AIR POLLUTION – THE SILENT PANDEMIC

and its impact on business

2021

Dalberg

CLEAN AIR FUND

CII

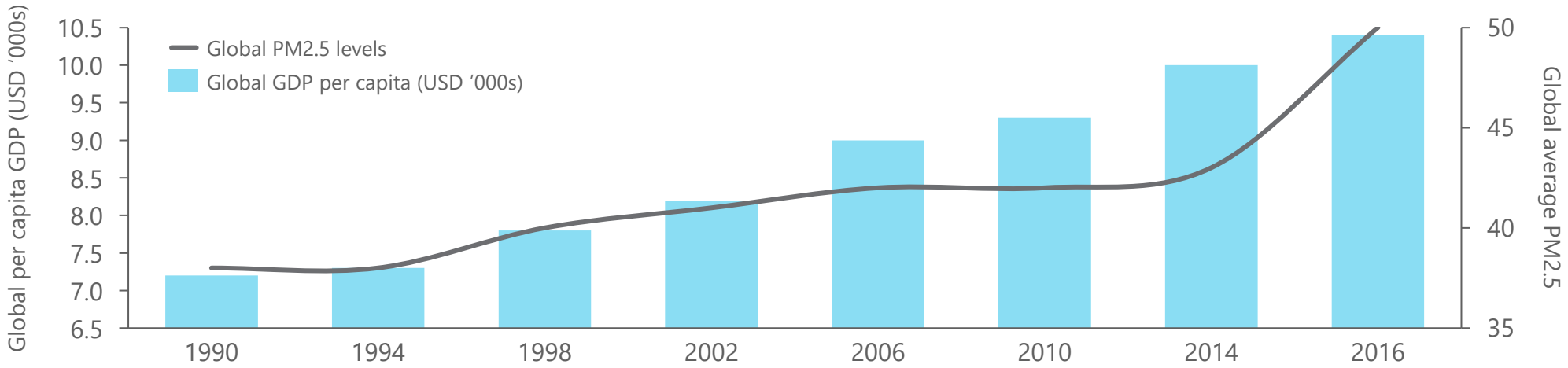
CONTENTS

Air pollution is often considered a byproduct of economic growth – something akin to an unavoidable cost of progress

Widely available data and prominent authorities have regularly emphasized the relationship between the two, particularly in emerging economies such as India

Air pollution due to economic growth[1]

GDP per capita (USD), Global average PM2.5 levels (µg/m³)



"With increasing GDP and energy demand – especially in fast growing economies such as **India and China – emissions of air pollutants rise"** – *OECD[2]*

"The **increase in industrial activity** in countries with lower levels of economic development leads to an increase in energy-intensive production and an **increase in pollutant emissions**" - *Jiang, Kim & Woo, 2020[3]*

"[Studies] suggested that if the economy continued with the same pattern… **we would reach unpredictable, and perhaps unacceptable, levels of pollution**, advising zero growth as an alternative to environmental catastrophe" – *Ali et al., 2018[4]*

Sources: (1) Dang et al., "Does GDP growth necessitate environmental degradation?", 2020; (2) OECD, "The Economic Consequences of Outdoor Air Pollution", 2016; (3) Jiang et al., "The Relationship between Economic Growth and Air Pollution", 2020; (4) Ali et al., "Pollution and economic development: an empirical research review", 2018

In reality, air pollution poses a huge cost to economic growth and businesses in India

This cost manifests across 6 major pathways

B Asset productivity

Decreased productivity and/or life span of physical assets and infrastructure

Current estimates suggest that air pollutants, e.g. ground-level ozone, is causing between **5-12% loss in global agricultural yields**, [2]

C Consumer footfall

Reduced revenue in consumer-facing sectors

A 10% increase in PM2.5 pollution reduced consumer spending in Spain by **EUR20-30 million everyday.**[3]

A Labor productivity

Lower output per worker due to absenteeism and presenteeism

A 10-point increase in AQI led to **0.35% fewer calls completed per day by** call-center workers in China.[1]

D Premature mortality

Lower economic output due to citizens dying earlier as a result of air pollution

1.4 million premature deaths due to pollution in 2013 cost India **USD 55.4 billion**[4]

F Non-market welfare loss

Decrease in social wellbeing and non-income generating activities

Air pollution prevents people from participating **in volunteer activities,**[6] such as elderly care. This puts burdens members of the workforce to act as caregivers, indirectly affecting workplace productivity.

