	423,745

Empirical approach

Dual Strategy:

1. Policy Effects→ RDD on days near contingency
2. 'Physiological' Effects→ FE on pollution effects.

Empirical Strategy: Pollution Alerts on labour supply

Deterministically beyond some 'loose IMECA thresholds' pollution will increase in salience to the local population. Notably not actually based on PM 2.5

What effect does this pollution abatement strategy have on hours worked?

$$Y_{cit} = \beta \text{Pollution Emergency} + f(\text{daysto/from P event}) + \omega_t + u_{cit} \quad (1)$$

Where ω is a vector of time fixed effects (quarter, individual, weekday),

days to/from P event is # days until the pollution alert,

Non-linearity pollution bins

Issue of non-linearity in labour market responses to pollution (Aragón et al., 2017). Following the approach from Dell et al. (2014); Schlenker and Roberts (2009); Burke et al. (2015)

- Solution: Implement a binned structure for pollution variables to allow for a fully flexible association between pollution and outcome variables
- Common approach in recent weather literature (Guerrero Compeán, 2013; Guiteras, 2009; Graff Zivin and Neidell, 2014; Barreca et al., 2016; Burgess et al., 2014; Schlenker and Roberts, 2009)

Empirical strategy: Pollution 'Physiological' effects

- Identification strategy exploits the temporal and spatial variation of pollution
- high-dimensional fixed effect identification

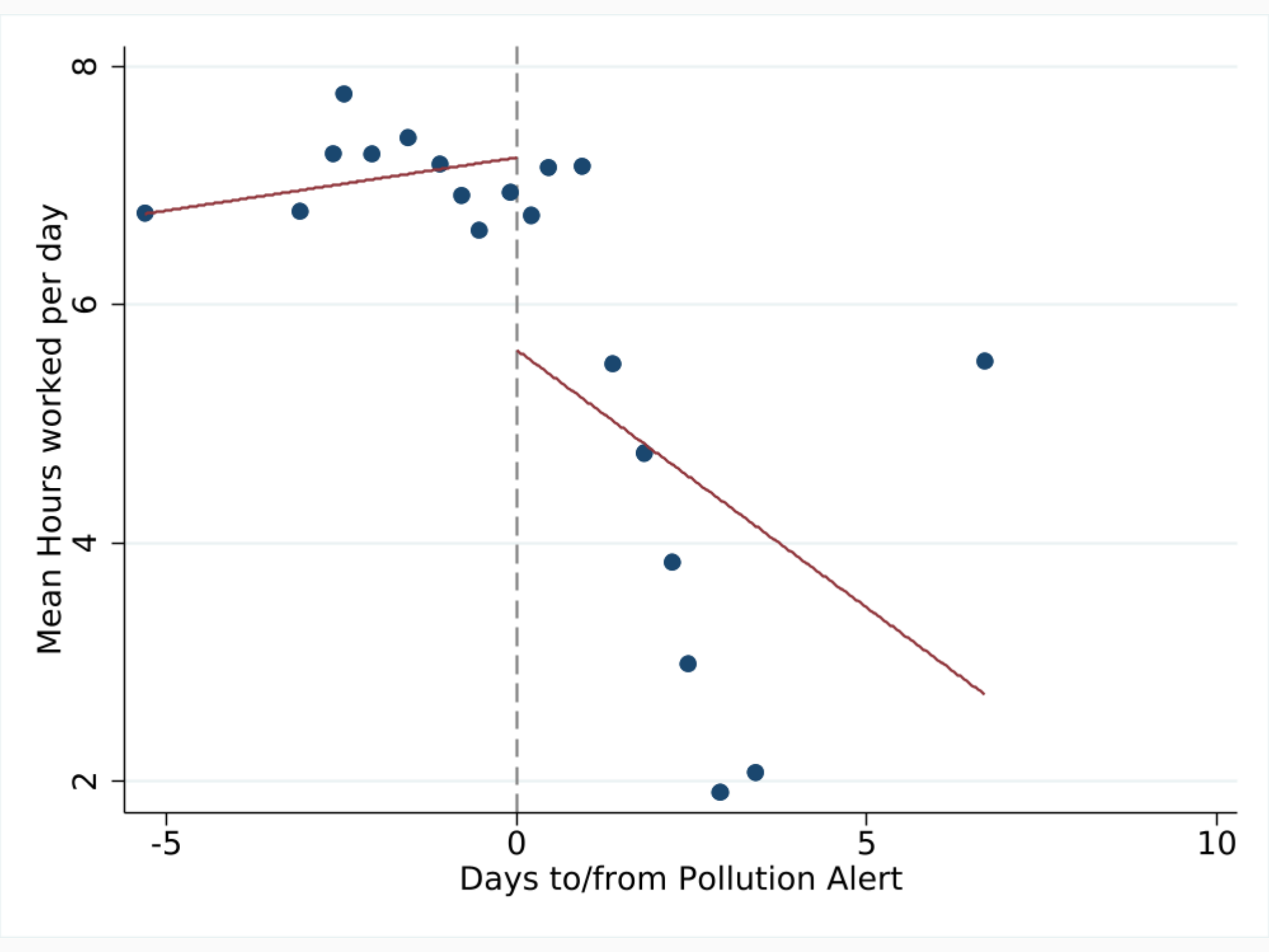
$$Y_{icdwq} = \sum_{b=1}^{B=7} \Theta E_{cd} + \alpha_i + \eta_w + \gamma_q + \epsilon_{icdwq} \tag{2}$$

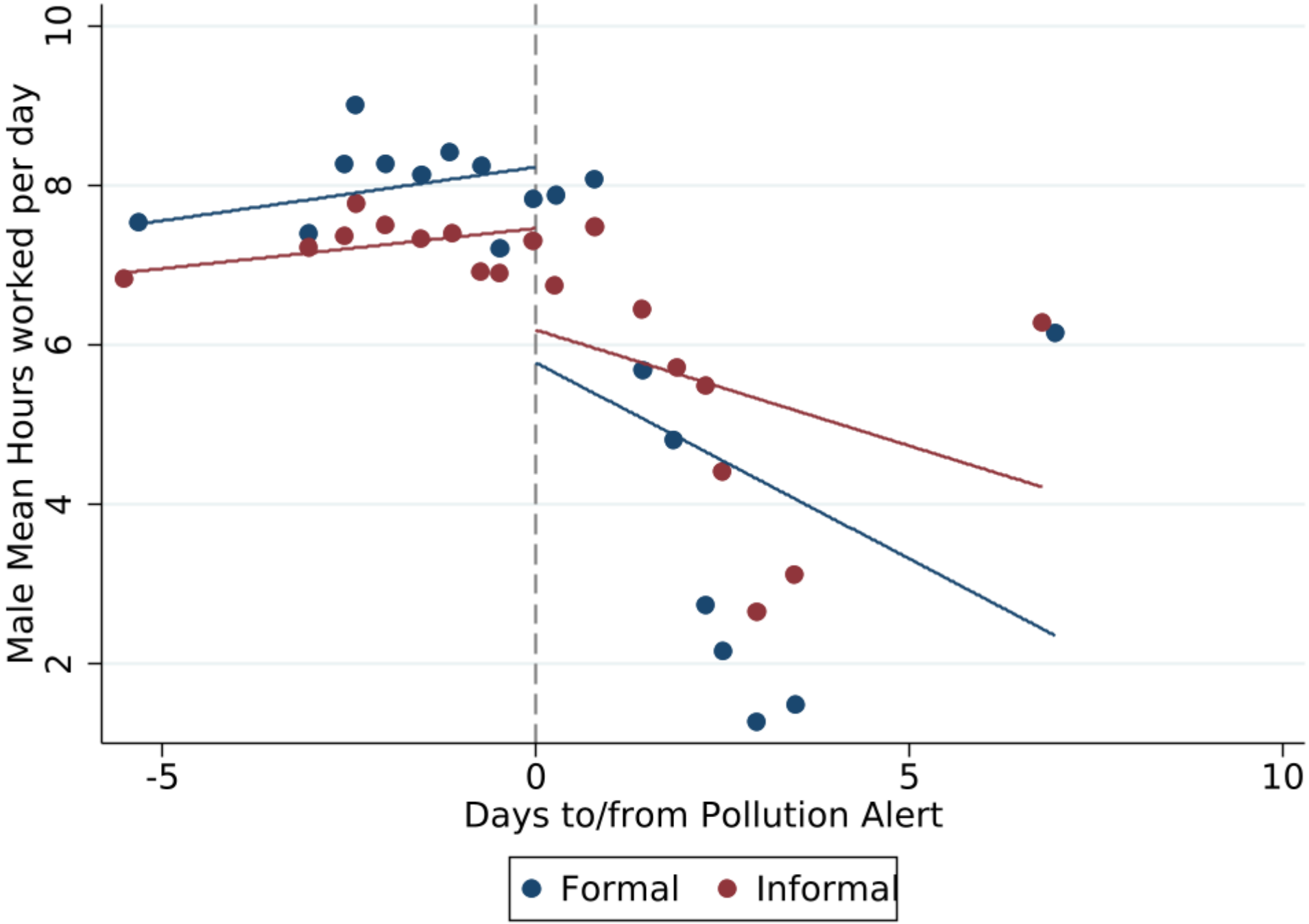
E_{cd}	Pollution bins	α_i	Individual fixed effects
η_w	Day of the week fixed effect	γ_q	quarter fixed effect

