Searching for Customers, Finding Pollution

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January 2023

Pollution in developing country cities

- **Air pollution** is increasing rapidly in developing country cities
  - leading causes: fast urbanization, rapid motorization and poor urban planning
  - Ugandan cities as polluted as Chinese cities

- Potentially important negative **health** and **productivity impacts**
  - life expectancy in SSA reduced by 2.1 years due to air pollution [AQLI 2021]

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Small Firms Dominate Production in LIC Cities

- **Small firms** predominant in developing country cities
  - produce mostly on road side and open air

Overview

1. **This paper**: study organization of production ⇔ exposure to pollution in LICs
   - Location choice & in-place adaptation
2. **Novel data: granular air pollution + firm survey** + road census
3. **Key findings:**
   - Bundling: road traffic bundle access to demand with exposure to pollution
   - Sorting to polluted areas to meet demand
   - Profitability / Health trade-off: value added per worker (++) > health effects (+)

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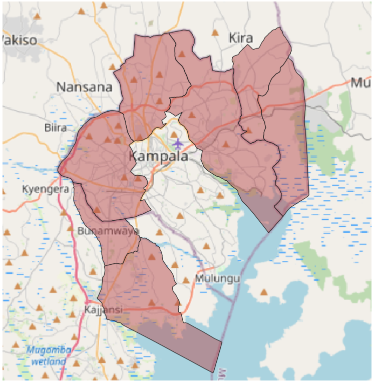
Data

Representative sample of urban areas

- sub-county = neighborhood or small city

Figure: Sampled sub-counties in Kampala



Pollution data

- We collected **granular geo-referenced measurements of PM2.5** Trend
  - in partnership with AirQo Pollution Decay Lit
  - 33 stationary monitors, 10 mobile monitors for 8 months $\Rightarrow \approx$ 3.3 million observations
  - average PM2.5 40-50 $\mu g/m^3$
  - isolated the spatial variation of pollution Residual
  - captured within-city spatial variation (unlike satellite data) Satellite

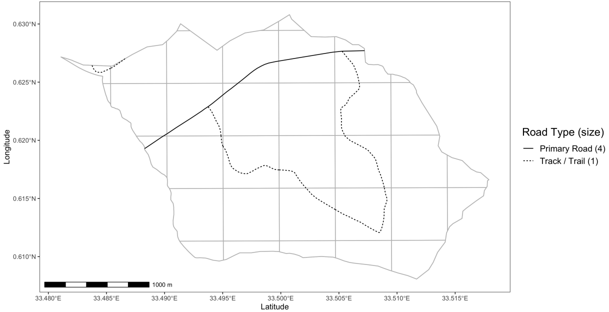
Firm data

- Focus on three prominent **manufacturing** sectors [Bassi et al. '22]
  - carpentry, metal fabrication, grain milling
- Full **listing** in sampled sub-counties, then detailed **survey** of ≈1,000 firms
  - standard index of managerial practices [McKenzie Woodruff '17] Manscore
  - location and reasons for location choice
  - mitigation investments: protective equipment and organizational strategies
  - employees' perceptions of pollution exposure
  - follow-up survey: manager's awareness of pollution distribution, WTP maps
- Average firm: small ($\bar{L} = 4.8$) but profitable ($\overline{profit} = 4 \times$gdp pc) Firm Xs

Road data

- 2017 census of Uganda's roads, organized by road-type
  - five categories, from 1 = "track/trail" to 5 = "motorway"

Roads



- Median road size in grid-cell
  - split sub-counties s into 500m × 500m grid cells j [Ahlfeldt et al. '15, Michaels et al. '21]

Stylized Facts and Conceptual Framework

Conceptual framework

- City: each location j is characterized by a bundle

$$\{\text{access to customers } z_j, \text{pollution } p_j\}$$

- Impacts of pollution exposure: Simple Model
  - reduces worker productivity
  - amenity cost
  - compensation differentials
- Focus on two core entrepreneurial decisions potentially affected by pollution
  - firm's location choice j
  - in place adaptation investment e, at cost ξ

Characterizing the Bundle

1. Road size & Pollution

$$\text{Pollution}_{j,s,r} = \alpha_0 + \alpha_1 \text{Median Road}_j + \delta_s + \eta \log(dist_r) + \nu_{j,s,r}$$

2. Road size & Profitability

$$\text{Profitability}_{i,j,s,r} = \beta_0 + \beta_1 \text{Median Road}_j + \beta_2 \text{Manscore}_i + \lambda_l + \delta_s + \eta \log(dist_r) + \nu_{i,j,s,r}$$

