Exposure to air pollution for small firms in African cities

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- We collected street by street measurements of air pollution within Ugandan cities, and matched this with a novel firm survey and data on the location and size of roads.
- We find that air pollution levels in Ugandan cities are as high as in Chinese cities, and pollution is particularly high along major roads due to road traffic.
- We show that small firms locate on busy roads to attract customers, increasing profits but exposing their workers to substantial air pollution, with substantial negative effects on workers' life expectancy.
- Firms and workers engage in limited protective strategies such as wearing masks, although better managers protect their workers more. An information experiment reveals that firm owners underestimate pollution levels, and providing more accurate information can increase adaptation strategies and protection.
- Reducing traffic emissions should be a policy priority to increase worker health. Industrial parks might also be a promising policy tool to address this problem by allowing a critical mass of firms to relocate away from congested areas.

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Overview of the research

In African cities, small firms operate in the midst of growing air pollution

Air pollution is increasing rapidly in developing country cities, fuelled by urbanisation and motorisation. Poor infrastructure and unstructured city growth make the problem worse, leading to traffic congestion and further increasing emissions. Sub-Saharan Africa is no exception: in Uganda, the context of our study, the main cities are as polluted today as Chinese cities, with level of PM2.5 more than four times those recommended by the Environmental Protection Agency. Recent estimates suggest that in sub-Saharan Africa pollution is becoming a health threat at least as important as malaria and HIV (AQLI 2022).

Production in developing countries is dominated by small manufacturing firms, often located within urban centres and thus operating amid this rising pollution. In a new working paper (Bassi, Kahn, Lozano, Porzio and Sorin 2022) we study the location choice of these small firms within cities in Uganda, and show that in their search for customer access, they overwhelmingly locate along the busiest and dirtiest roads, increasing their profits but exposing their workers to substantial amounts of air pollution, with dire consequences for their health and life expectancy.

Measuring local pollution and economic activity in urban Uganda

We collected novel pollution data and a firm survey in a representative sample of urban areas, together with AirQo and the NGO BRAC. To collect the pollution data, we deployed both stationary and mobile monitors. The stationary monitors were mounted on fixed locations (Figure 1a). The mobile monitors were placed on motorcycle taxis, and the drivers were instructed to drive around all the streets of our sampled urban areas (Figure 1b). Together, the two types of monitors allow us to recover the spatial variation in PM2.5 levels within the city at a high level of granularity, street by street. We matched the pollution data with a geo-coded survey of 1,000 firms in carpentry, metal fabrication, and grain milling that we conducted in the same urban areas and at the same time as the pollution measurements. We gathered information about their profitability, the reasons for their location choice, their marketing practices, as well as perceptions of air pollution and strategies to protect employees from pollution exposure. Finally, we gathered data on the size and exact location of all the roads in our sampled areas.

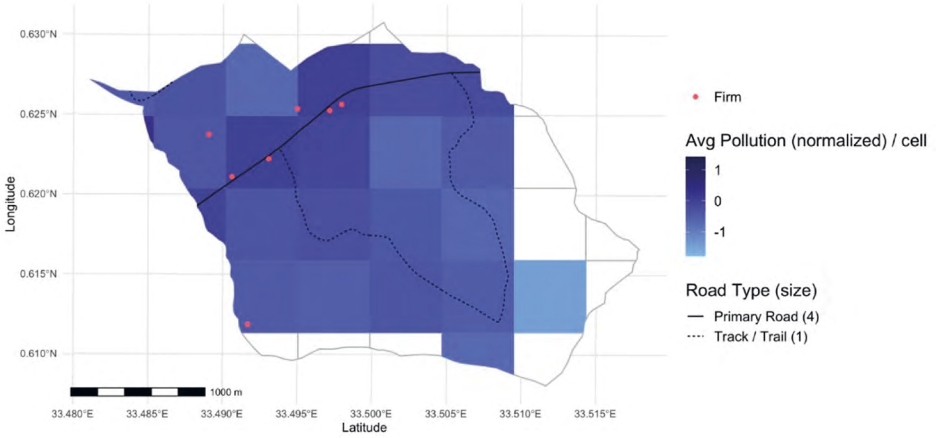
Figure 1: Stationary and Mobile monitors

(a) Stationary monitor **(b) Mobile monitor**

Small firms locate along polluted streets to access customers

Our main results can be illustrated by Figure 2, which displays a map of one sampled urban area. The figure shows that small firms (red dots) tend to locate near the largest city roads (solid dark line). Using our survey, we show that profits and customer access are indeed higher along major roads, and consistent with this, firms report access to customers as the main reason for their location choice. The figure shows that these same roads, however, are also the most polluted parts of the city (dark blue cells). As a result, while firms are only searching for customers, they also find, bundled with customer demand, exposure to air pollution: road traffic generates both. This exposes workers to substantial pollution, and we show that investments in equipment or organisational strategies to protect workers from pollution – such as providing masks or flexibility in commuting time to avoid exposure to traffic pollution at rush hour – are limited.

Figure 2: Firm location choice and pollution levels in one sampled sub-county



Notes: pollution levels, roads and firm location in one sampled urban area.