- Following the advice of Cameron and Miller (2015), Wooldridge (2003) and Abadie et al. (2017) we cluster our standard errors on the census block level

Results

Recall the RDD on pollution policy


Mean Hours worked per day
2
4
6
8
-5
0
5
10
Days to/from Pollution Alert


Male Mean Hours worked per day
2
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-5
0
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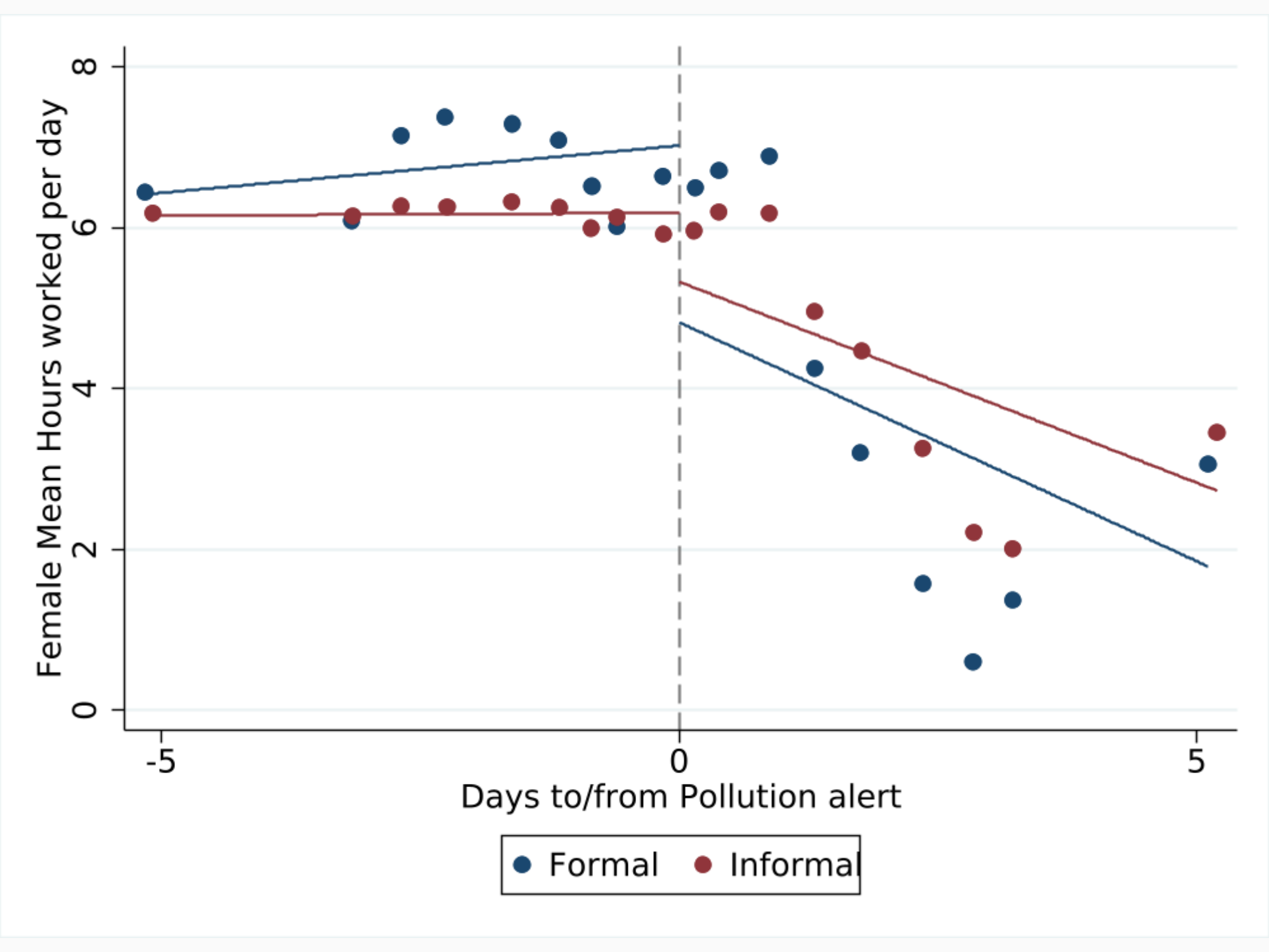
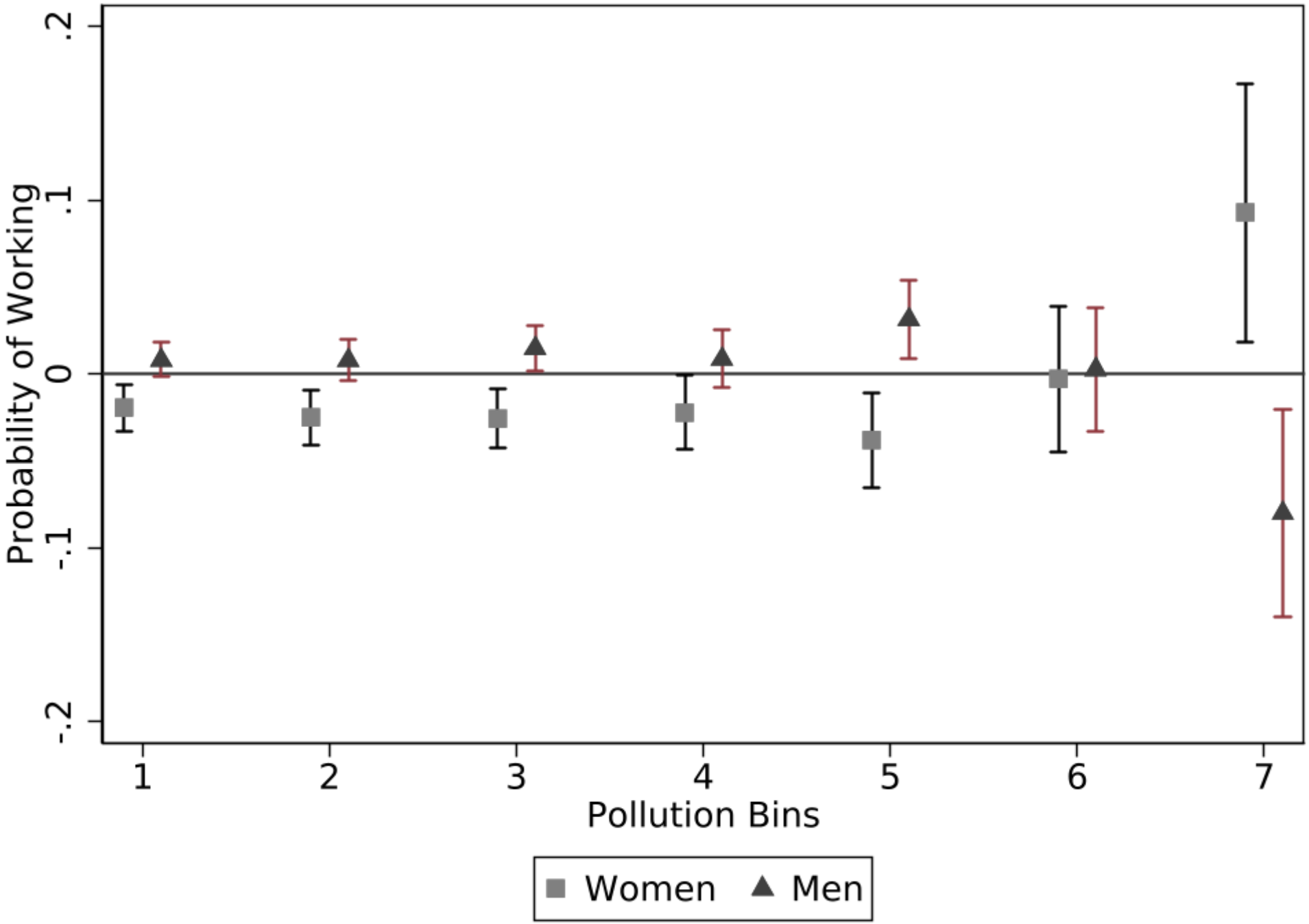
10
Days to/from Pollution Alert
Formal
Informal


Female Mean Hours worked per day
0
2
4
6
8
-5
0
5
Days to/from Pollution alert
Formal
Informal

Parametric Results

	worked All	worked Informal	worked Informal Women	minutesworked All	minutesworked Informal	minutesworked Informal Women
(a) All Households						
Pollution Alert	-0.038***	-0.032*	-0.056**	-23.827***	-17.852*	-27.410**
	(0.014)	(0.017)	(0.022)	(7.726)	(9.298)	(11.303)
R^2	0.37	0.28	0.29	0.38	0.28	0.29
N	30,891	18,406	8,053	29,346	17,567	7,647
FEs	Yes	Yes	Yes	Yes	Yes	Yes
(b) Households with kids						
Pollution Alert	-0.067***	-0.076***	-0.131***	-37.579***	-42.648***	-54.030**
	(0.022)	(0.028)	(0.043)	(11.742)	(15.280)	(20.861)
R^2	0.37	0.28	0.28	0.38	0.28	0.27
N	11,234	6,779	3,040	10,649	6,438	2,867
FEs	Yes	Yes	Yes	Yes	Yes	Yes
(c) Households with kids and grandmothers						
Pollution Alert	-0.020	-0.004	-0.022	-15.781	-3.208	-10.800
	(0.019)	(0.022)	(0.027)	(10.182)	(12.071)	(13.524)
R^2	0.37	0.28	0.31	0.38	0.28	0.30
N	19,657	11,627	5,013	18,697	11,129	4,780
FEs	Yes	Yes	Yes	Yes	Yes	Yes