δ_s: sub-county fixed effect ; λ_l: sector fixed effect ; $dist_r$: distance to the main city in the region

Identification assumptions

1. Pre-determined roads + firms not major polluters
2. Pre-determined roads + no sorting of more productive firms next to larger roads

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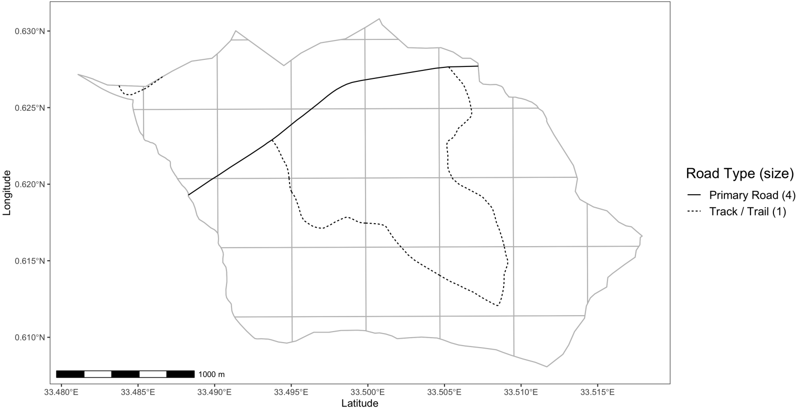
Bundling Results (1): Larger roads are more polluted



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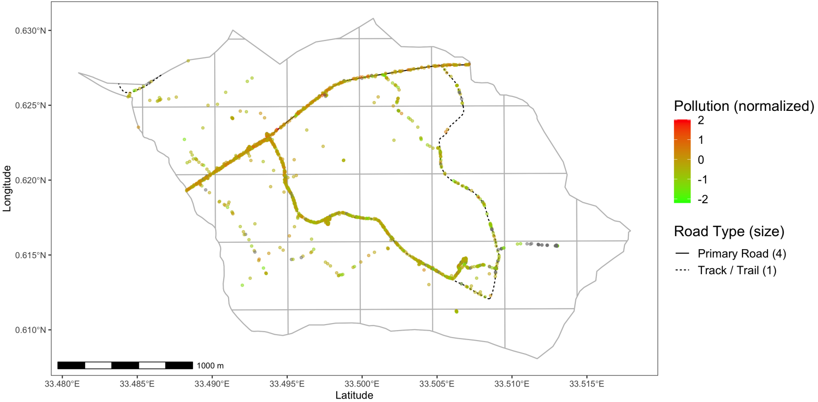

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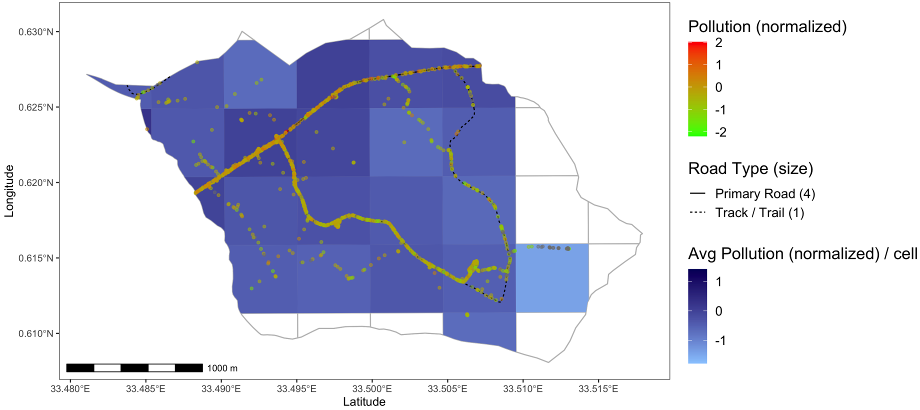

⇒ going from "secondary road" to "primary road" ⇒ 6-10% increase in pollution Reg Table