Workers incur plausibly significant health costs due to firm location choice

Using our data on profitability and pollution levels across different areas of the city, together with estimates from the literature on the effect of PM2.5 on life expectancy, we estimate that if firms were distributed randomly within the city (as opposed to clustering along major roads) their workers would gain an average of 2 months of life expectancy from decreased prolonged pollution exposure. However, such a move would come at the significant cost of $195 for firm owners in lost profit every year (27% of Uganda's GDP per capita) due to lower customer access. While these numbers are striking, we caution that this trade-off is relevant for the marginal firm deciding where to locate since it keeps constant the location of customer demand. Relocating all the firms to less polluted areas could achieve the life expectancy gains without the profit losses as customer demand would relocate as well.

Policy implications

We highlight six main implications of our results for development policy.

1. Given the current distribution of firms and customers, paying firms to move to less polluted areas would not necessarily be cost-efficient

Should these firms be compensated to move away from polluted areas? The answer is not obvious: the WHO guidelines indicate that a policy investment should cost no more than three times GDP per capita for each year of life saved, thus suggesting that a policy that would compensate a firm to move away from polluted areas should cost no more than $340 per employee in the case of Uganda. Yet, the corresponding present discounted value of value-added per worker losses from this move would be above $750 as a result of lost profits, so that the policy would not be cost-effective for the average firm.

2. Workers bear the net costs of firm location

Unlike firm owners, who get significant additional profits ($195 per year) from locating in high-pollution areas, workers do not capture much of the benefits ($11 per year), while still bearing the same health costs. These distributional considerations would make the relocation policy discussed above highly cost effective for workers, but not firm owners.

3. Low adaptation partially results from lack of information

Given the high health costs of air pollution, the low levels of in-place adaptation observed may be puzzling. Is there an information issue? On the one hand, our survey reveals that both firm owners and employees are aware that pollution hurts their health and productivity, and that high-traffic locations come with high levels of pollution. On the other

hand, they tend to underestimate their local pollution exposure. To assess whether an information intervention could increase awareness, we run a randomized information experiment. We show that informing firm owners about pollution levels near their firm (relative to other areas of the city) increases their willingness to pay for maps of the local distribution of air pollution, thus suggesting that lack of information on pollution levels may result in under-provision of adaptation investments. Information interventions about pollution levels may thus be promising in fostering adaptation.

4. Better managers protect their workers more

We show that while firm owners adopting better managerial practices similarly locate in busy and polluted areas, they are more likely to protect their workers against air pollution. They are also willing to pay larger amounts for new information related to air pollution. This pattern shows that the best firms not only pay higher wages but also provide better pollution protection. This has implications for welfare inequality among workers. It also suggests that overall improvement in managerial skills may reduce workers' effective pollution exposure.

5. Reducing traffic emissions would lead to a significant increase in worker health

Estimates from the literature suggest a loss of life expectancy of almost 1 year for an increase of 10 milligrams per cubic meter of PM2.5 concentration in the air (Ebenstein et al 2017). Reducing traffic emissions would thus lead to significant improvements in worker health from reduced prolonged exposure to air pollution near large roads. Several policy actions would help towards this goal, in particular:

a. Reducing the Sulphur levels in diesel and gasoline fuel: Uganda currently allows a maximum Sulphur content of 50 parts per million (ppm) in diesel and 150 ppm in gasoline. Reducing these closer to levels allowed in US and Europe would be important: the standard for diesel and gasoline in Europe and US are both around 10-15ppm.

b. Incentivising the adoption of catalytic converters: research has shown that most of the decline in car-related air pollution in the US since the 1960s was due to the implementation and enforcement of exhaust standards, achieved by incentivising car manufacturers to install catalytic converters (Jacobsen et al 2022).

c. Facilitating the transition away from old vehicles and towards more efficient and electric vehicles: in 2018 Uganda enacted a ban on imports of vehicles older than 15 years. This is a very useful measure, which led to a sharp reduction in the average age of newly registered vehicles. It would be important to make the ban more stringent by reducing the maximum allowed age for imported vehicles. Such bans should be preferred to taxing older vehicles, which can backfire by increasing substitution towards even older vehicles (Forster and Nakyambadde 2021). It would also be important to pair the ban with incentives for consumers to purchase newer vehicles including

electric vehicles (and providing the required infrastructure to enable charging of electric vehicles).

d. Fostering integrated public transportation systems including a Bus Rapid Transit (BRT) system: an efficient public transportation system would have the benefit of reducing pollution emissions by reducing congestion. Creating dedicated bus and BRT lanes is crucial to ensure usage of the system.

6. Big-push structural policies are promising to induce small firms to relocate

Policies fostering firm growth could enable firms to grow larger, separate production and retail activities, and invest in marketing to build a reputation. In turn, this might allow them to break the bundling problem and locate production in less polluted areas of the city while retaining customer access. When reproducing our analysis on the universe of Ugandan firms using the firm census data, we indeed find that larger manufacturing firms were less likely to cluster near large roads. Finally, more structural urban policies like industrial parks might help even small firms in breaking the bundling problem, by allowing a critical mass of small firms to relocate away from congested areas while still retaining visibility to customers and access to demand through the scale of the park. Combining pollution emission regulation with such urban planning interventions to help firms relocate away from congested areas might be a promising way forward for policy intervention.

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