Recall the high dimensional FE strategy on pollution bins


Probability of Working
.2
.1
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-.1
-.2
1
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3
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5
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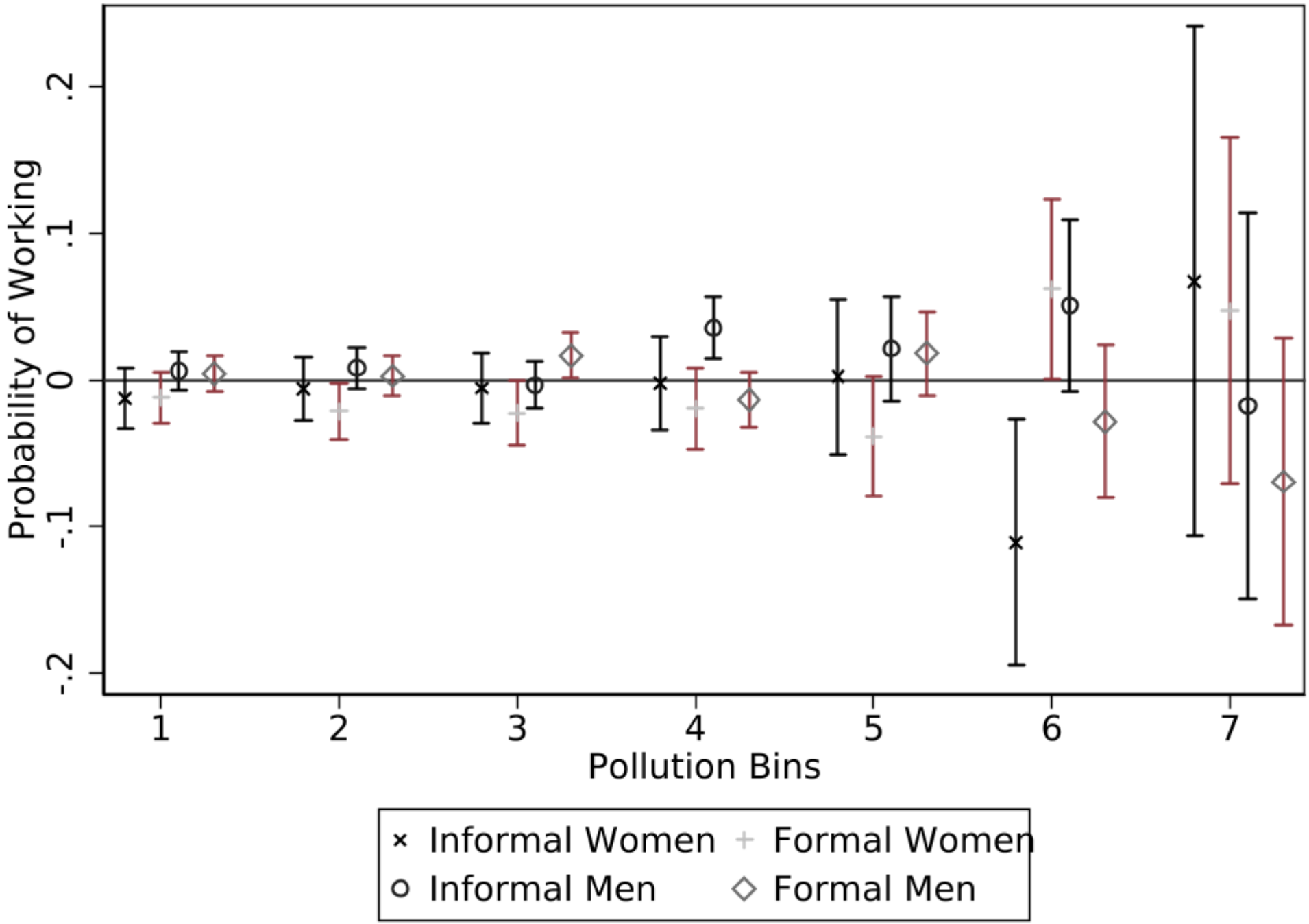
7
Pollution Bins
Women
Men


Probability of Working
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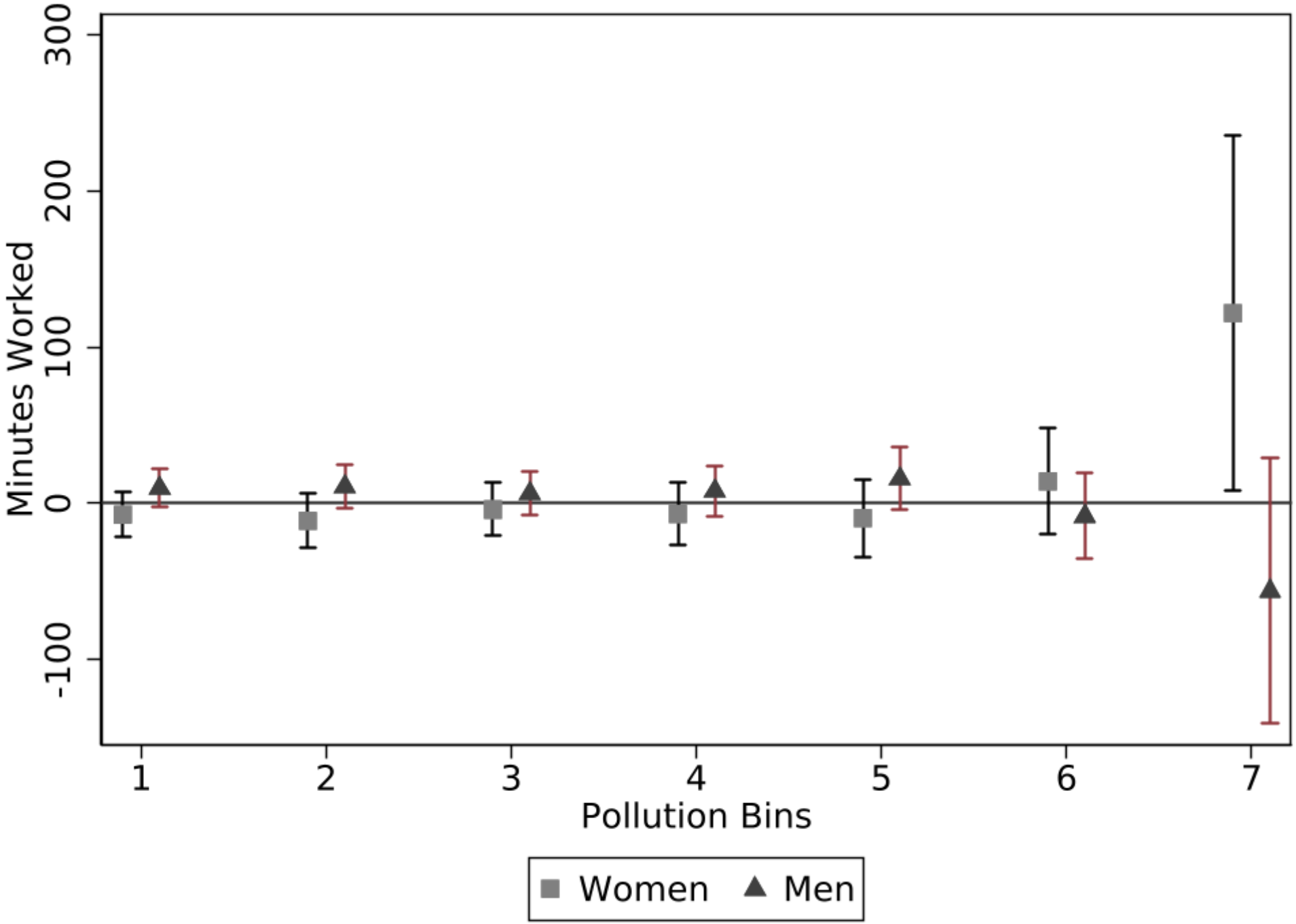
Pollution Bins
Informal Women
Formal Women
Informal Men
Formal Men