E Health expenditure

Public and private expenditure on healthcare to treat air pollution-induced illness

USD 21 billion spent on healthcare globally due to air pollution in 2015.[5] A share of this cost is transferred on to employers, who in some cases bear it as direct costs.

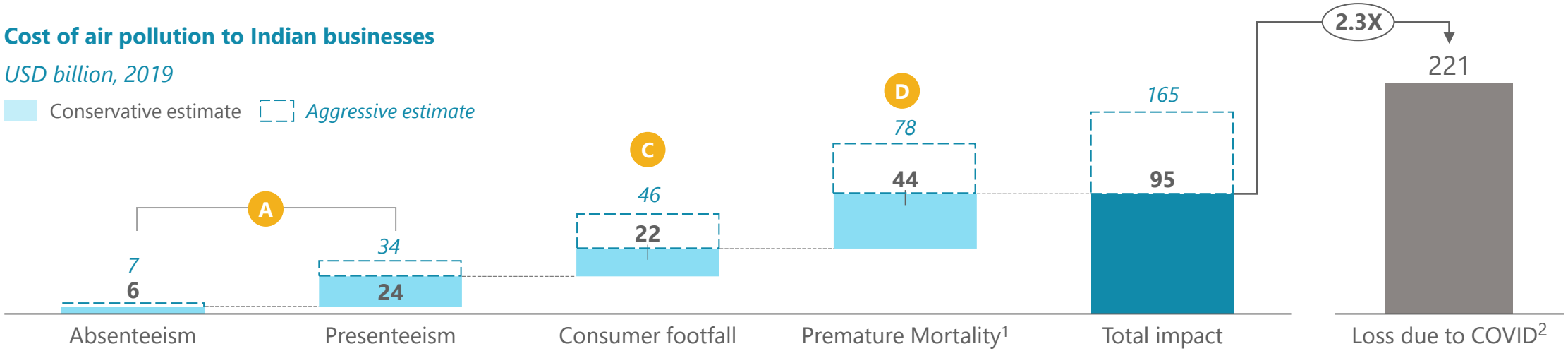
Sources: (1) Graff-Zivin et al., "The Effect of Pollution on Worker Productivity: Evidence from Call-Center Workers in China", 2012; (2) Sustainable Food Trust, "The impact of air pollution on crops", 2019; (3) Holub et al., "Air pollution and labor supply: Evidence from social security data", 2016; (4) The World Bank, "The cost of air pollution: strengthening the economic case for action", 2016; (5) OECD, "The economic consequences of outdoor air pollution", 2016; (6) DEFRA, "Valuing the Impacts of Air Quality on Productivity", 2014

Conservative estimates place the impact of air pollution on Indian businesses at **USD ~95 billion (INR 7 lakh crore)**, or **~3% of GDP**

In other words, every year air pollution costs India's businesses close to 50% of the cost of managing the COVID-19 pandemic

Cost of air pollution to Indian businesses

USD billion, 2019



- *~1.3 billion working days are lost p.a. due to absenteeism*
- *Absenteeism impact is higher with working age population with dependents, such as children*

- *Skilled services and manufacturing sector bear a disproportionate cost of air pollution*
- *Presenteeism is a hidden cost which may directly impact corporate profits*

- *Air pollution drives a 1.3% decrease in India's consumer spending*
- *The impact in segments such as international tourism is as high as 7.4%*

- *India had 1.7 million premature deaths from air pollution in 2019,[1] ~18% of overall mortality in the same year*
- *India contributes ~25% to the global cost of premature mortality*

The total economic impact of air pollution is equal to:

- *150% India's healthcare budget*
- *150% India's defense spending*
- *50% of tax collected annually*

- *Air pollution causes business impact equal to 43% of pandemic*
- *Unlike the pandemic, this economic cost is incurred every year*
- *Despite this, only INR 4,400 cr. has been invested in air pollution, <10% of total outlay on COVID response*

Sources: (1) A World Bank study estimated that 1.4 billion deaths (including children) account for a loss of USD 55.4 billion in 2013 by applying the economic value of a working year to the average number of working years lost per deceased person. This number has been extrapolated to 2019 by adjusting for the change in GDP and pollution levels; (2) India Ministry of Statistics & Programme Implementation, 2021; Dalberg analysis

A Air pollution carries an increasingly visible impact on **absenteeism** , driving ~10% lower attendance on high air pollution days

Absenteeism is the most visible impact of air pollution on labor productivity, costing India 0.2% of its GDP in 2019…

1.3
billion

working days lost to air pollution-induced absenteeism per year

Where is this manifesting?

