Dual Misbeliefs and Technology Adoption: Evidence from Air Purifiers in Bangladesh

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Motivation and Puzzle

- High levels of ambient air pollution impose severe economic and welfare costs, especially in low-income countries (Oliva et al., 2019)
  - Over five million people die annually from exposure to ambient air pollution
  - In South Asia, ambient air pollution is responsible for 1.4 million deaths per year (GBD Risk Factors, 2024)

- Demand for private preventive technologies like air purifiers remains remarkably low (Greenstone and Jack, 2015; Greenstone et al., 2021)
  - Air purifiers can reduce air pollution by 80%
  - Electricity consumption of a ceiling fan, upfront cost only BDT 16,500
  - Fewer than 1% of middle-class households in Dhaka, Bangladesh own an air purifier

- **Why don't households, for whom air purifiers are affordable, adopt them despite extremely high ambient air pollution levels?**

Experiment and stylized facts

- Multi-phase field experiment providing air monitors and purifiers to households
- **Stylized facts:**
  1. Air in homes is almost as polluted as outdoor air but households think air in their homes is much less polluted than outdoor air
  2. Air purifiers are very effective in filtering polluted indoor air but households are uncertain about its effectiveness

Results preview

- **Main experimental results:**
  1. Households provided a monitor believe air in their homes is more polluted but are not willing to pay more for an air purifier
  2. Households provided a purifier are less uncertain about its effectiveness but they rarely use the purifier
  3. Households provided both monitors and purifiers increase purifier use and its valuation

- **Model explaining results:**
  - Results consistent with a model where valuation of preventative health technologies equals product of perception of problem and perception of effectiveness of solution
  - Multiple equilibria where some technologies are widely adopted while others are not

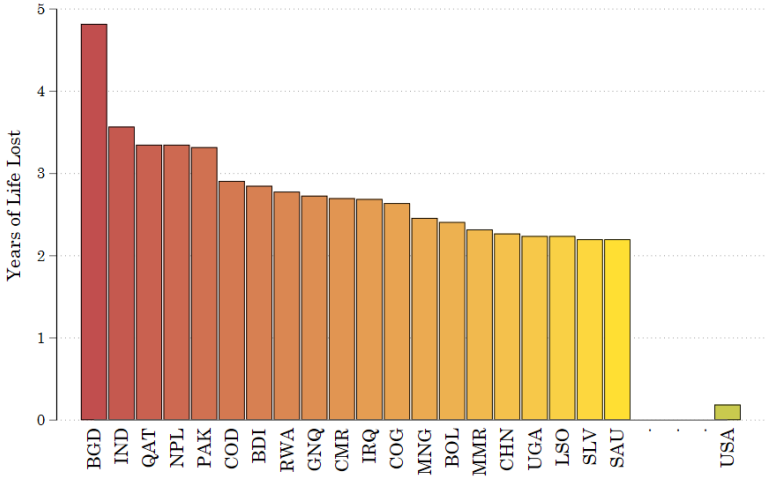
Contributions to the literature

First to show inaccurate beliefs about the severity of the problem and the effectiveness of the solution contributes to low adoption and use of a preventive environmental health technology

- Large development economics literature on underadoption of seemingly beneficial technologies (Dupas, 2011, 2014; Magruder, 2018; Verhoogen, 2023)
  - Little is known empirically about how these beliefs form and to what extent they influence the reluctance to invest in preventive health technologies (Kremer et al., 2019)
- Environmental economics that examines why marginal willingness to pay for environmental quality improvements is so low in developing countries (Greenstone and Jack, 2015)
  - Our results help reconcile seemingly disparate findings about the under adoption of defensive technologies against ambient air pollution (Baylis et al., 2024; Ahmad et al., 2023; Greenstone et al., 2021; Ito and Zhang, 2020; Barwick et al., 2024)

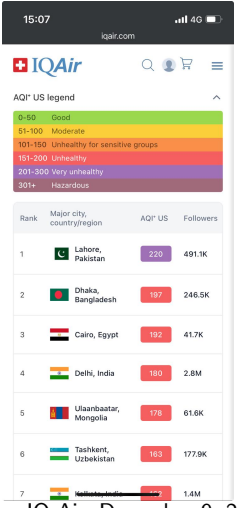
Context & Research Design

Health Effects of Air Pollution



Data: AQLI (2023).