Minutes Worked
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Pollution Bins
Women
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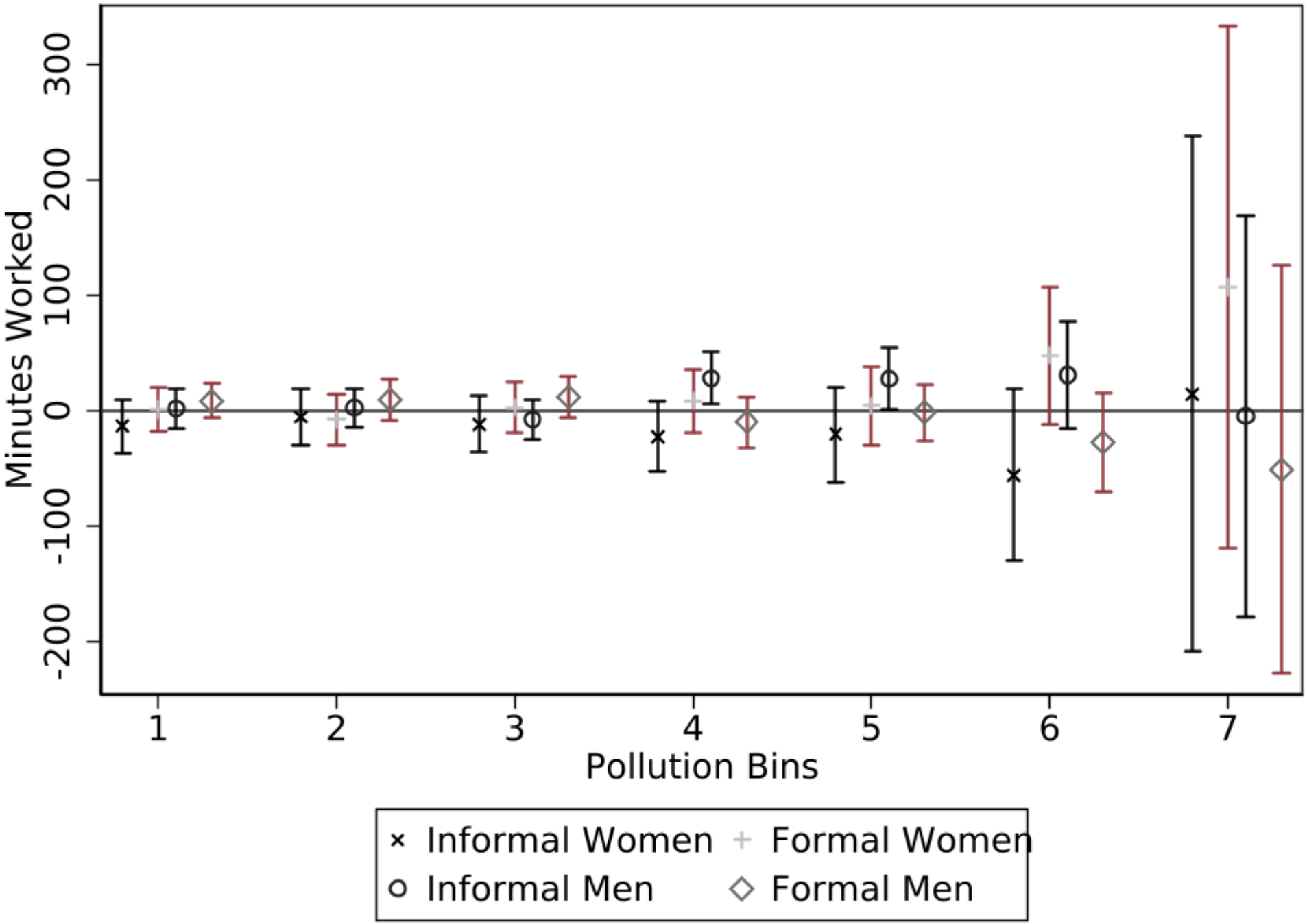
Minutes Worked
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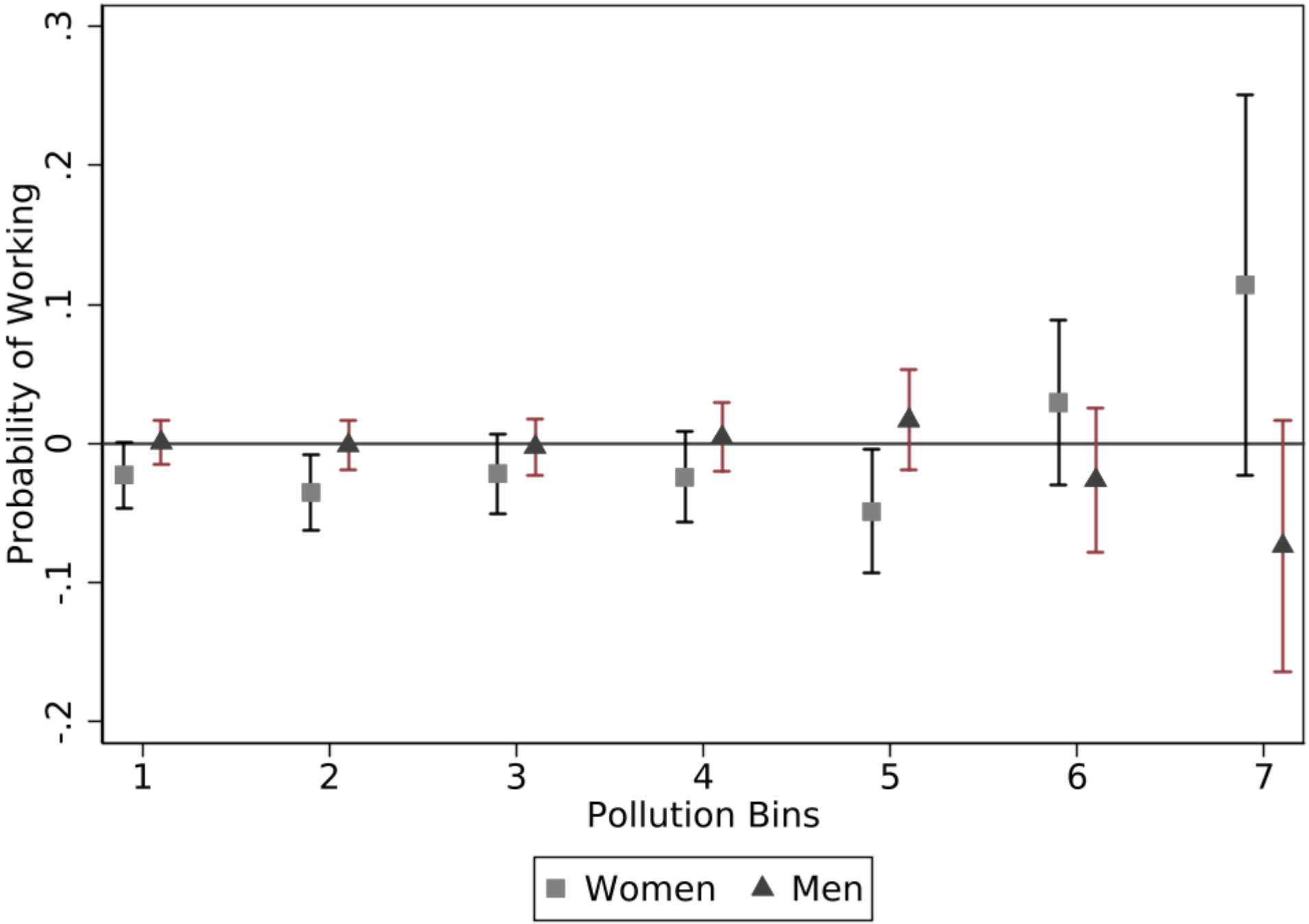
Pollution Bins
Informal Women
Formal Women
Informal Men
Formal Men

But what if the household has children?