- ~**98% of total absenteeism is driven by the northern and eastern parts of the country**, where pollution frequently crosses hazardous levels (300+ AQI).
- Absenteeism is driven by sectors in which **employees do physically intensive and/or outdoor work**, e.g. construction (20% of overall absenteeism impact) and food processing (13% of overall impact).

Who does this affect?

- Older members of the labor force are affected disproportionately; **people aged >60 years contributed ~44% to total absenteeism**, but comprise only 10% of the labor force[1].

…however, this impact is relatively muted in India, given the high opportunity cost of taking time off work

"Our employees need to work to earn and they need to earn to survive. **Most won't suddenly stop coming to work unless the air is really, really bad**"

-Business head, Ghaziabad

"The culture in many Indian companies is that you need to slog hard to stay employed, keep earning, and move upwards. For most people, **staying home to avoid a slight cough is not worthwhile**."

- Business head, Mumbai

Sources: (1) ILOSTAT; Survey data; Primary interviews with IT businesses; Dalberg analysis

A As an example, Bengaluru's Whitefield corporate zone sees a 12% average reduction in worker traffic during bad air quality periods

What we did

Analyzed movement of..

300,000+
workers

Across..

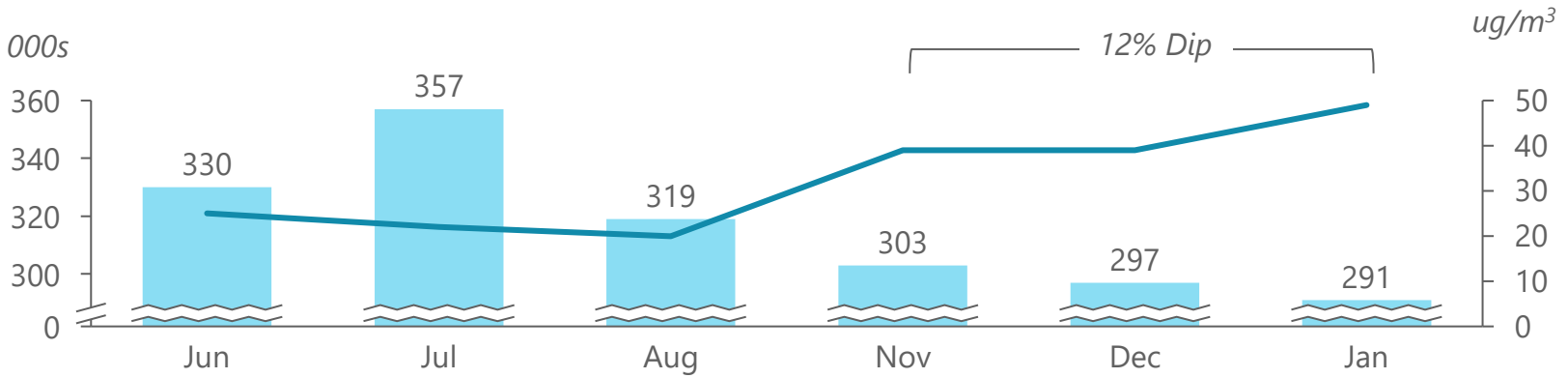
6
months

Controlling for..

- Holidays / Irregular events
- Rainfall level
- Temperature

What we saw

Weekly worker traffic in Whitefield, Bengaluru vs PM2.5 levels[1]
in 000s, ug/m³, 2019



Key highlights

- Bengaluru's Whitefield suffers a **3.9% drop in worker traffic for every 10 unit increase in PM2.5 levels [2].**
- This translates to an overall **11.6% fall in worker attendance** during high pollution winter months (November to January) vs low pollution months (June to August), when **PM2.5 levels nearly double.**
- This **despite Bengaluru having 62% lower pollution levels than high pollution cities** like Delhi and Gurugram, which indicates that workers react to PM2.5 spikes **even if the absolute pollution levels are low.**

*Air pollution is therefore **not just a North India problem**, but **extends even to regions with cleaner air, i.e., South and West India***

Sources: (1) Dalberg analysis, (2) Analyzed traffic levels in Whitefield, Bengaluru as a proxy for worker attendance in office spaces in Bengaluru

A The productivity costs of air pollution go beyond absenteeism; employees overwork to compensate for lost productivity, leading to burnout and attrition

A

Under-productivity

- Employees continue working despite pollution – sometimes persisting through health problems of their own– **causing on-the-job productivity loss.**
- These losses are even more severe for **employees working overtime to compensate** for absent colleagues.