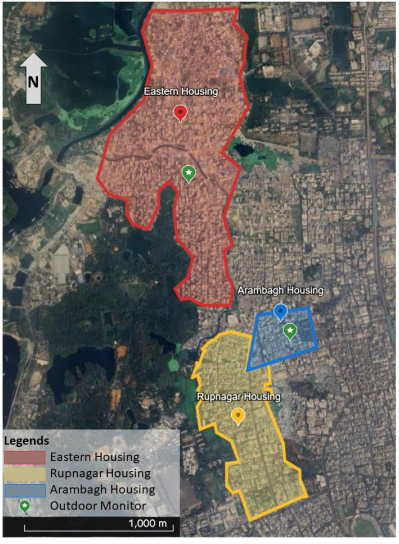
Dhaka's air pollution right now



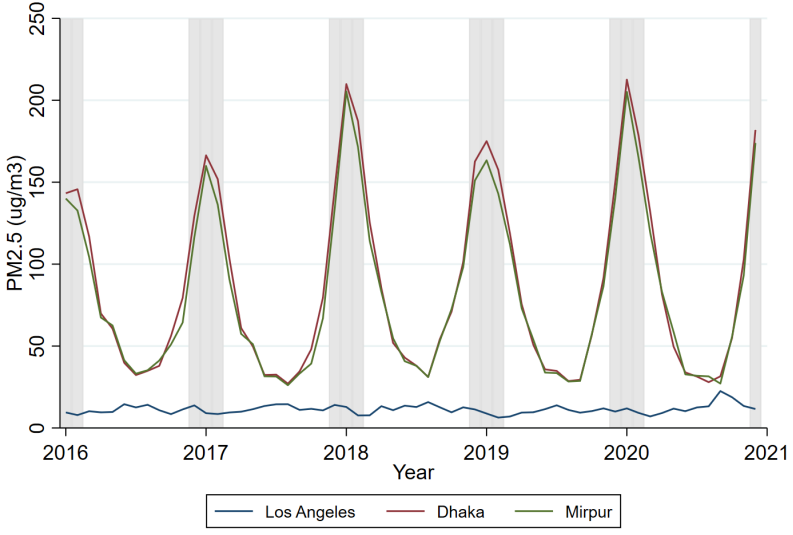
Data: IQ Air, December 9, 2024

Study area

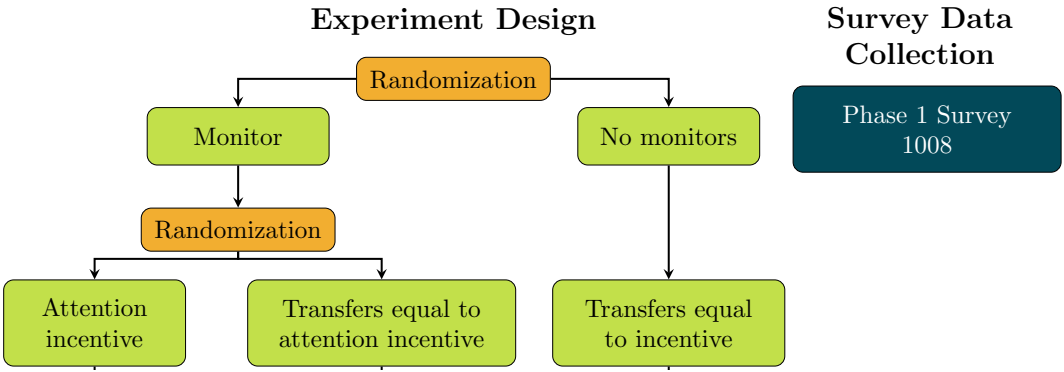
- 1,008 middle-class households living in apartment buildings in 3 housing societies
  - All households have a Wi-Fi connection
  - 80% of households have someone with some tertiary education
  - Average monthly household income BDT 60,000
  - 34% has air conditioner, which costs at least twice as much as an air purifier and consumes substantially more electricity
  - 1% own an air purifier