Probability of Working
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Pollution Bins
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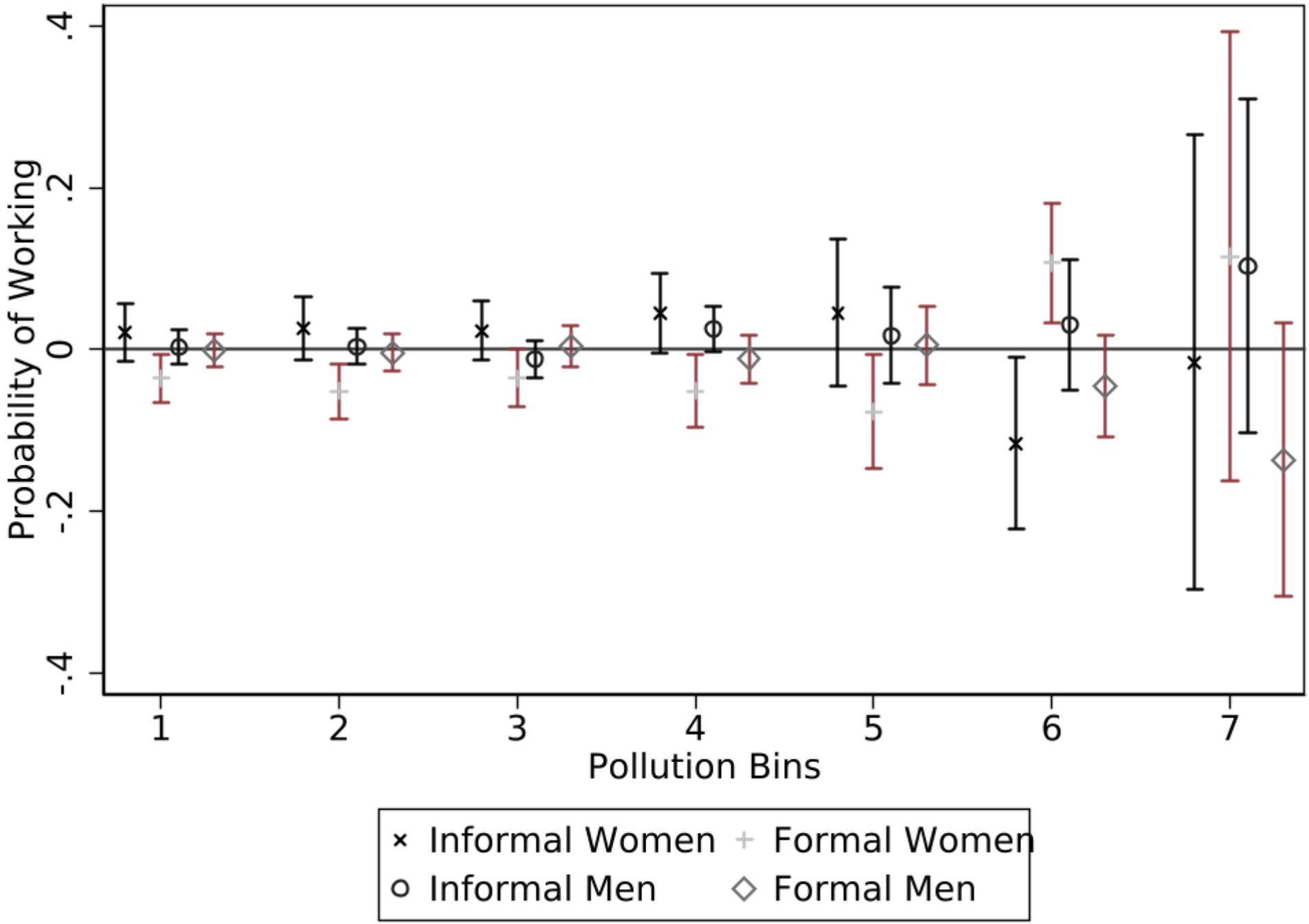
Probability of Working
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Pollution Bins
Informal Women
Formal Women
Informal Men
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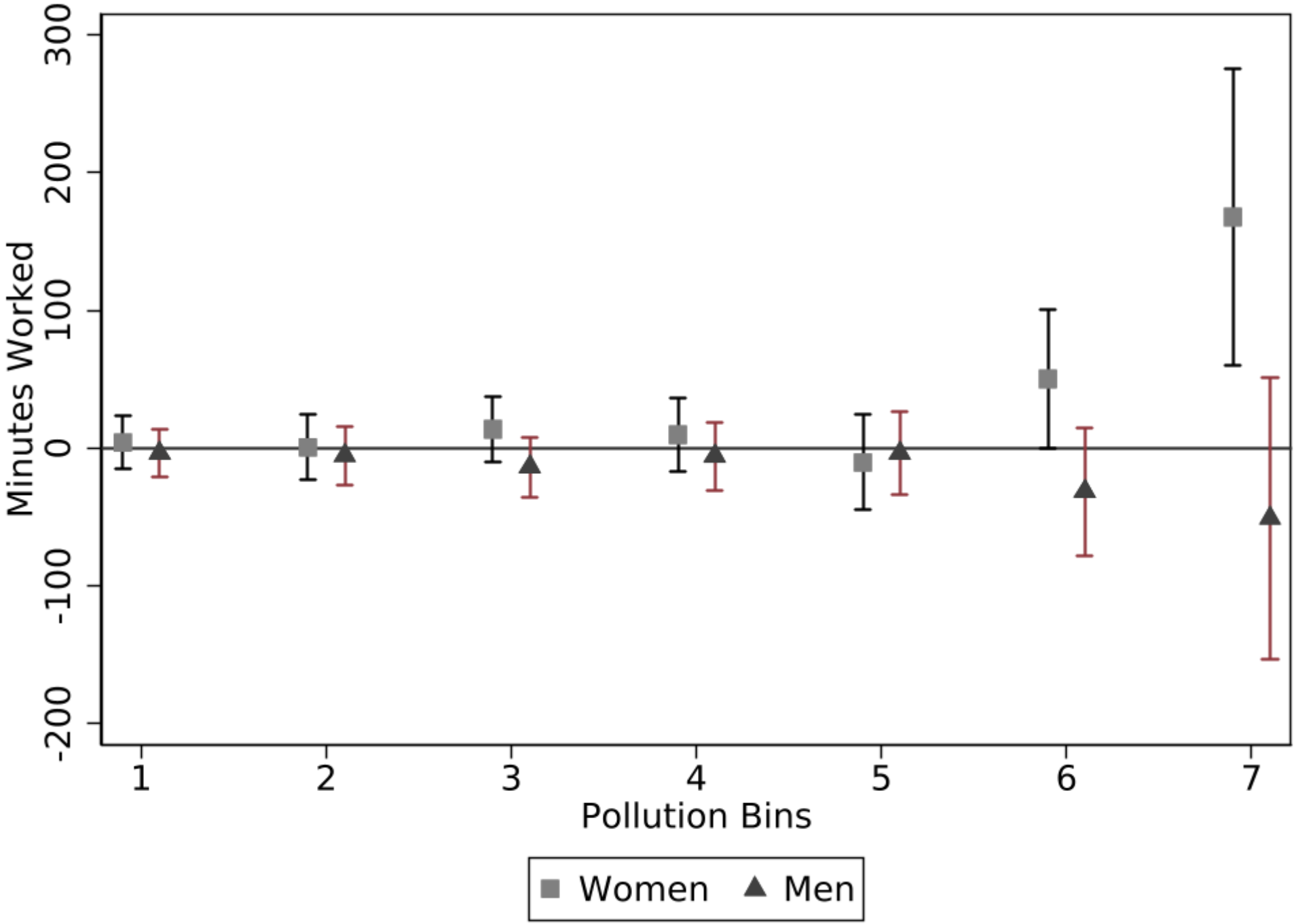
Minutes Worked
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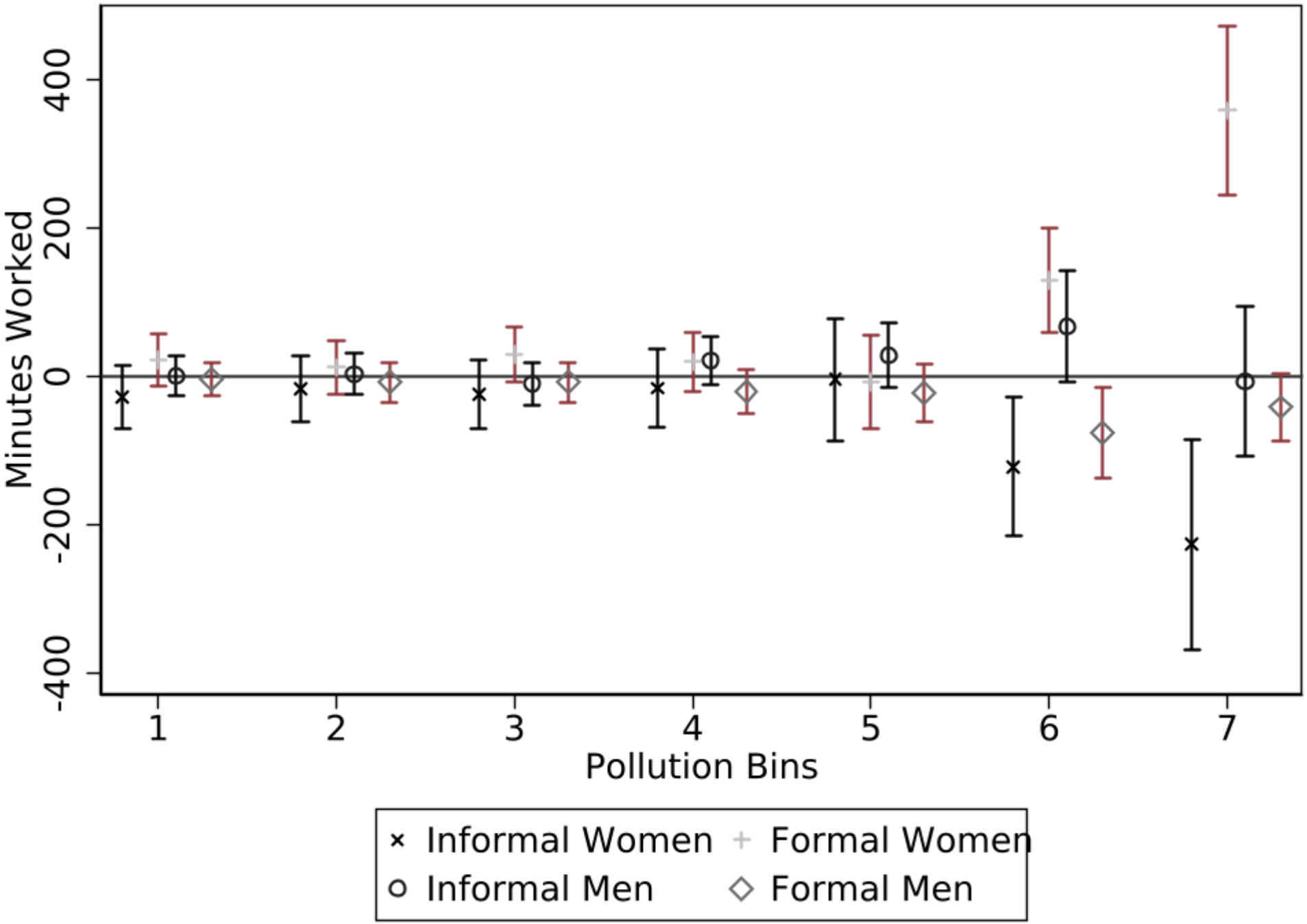
Pollution Bins
Women
Men