B

Burnout and overworking

- Overworking and declining health are among many factors contributing to **morale loss (reported by 65% of employers).**
- These contribute not only to individual productivity loss, but could potentially lead to **wider dips in productivity, and even additional absenteeism in the long term.**

C

Employee Attrition

- Declining morale and feelings of overexertion lead to burnout, and **potentially higher rates of attrition.**
- Companies incur costs to either **incentivize employees to stay** or to more frequently **identify, recruit, hire, and train talent.**

D

Difficulty in Hiring

- **Attracting talent**, particularly in 'white-collar' industries such as IT and BFSI, becomes a challenge in highly polluted cities.
- This forces employers to either **overpay for talent** or to **sacrifice on the quality of talent hired.**

Sources: Primary research with IT businesses; Dalberg analysis

A At a point in time, employers estimate these effects result in a 8-10% decrease in productivity; this is more pronounced in cognitively demanding professions

Presenteeism creates hidden but extremely significant costs for Indian businesses…

8-10%

output lost on high pollution days

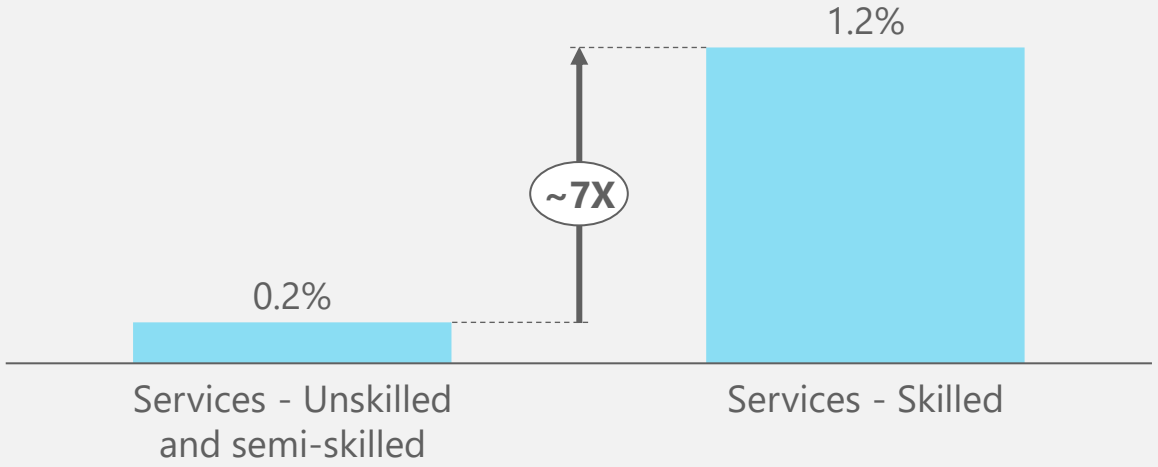
Overall productivity loss estimated by business heads[1]

- India loses **0.84% of GDP to pollution-induced presenteeism -** representing **26% of the overall impact of air pollution.**
- This is approximately equal to **individual values of the media, pharmaceutical, capital goods, and chemical sectors.**

…particularly in cognitively intensive professions, where impaired cognitive function results in steeper losses in productivity and value

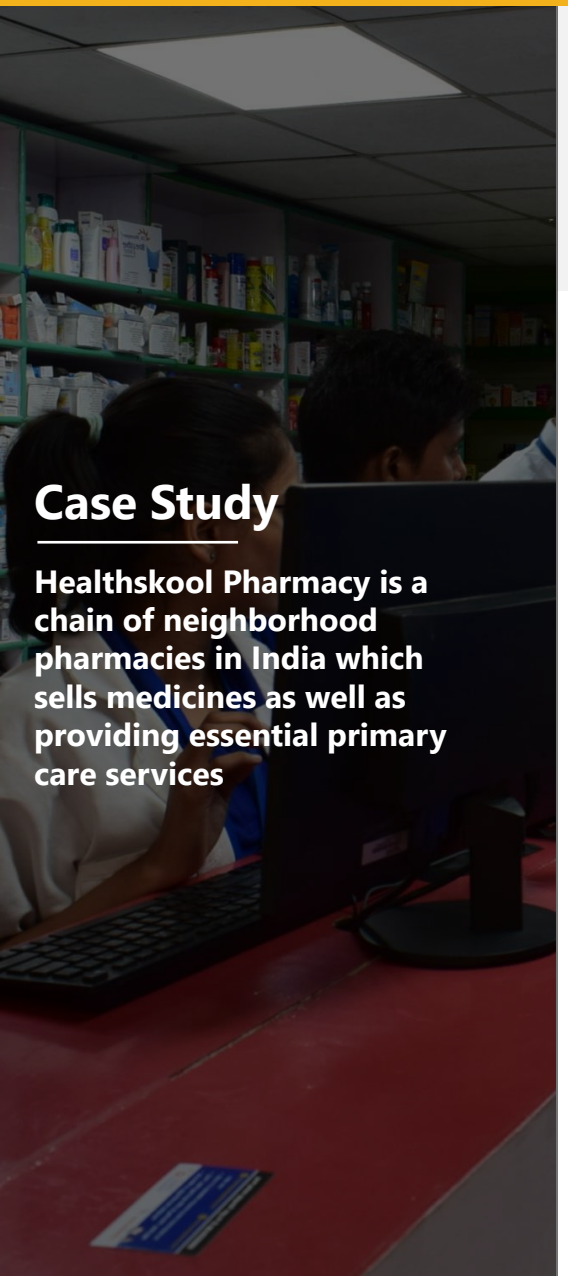
Impact of presenteeism across service job roles[2]