Air Pollution During Winter in Mirpur, Dhaka

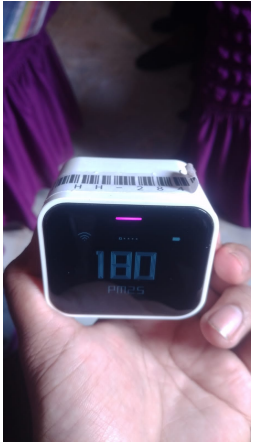


Research Design: Phase 1 (November 2023)



Phase 1: Air Quality Monitor Treatment

- Screen reports $PM_{2.5}$ in $\mu g/m^3$
- Monitors continuously provide air pollution data
- Households received a chart categorizing PM2.5 levels into: good, moderate, unhealthy for sensitive groups, unhealthy, very unhealthy, and hazardous
  - Chart also had elevation of disease risk at each level



Monitor details: `https://www.qingping.co/air-monitor-lite/overview`

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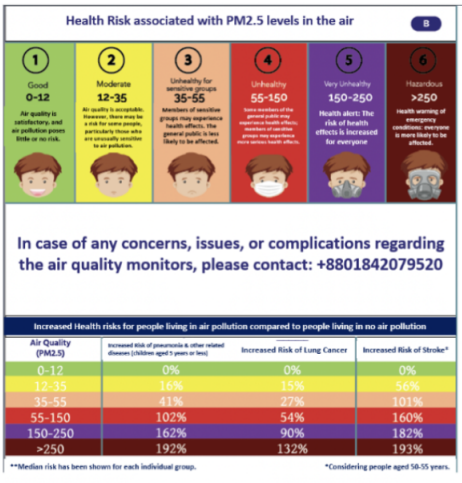
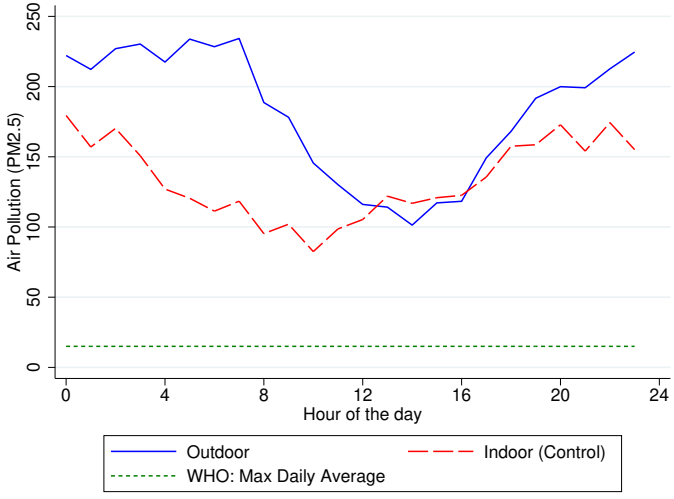
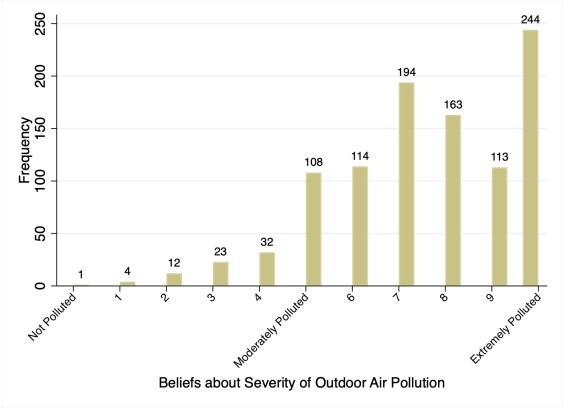