Minutes Worked
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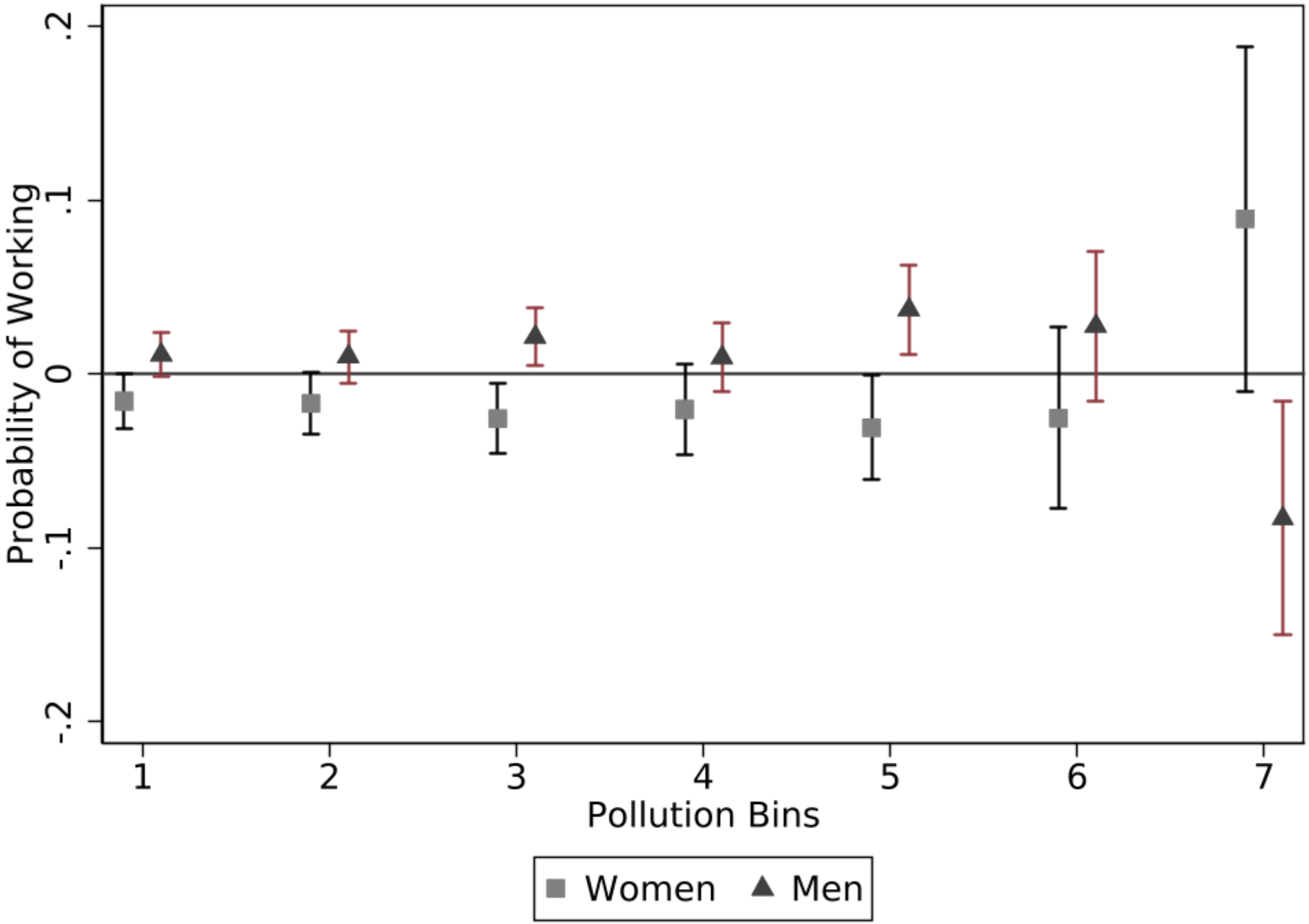
Pollution Bins
Informal Women
Formal Women
Informal Men
Formal Men

What about those with children and grandmothers?


Probability of Working
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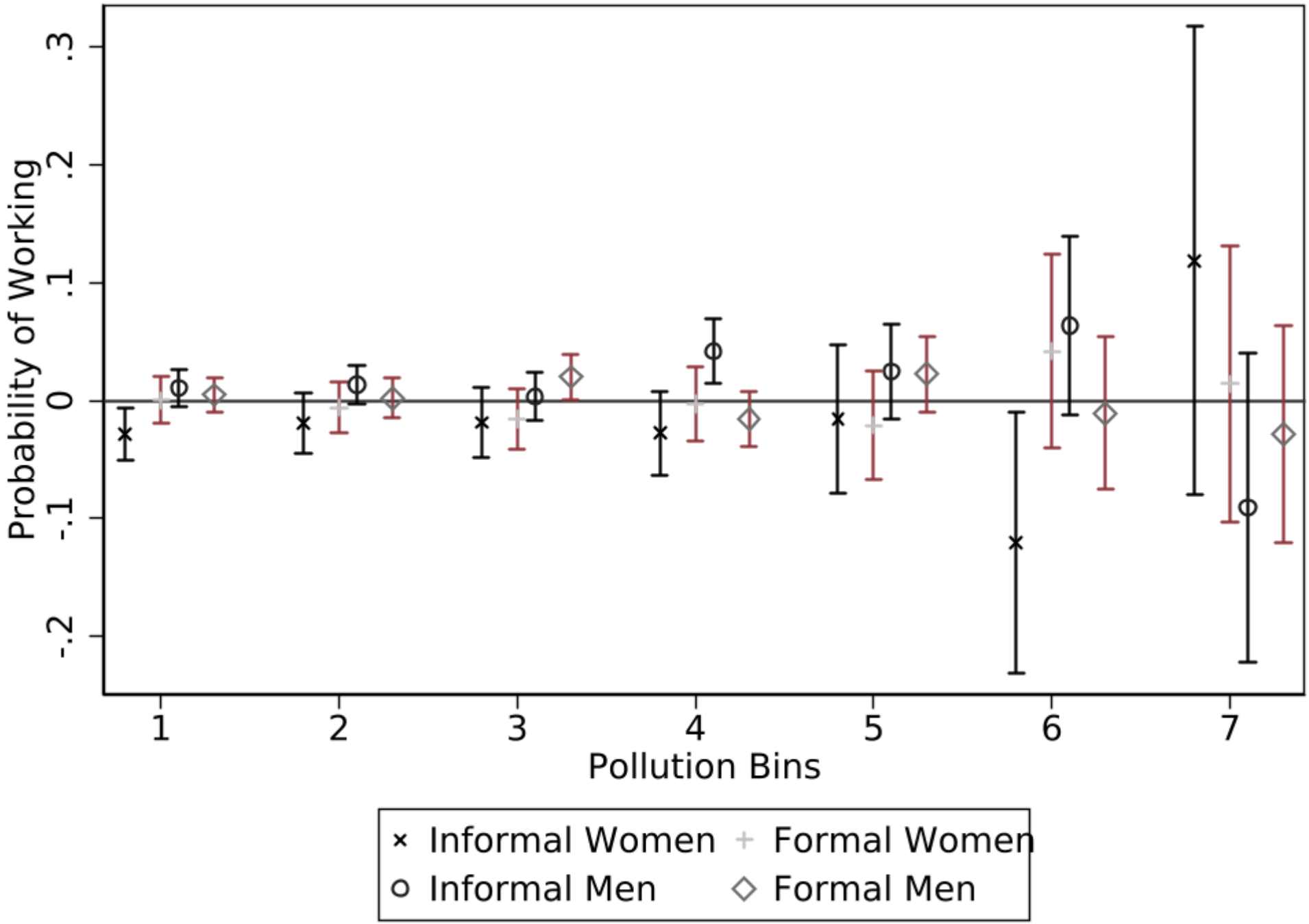
Pollution Bins
Women
Men