Bundling Result (2): Larger roads bring additional profits

	(1)	(2)	(3)	(4)	(5)	(6)
	log(Profit)	log(Profit)	Nb Customers	log(Rev)	log(Salary)	log(Rent)
Med. Road Size	0.155	0.145	0.250	0.132	0.0250	0.106
	(0.0314)	(0.0325)	(0.0975)	(0.0316)	(0.0152)	(0.0288)
Man. Score		0.237	0.413	0.292	0.0842	0.0747
		(0.0310)	(0.106)	(0.0296)	(0.0192)	(0.0296)
log(Size Premises)						0.0499
						(0.0213)
N	967	967	792	976	2272	655
R2	0.506	0.537	0.374	0.449	0.392	0.476
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Sub-county FE	Yes	Yes	Yes	Yes	Yes	Yes
Level of Observation	Firm	Firm	Firm	Firm	Employee	Firm
SE clustering	Grid Cell	Grid Cell	Grid Cell	Grid Cell	Grid Cell	Grid Cell
Employee Controls					Yes	

- Road traffic provides access to customers:
  - walk-in customers prevalent, limited marketing
  - consistent with lit. on output market frictions in LICs [Jensen Miller '18, Startz '18, Hjort et al. '20]

Access to Demand Pollution Additional

Avoidance and Adaptation

Conceptual framework: Avoidance and Adaptation

- City: each location j is characterized by a bundle

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- Focus on two core entrepreneurial decisions potentially affected by pollution
  - **firm's location choice j**
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Empirical strategy: Avoidance & Adaptation

1. Avoidance

$$\log(\text{Firm Density})_{j,s,r} = \alpha_0 + \alpha_1 \text{Median Road}_j + \delta_s + \eta \log(dist_r) + \nu_{j,s,r}$$

2. Adaptation

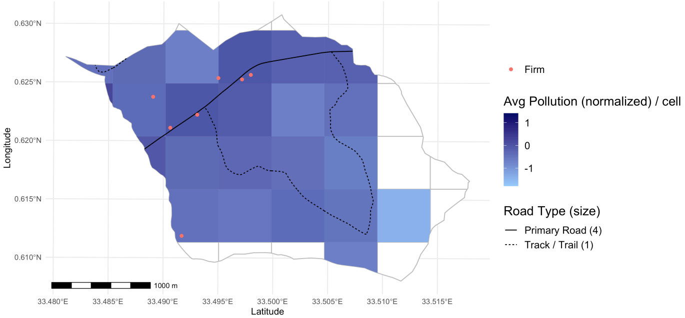
$$\text{Protection}_{i,j,s,r} = \beta_0 + \beta_1 \text{Median Road}_j + \beta_2 \text{Manscore}_i + \lambda_l + \delta_s + \eta \log(dist_r) + \nu_{i,j,s,r}$$

δ_s: sub-county fixed effect ; λ_l: sector fixed effect ; $dist_r$: distance to the main city in the region

Standard errors

- SHAC [Conley 1999, Hsiang 2010] for grid cell level regressions
- Clustered at grid cell level for firm level regressions

Location: Firms cluster in busy & polluted locations to access customers



- from secondary to primary road: firm density increases by 13-17%
- one standard deviation increase in pollution: firm density increases by 31%
- access to customers is the main reason for location choice (by far)

Regression Table
Location Choice

Adaptation: Low but Increasing with Managerial Ability

1. Overall low levels of adaptation:
   - 5% of firm owners provide protection equipment to their workers
   - $<$ 20% of firm owners are careful about exposing workers to pollution
2. High-ability managers better protect their workers from pollution Awareness
   - 1 sd $\uparrow$ managerial ability $\Rightarrow$ 40% $\uparrow$ proba that firm owners provide protection
3. Workers w. better managers take more protective measures and are more aware Limited Sorting

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Location implication: meaningful profitability-pollution trade-off

- Predict pollution and value-added (profits + salary) in each grid-cell using our elasticities
- Impute life expectancy impacts of pollution using elasticity from Ebenstein et al '17
- **Counterfactual**: compare average outcomes from the observed location to random allocation within sub-county

	Per Person (1)	Firm Owners (2)	Workers (3)
Panel B: Results			
Move to Random Location Within the Same Sub-county			
Δ PM2.5 Exposure ($/m^3$)	-1.61	-1.61	-1.61
Δ Life Expectancy (Months)	+1.89	+1.89	+1.89
Δ Annual Earnings ($)	-42.1	-195.2	-10.9
NPV Δ Lifelong Earnings ($\beta = 0.95$; Over 40 years) ($)	-758.7	-3516.2	-196
NPV Δ Lifelong Earnings ($\beta = 0.90$; Over 40 years) ($)	-453	-2099.4	-117

→ value added per worker decreases by $42 per year; life expectancy increases by 2 months

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$\rightarrow$ earnings losses much higher for firm owners

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- **Policy**: relocate marginal firms/workers compensating for NPV lifetime loss earnings

	Per Person (1)	Firm Owners (2)	Workers (3)
Panel C: Net Surplus From Policy Intervention (WHO Guidelines)			
Move to Random Location Within the Same Sub-county			
(i) Main			
- $\beta = 0.95$; Over 40 years ($)	-418	-3176	145
- $\beta = 0.90$; Over 40 years ($)	-112	-1759	224

- **not** cost efficient on average: earnings gains in polluted areas outweight the health costs!