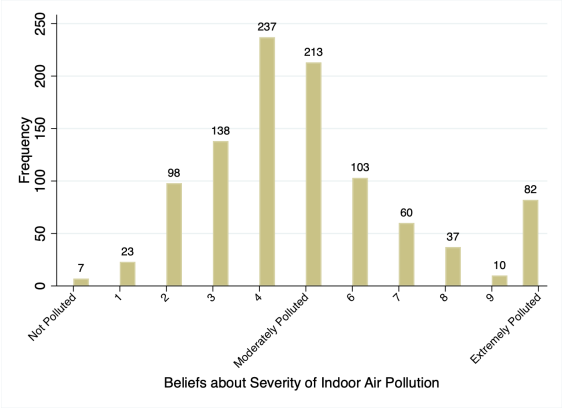
Outdoor and indoor pollution levels can be equally as high

Infiltration coefficient is 0.8

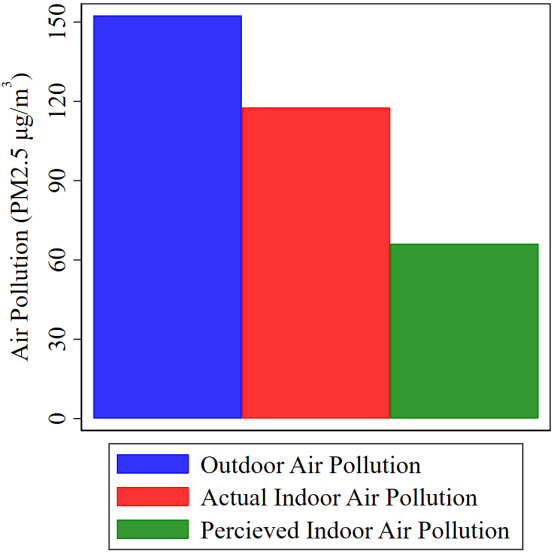


Households believe air in home is much less polluted than outdoor

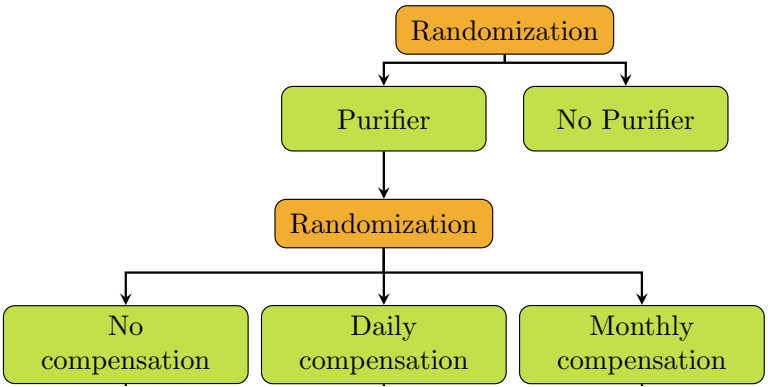




Perceptions vs. Reality



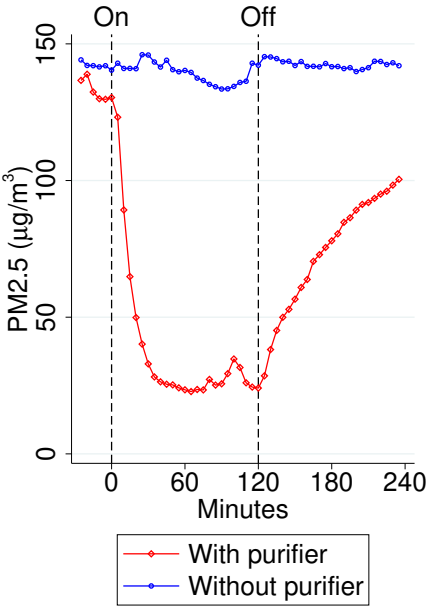
Research Design: Phase 2 (January 2024)