Probability of Working
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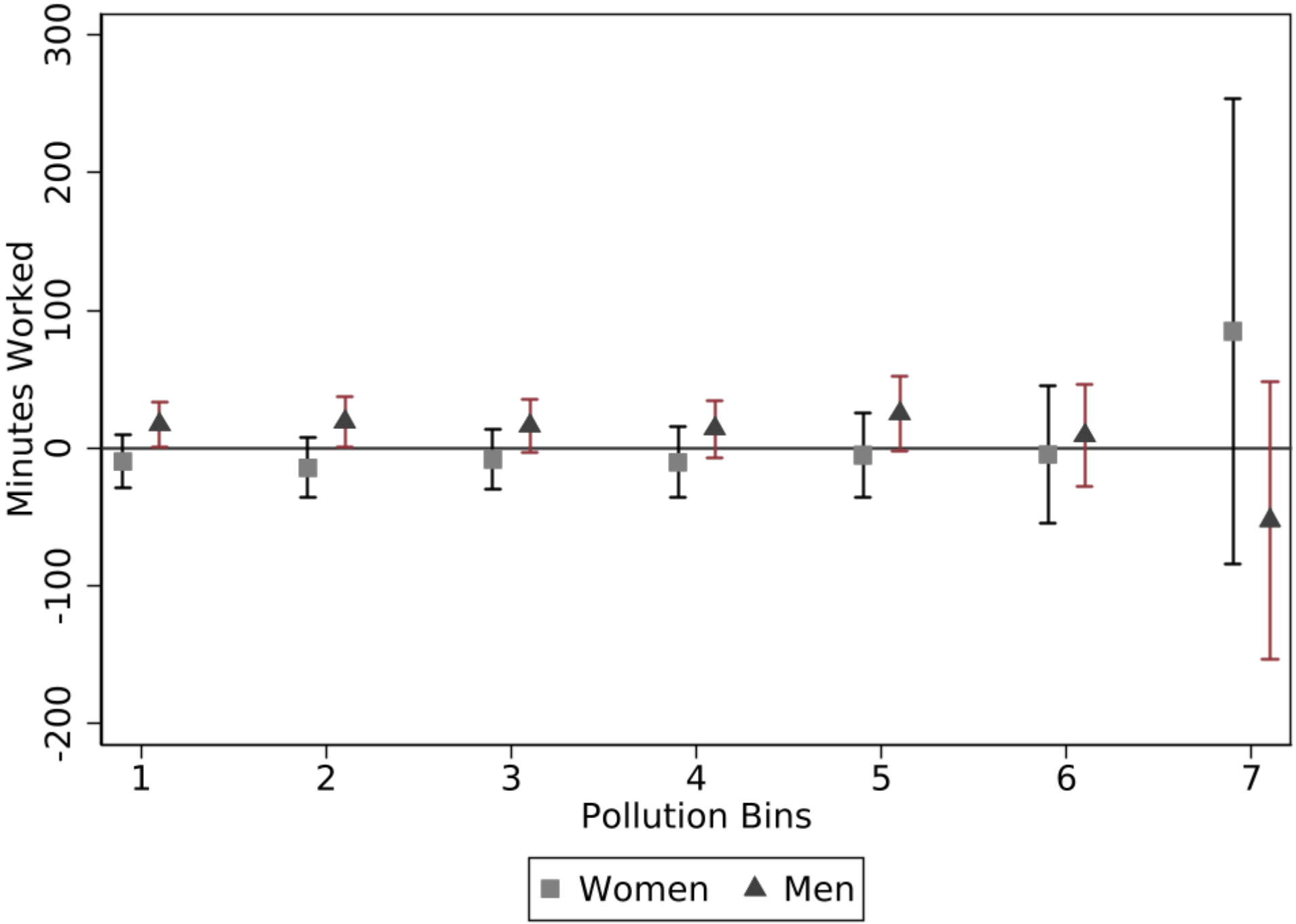
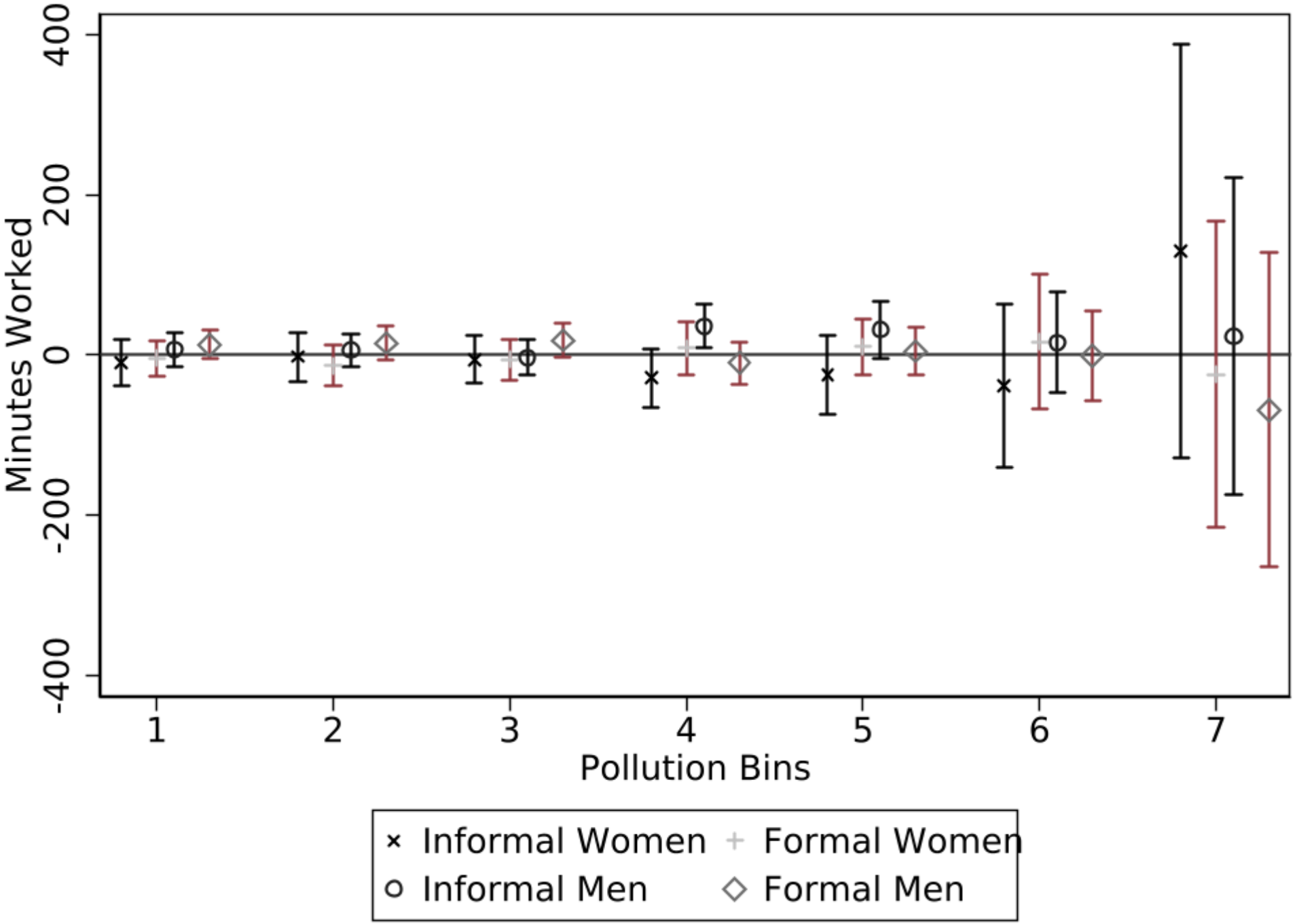
Pollution Bins
Informal Women
Formal Women
Informal Men
Formal Men


Minutes Worked
300
200
100
0
-100
-200
1
2
3
4
5
6
7
Pollution Bins
Women
Men


Minutes Worked
400
200
0
-200
-400
1
2
3
4
5
6
7
Pollution Bins
Informal Women
Formal Women
Informal Men
Formal Men

Conclusions & next steps

Conclusions

Effect of pollution on labour supply → fine data w/ 5km radius matters for detailed (gender) analysis.

Policy effects (RDD):

1. In the run-up to a pollution alert there is a weakly decreasing hours → health effect.
2. Once the alert kicks-in, there is a salient ↓, followed by catchup
3. Gradient effect: formal workers drop more hrs (than informal) & effect more prominent for men (than women).
4. Gendered response: Informal female workers catching-up is much different than formal female (& men).

Physiological effects (binned pollution FE):

6. Male workers experiencing an income effect (as pollution ↑ min ↑) *vs* Female workers tend to overcompensate more than their male counterparts at highest levels of pollution (70+ bin).
7. Physiological reduction at 41-50 $\mu g/m^3$ bin (-11 min for male formal workers); informal workers (f/m) put much more time into work across the bin distribution (+ ↑ at 40 and 50 bins).
8. Differential female response: overcompensating at high level of pollution (s.s. bin 61-70); Informal female workers are putting-in the greatest effort into work in highest bin (s.s. sign switch at 70+).

→ Policy need for improving (female) workers capability to bounce back from the pollution events (jobs quality, availability of care packages, incl. childcare services)

Next steps & discussion with the room

1. Perform binned pollution analysis exploring workers' care responsibility (having minor dependents);
2. Leads and lags for exploring physiological effects;
3. Test correlation between PM2.5 & IMECA thresholds;
4. Back-of-the-envelop calculation: do job-characteristics matter in defining the pollution-effect if we calculate the value of lost-hours? (expectation: high $ per hr for female informal worker);
5. Updating the data to the 2020s: ongoing proposal under writing.