Relocation Policy

Inefficient Markets, Sorting and Adaptation

Why are there positive net profits of locating near the busiest roads?

- Complex Land Tenure System
- High Transportation costs / preference for working close to home

Do all firms benefit from locating near the busiest roads?

- Firm Size

Why is adaptation not heterogeneous over space?

- Information Frictions

Why are there positive net profits of locating near busy roads?

1. Complex land tenure system

- Kampala: *mailo:* $\Downarrow$ profits & $\not\Downarrow$ rents $\Rightarrow$ amenities or frictions [Bird and Venables '20]

	(1) Any Firm	(2) log(Firm Density)	(3) Avg Pollution	(4) Log Profits	(5) Nb Customers	(6) Log Rent
Median Road Size	0.0394	0.117	0.0654	-0.0159	-0.297	0.0512
	(0.0277)	(0.0724)	(0.0247)	(0.0807)	(0.294)	(0.101)
Mailo	0.0310	-0.110	-0.0187	-0.545	-0.898	-0.132
	(0.0456)	(0.267)	(0.103)	(0.272)	(0.955)	(0.290)
Mailo * Median Road	0.0176	0.0777	-0.00171	0.198	0.382	0.0953
	(0.0206)	(0.0946)	(0.0269)	(0.0866)	(0.309)	(0.105)
Manscore				0.155	0.391	0.0986
				(0.0469)	(0.128)	(0.0377)
Log size						0.0769
						(0.0246)
N	742	261	427	344	255	259
R2	0.227	0.408	0.0836	0.221	0.135	0.272
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Sub-county FE				Yes	Yes	Yes

2. High transportation costs / preference for working near home

Home

- Manager: distance from home as a driver of non-sorting into polluted & busy locations
- Consistent with Vitali '22 (same context) and Le Barbanchon et al. '20

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Do all firms benefit from locating near the busiest roads?

- **Firm Size** ⇒ larger firms might be able to break the bundle and relocate production
  - UBOS 2011 Census of Bureau Establishments

Dep. Var:	Log(Firm Density)						
Sample:	Our survey	UBOS	UBOS	UBOS	UBOS	UBOS	UBOS
Sector:	Manuf (Weld + Carp.)	Manuf	Manuf (> 10 emp.)	Agr	Retail	Low Skill Serv	High Skill Serv
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Median Road Size/Cell	0.127	0.125	0.0513	-0.0671	0.216	0.143	0.0635
	(0.0428)	(0.0240)	(0.0300)	(0.0356)	(0.0213)	(0.0247)	(0.0303)
N	410	4942	382	1776	13994	6971	2602
R2	0.378	0.514	0.645	0.486	0.416	0.505	0.632
Sub-county FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Level of Observation	Grid Cell	Grid Cell	Grid Cell	Grid Cell	Grid Cell	Grid Cell	Grid Cell
SE clustering	SHAC	Sub-county	Sub-county	Sub-county	Sub-county	Sub-county	Sub-county

Do Information Frictions Distort Adaptation and Sorting?

- **Information Frictions** ⇒ Survey suggests that firms underestimate pollution
  - RCT: Can information campaigns correct firm owners' underestimation of pollution?
    - promising role of information interventions in increasing awareness
    - higher ability owners have higher WTP for information

RCT

Conclusion

- **Focus:** how organization of production shapes firms' exposure to pollution in LIC cities
  - collect pollution data at a granular level + firm survey + road census
- **Key takeaways**:
  - firms sort in the most polluted part of the city in search for customer access
  - the health costs of within-city firms' location choice are substantial and must be accounted for
  - profitability benefits plausibly outweigh health costs for owners; workers bear net costs
  - location choice shaped by high transportation costs & land market
  - information interventions can increase awareness; bigger push policies needed for relocation
- **Research agenda:**
  - which relocation policies can reduce exposure while minimizing productivity losses? (Gechter and Kala '22)
  - role of information/training interventions in increasing adaptation

Thanks!