Phase 2 Survey
832

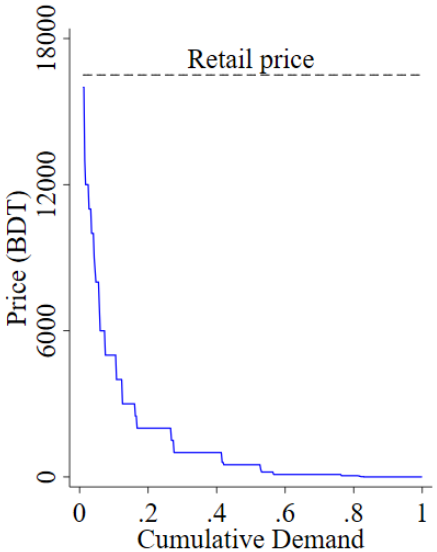
Phase 2: Air Purifier Treatment

- **Purifier use reduces pollution by 80% when windows and doors are closed**
- Retail cost: BDT 16,500 (USD 138)
- Electricity cost: BDT 0.24 (USD 0.002) per hour
  - USD 0.72 per month for 12 hour usage per day
- 3 sub-treatments:
  - No Electricity Compensation
  - Daily Electricity Compensation
  - Monthly Electricity Compensation
- Continuous usage data from smart plugs

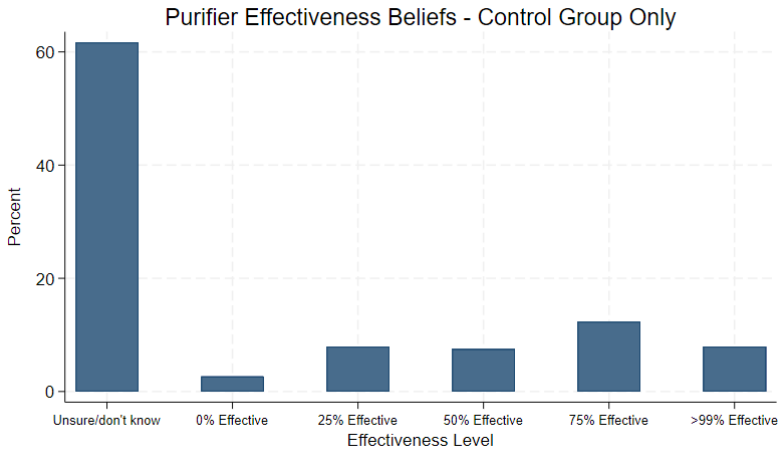


Demand for air purifiers is low

- No one willing to pay the retail price
  - Consistent with no ownership
- Average WTP is BDT 1,400 (USD 12) or 8.4% of the retail price
- Consistent with general finding of low demand for preventative technologies Dupas (2011); Kremer et al. (2019)



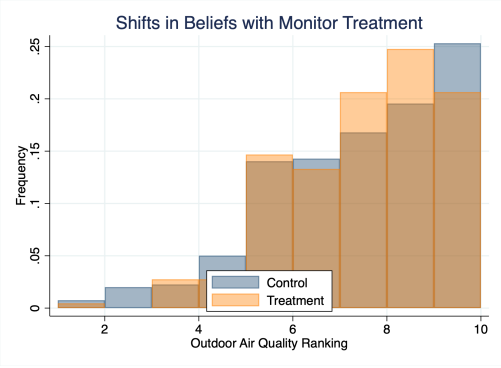
Households are uncertain air purifier effectiveness



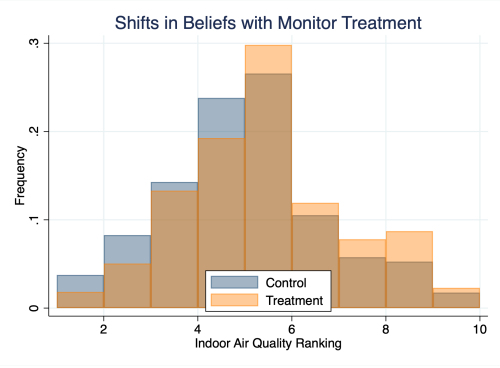
Experimental Results

Result 1: Households provided monitors believe air in their homes is more polluted...