Appendix

Bin frequency of maxima of PM2.5 over the year

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	2005	2006	2007	2008	2009	2010	Total
0	8,622	9,401	8,998	10,349	11,627	16,544	65,541
	13.16	14.34	13.73	15.79	17.74	25.24	100.00
10	18,213	18,468	21,182	20,774	24,773	24,986	128,396
	14.19	14.38	16.50	16.18	19.29	19.46	100.00
20	14,452	17,839	19,353	19,309	21,860	17,666	110,479
	13.08	16.15	17.52	17.48	19.79	15.99	100.00
30	11,724	11,303	12,393	13,545	11,027	9,806	69,798
	16.80	16.19	17.76	19.41	15.80	14.05	100.00
40	7,612	6,246	6,237	7,653	5,420	5,188	38,356
	19.85	16.28	16.26	19.95	14.13	13.53	100.00
50	4,195	3,395	3,047	3,851	2,319	2,434	19,241
	21.80	17.64	15.84	20.01	12.05	12.65	100.00
60	2,174	1,708	1,426	1,667	892	1,098	8,965
	24.25	19.05	15.91	18.59	9.95	12.25	100.00
70	2,913	1,624	1,297	1,800	814	1,010	9,458
	30.80	17.17	13.71	19.03	8.61	10.68	100.00
Total	69,905	69,984	73,933	78,948	78,732	78,732	450,234
	15.53	15.54	16.42	17.53	17.49	17.49	100.00

Hoy No Circula II

HOY NO CIRCULA /// Restricciones semanal y sabatina

TIPO DE VEHÍCULO	ANTIGÜEDAD	HOLOGRAMA	1. RESTRICCIÓN SEMANAL	2. RESTRICCIÓN SABATINA
HÍBRIDO o ELÉCTRICO	-	-	NO	NO
A COMBUSTIÓN	0 a 2 años	"00"		
	0 a 8 años	"0"		
	9 a 15 años	"1"	1 día a la semana	2 sábados al mes
	15 o más años	"2"	1 día a la semana	Todos los sábados
FORANEO	-	-	1 día a la semana	Todos los sábados

Hoy No Circula III

CALENDARIO HOY NO CIRCULA

CONTRIBUYE A TENER UNA
MEJOR CALIDAD DEL AIRE

COLOR DEL ENGOMADO DEL VEHÍCULO	ÚLTIMO DÍGITO NUMÉRICO DE LA PLACA DE CIRCULACIÓN	LIMITACIÓN A LA CIRCULACIÓN		
		DÍA ENTRE SEMANA	HOLOGRAMA 1 SÁBADO	HOLOGRAMA 2 SÁBADO
	5 o 6	LUNES	Dejan de circular conforme al último número de la placa de circulación. IMPARES (1, 3, 5, 7 y 9) Primer y tercer sábado de cada mes. PARES (0, 2, 4, 6, 8) Segundo y cuarto sábado de cada mes. HORARIO De las 5 a las 22 horas.	TODOS LOS SÁBADOS HORARIO De las 5 a las 22 horas.
	7 u 8	MARTES		
	3 o 4	MIÉRCOLES		
	1 o 2	JUEVES		
	9 o 0	VIERNES		

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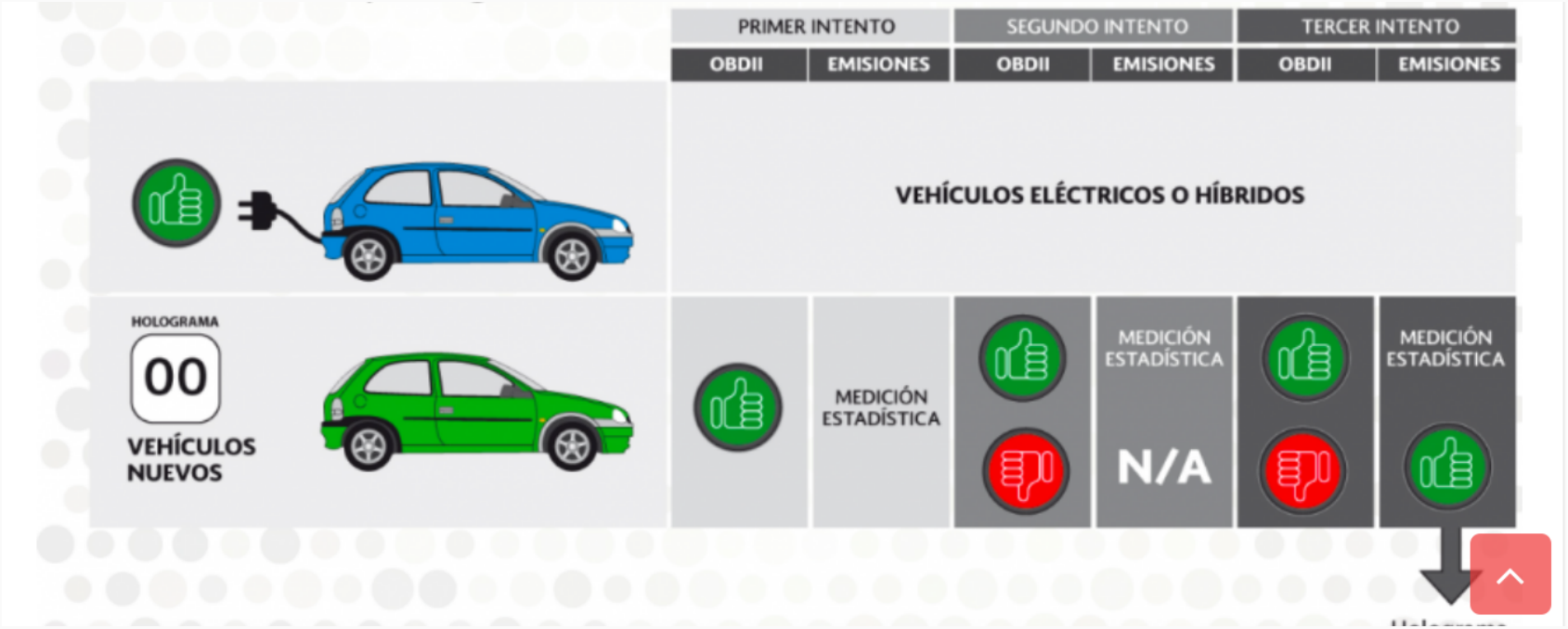
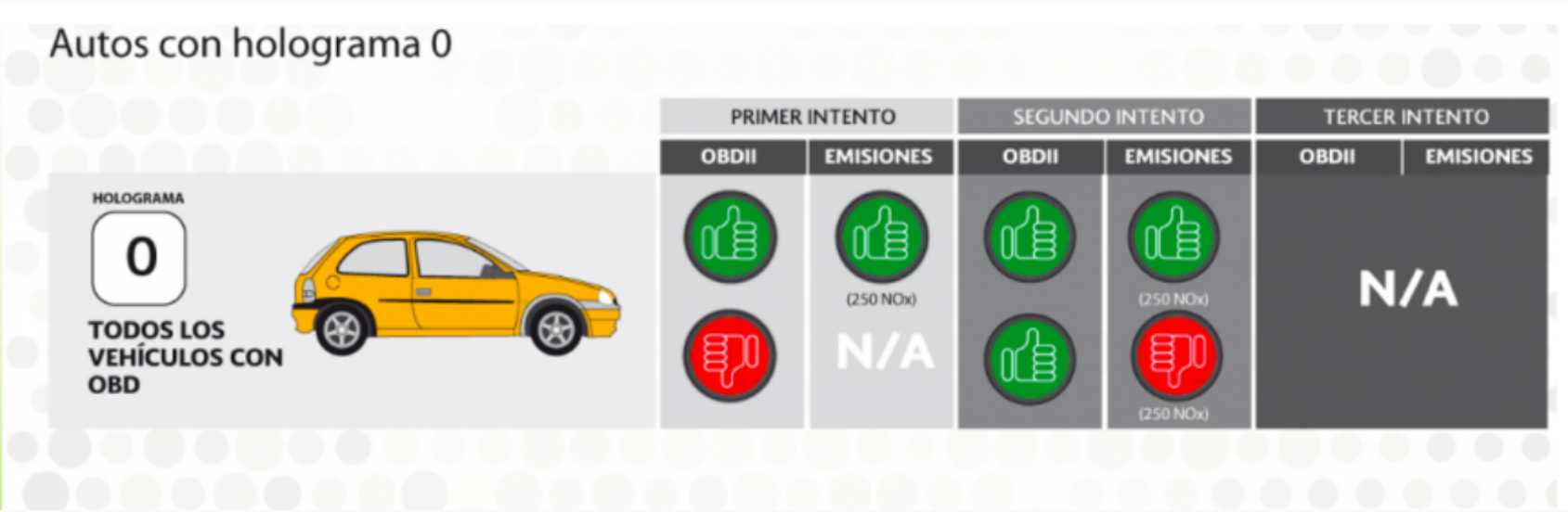
Hoy No Circula IV



Hoy No Circula V



Hoy No Circula VI

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Autos con holograma 1 y 2

		PRIMER INTENTO		SEGUNDO INTENTO		TERCER INTENTO	
		OBDII	EMISIONES	OBDII	EMISIONES	OBDII	EMISIONES
HOLOGRAMA 1		N/A	(700 NOx)	N/A	(700 NOx)	N/A	
HOLOGRAMA 2		N/A	(2000 NOx)	N/A	(2000 NOx)	N/A	

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On Pollution

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	PM10	PM2.5
1.treatprecont	12.031**	0.209
	(4.562)	(0.188)
R^2	0.14	0.18
N	10,632	10,632
FEs	Yes	Yes

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