Perceptions: Outdoor Pollution



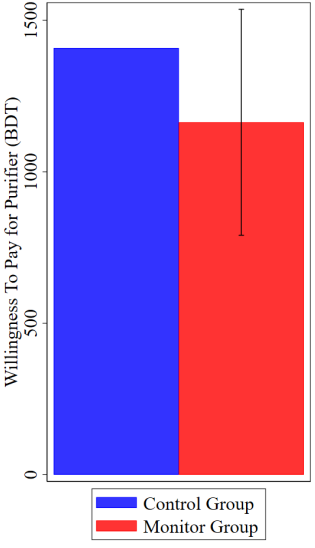
Perceptions: Indoor Pollution



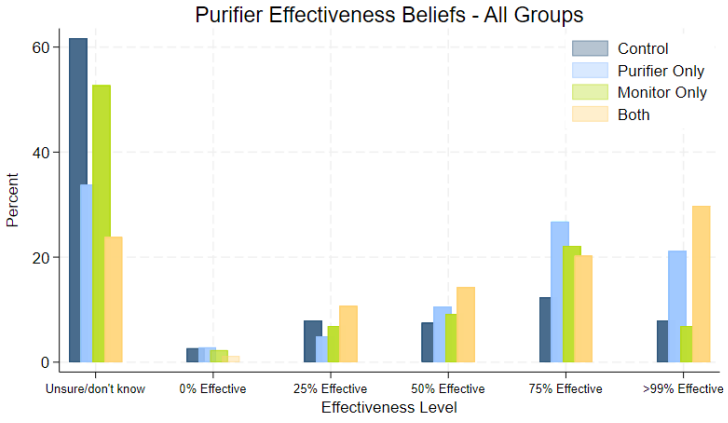
Result 1: Households provided monitors believe air in their homes is more polluted...

	(1) Beliefs about Severity of IAP	(2) Beliefs about Severity of AAP	(3) Beliefs about IAP Relative to AAP
Monitor	0.479***	0.0814	0.327*
	(0.149)	(0.162)	(0.175)
Observations	832	832	826
Clusters	832	832	826
Control mean	4.54	7.05	4.34
Sample	Phase 2	Phase 2	Phase 2
Phase 1 Controls	Y	Y	Y

... but are not willing to pay more for air purifiers



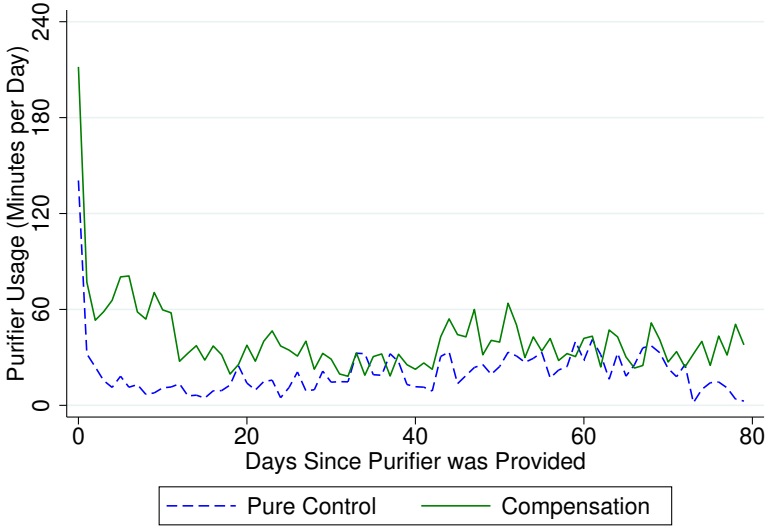
Result 2: Households provided purifiers are less uncertain about its effectiveness...



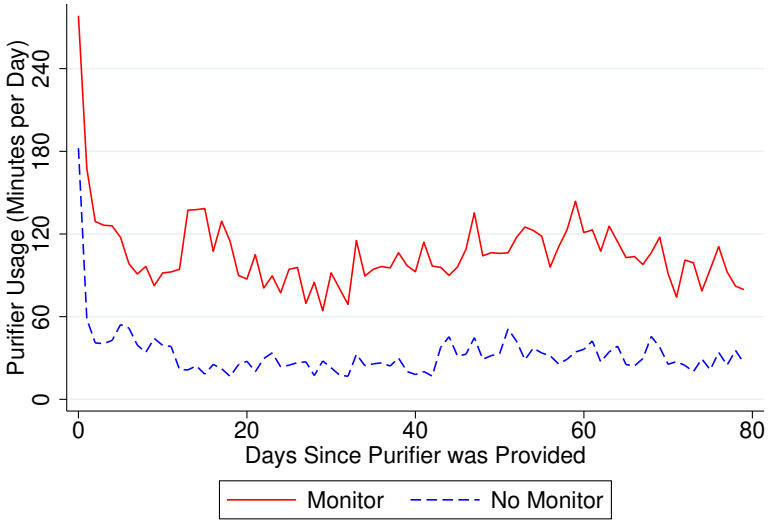
Result 2: Households provided purifiers are less uncertain about its effectiveness...

	(1) Has Opinion	(2) $> 0\%$ effective	(3) $> 25\%$ effective	(4) $> 50\%$ effective	(5) $> 75\%$ effective
Monitor	0.090*	0.094*	0.104**	0.087*	-0.011
	(0.054)	(0.054)	(0.052)	(0.048)	(0.029)
Purifier	0.279***	0.277***	0.307***	0.276***	0.132***
	(0.051)	(0.052)	(0.051)	(0.050)	(0.039)
Purifier x Monitor	0.010	0.023	-0.046	-0.066	0.097
	(0.082)	(0.083)	(0.085)	(0.084)	(0.067)
Observations	784	784	784	784	784
Control mean	0.407	0.380	0.315	0.228	0.073

... but rarely use the purifier (even with electricity comp.)



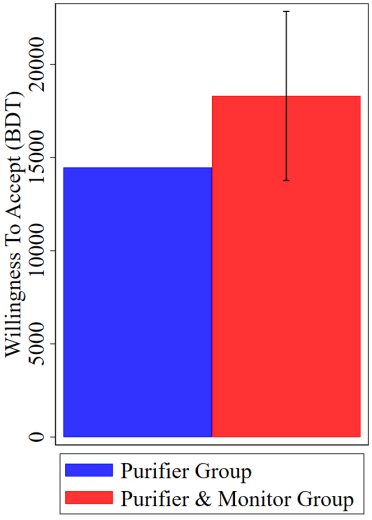
Result 3a: Monitors and purifiers increase usage



Result 3a: Monitors and purifiers increase usage

	(1) Min per Day	(2) Days Used 30+ min	(3) Days Used 30+ min
Monitor	73.42***	0.609***	0.470*
	(23.56)	(0.233)	(0.275)
Time FE	Yes	Yes	Yes
Sample	All Days	All Weeks	Week Before Survey
Observations	22,896	3,552	308
Clusters	309.000	309.000	308.000
Control mean	31.110	1.077	0.958

Result 3b: Monitors and purifiers increase purifier valuation



Summary of experimental results

- **Result 1:** Households provided a monitor believe air in their homes is more polluted but are not willing to pay more for an air purifier
  - Monitor $\rightarrow$ Perceptions of Indoor Pollution $\uparrow$
  - Monitor $\rightarrow$ No effect on WTP (before purifier provision)
- **Result 2:** Households provided a purifier are less uncertain about its effectiveness but they rarely use the purifier
  - Purifier $\rightarrow$ Perceptions of Purifier Effectiveness $\uparrow$
  - Purifier $+$ electricity compensation $\rightarrow$ Usage still low
- **Result 3:** Households provided both monitors and purifiers increase purifier use and its valuation
  - Monitor $\rightarrow$ Purifier Usage $\uparrow$
  - Monitor $+$ Purifier $\rightarrow$ Purifier Valuation $\uparrow$

Theory for Valuation of Preventative Health Technologies

Microfoundation of purifier valuation

Utility function:

$$U = Income - Purifier \times p_{purifier} - PerceivedIAP(1 - PerceivedPE \times Purifier) \quad (1)$$

- PerceivedIAP is Perceived Indoor Air Pollution
  - General form: Perceived magnitude of the problem
  - PerceivedIAP=0 if Indoor Air Pollution is perceived to be acceptable
- PerceivedPE is Perceived Purifier Effectiveness
  - General form: Perceived effectiveness of solution

Valuation of Purifier:

$$WTP = PerceivedIAP \times PerceivedPE \quad (2)$$

Household will use purifier when:

$$MC_t \leq PerceivedIAP_t \times PerceivedPE \quad (3)$$

Air pollution perceptions

If you own a monitor, you have correct perceptions:

$$PerceivedIAP_i = IAP \tag{4}$$

If you do not have a monitor, perceptions are determined by perceptions of community:

$$PerceivedIAP_i = \frac{1}{N-1}\sum_{j \neq i}^{N} PerceivedIAP_j = \overline{PerceivedIAP_i} \tag{5}$$

Purifier effectiveness perceptions

If you own a purifier, you have correct perceptions:

$$PerceivedPE_i = PE \tag{6}$$

If you do not own a purifier, perceptions are determined by perceptions of community:

$$PerceivedPE_i = \frac{1}{N-1}\sum_{j \neq i}^{N} PerceivedPE_j = \overline{PerceivedPE_i} \tag{7}$$

Multiple equilibria

Let's assume that:

$$p_{purifier} \leq IAP \times PE \tag{8}$$

and for at least some times:

$$MC_t \leq IAP_t \times PE \tag{9}$$

If perceptions were correct, household would buy purifier and use it some of the time

Good equilibrium:

- Everyone has correct beliefs and own and use purifiers
- If someone doesn't have monitor or experience with purifier, they use the community beliefs and buy the purifier

Bad equilibrium

- Downward biased beliefs about both indoor pollution and the effectiveness of purifiers
- No one buys purifiers (or monitors), and no one update beliefs

Predicted effects of interventions in bad equilibrium

- If $\overline{PerceivedPE_i}$ is sufficiently low, correcting $PerceivedIAP_i$ will not change WTP_i much
  - In the extreme case where $\overline{PerceivedIAP_i} = 0$, WTP_i would stay at zero
- Furthermore, if $\overline{PerceivedIAP_i}$ is sufficiently low, $MC_t > \overline{PerceivedIAP_{it}} \times PE$
  - This can explain why even households who have been given an air purifier (and now have $\overline{PerceivedPE_i} = PE$) are not using it
- Only when provided with both purifier and monitor, would people use the purifiers

Reconciliation of findings across literature

- Baylis et al. (2024) and Ahmad et al. (2023) both find that pollution information increase demand for face masks in India and Pakistan
- But, Greenstone et al. (2021) find that providing households with air quality monitors in Delhi has no impact on demand for air purifier rentals (consistent with our results)
- This differs from evidence from China, where pollution information increased air purifier demand (Ito and Zhang, 2020; Barwick et al., 2024)
- Our model can reconcile these findings, since consumers in India and Pakistan are familiar with masks but not with purifiers, while consumers in China are familiar with purifiers

Generalization of model

- We believe this basic model can explain why some preventative health technologies are scaled and adopted rapidly:
  - E.g. water filters, hand washing, blood pressure medication
- While other preventative health technologies fail to reach scale
  - E.g. Air purifiers, clean cookstoves, seatbelts in the back of car
- The key policy implication is that you have to convince people of the severity of the problem **AND** convince them of the effectiveness of the solution

Conclusion

Conclusion

- We propose a simple yet powerful model to explain why so few households use air purifiers
- The key policy implication is that it is insufficient to correct one biased belief when the adoption and use of preventative health technologies depend on both the perception of the severity of the problem as well as the perception of the efficacy of the solution
- The model also shows that another world is possible, when community perceptions change then a different equilibrium may be sustainable at current prices
- Policy approaches to increase air purifier adoption include:
  - Subsidizing air purifiers (or lowering taxes/duties on them) temporarily until widespread adoption has been achieved
  - Information campaigns explaining that air pollution indoors is almost as bad as outdoors

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