% of overall sector value, 2019



Sources: (1) On high pollution days, productivity losses are estimated by business heads to be 8-10%. Workers often make up for these by working longer hours; (2) Based on an analysis of the IT sector, with call-center employee productivity used as a proxy for the 'unskilled and semi-skilled' bucket and IT services employees (e.g. software engineers) used as a proxy for the 'skilled bucket; Primary research with IT businesses; Dalberg analysis

An analysis of pharmaceutical chains in Delhi reveals an exponential increase in sales of respiratory medicines during high pollution months, suggesting productivity decline



Case Study

Healthskool Pharmacy is a chain of neighborhood pharmacies in India which sells medicines as well as providing essential primary care services

What we did

Analyzed data from..

26 pharmacies in Delhi-NCR

Across..

52 weeks

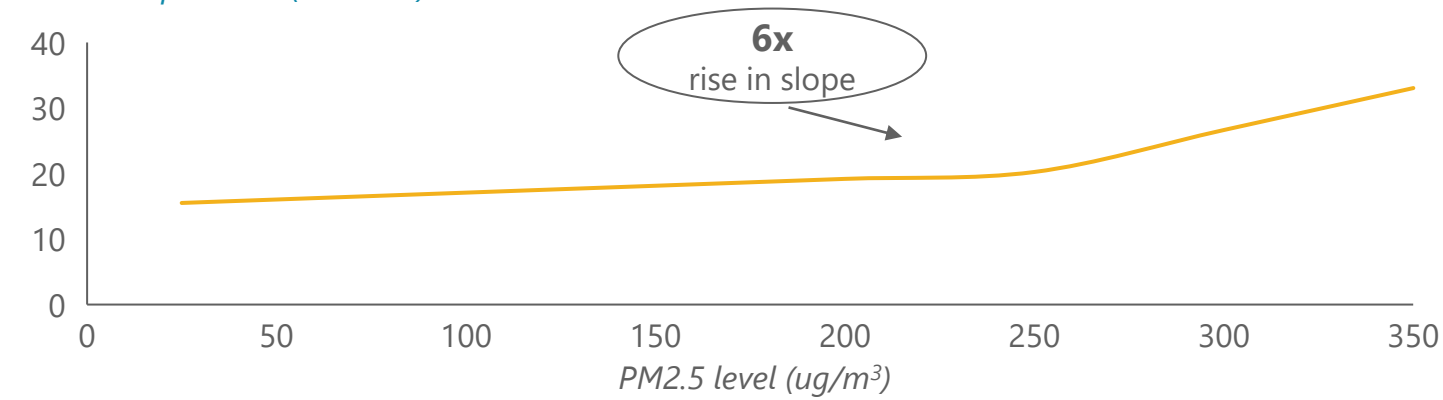
Controlling for..

- Location of pharmacy
- Rainfall level
- Temperature

What we saw

Projected relation between sales of respiratory medicines and PM2.5 levels

Sales per store (INR '000)



- A100-unit rise in PM2.5 leads to a **22% rise in sale of respiratory medicines;** this rate increase 6x when PM2.5 crosses 250 ug/m^3.
- In real terms, this translates to a **114% rise in sale of respiratory medicines during peak pollution months.**

What this means

Higher healthcare spending indicates increased respiratory disease burden..

- **Direct impact on working age population** affected by disease.
- **Indirect impact on caregivers** taking care of children and elderly affected by disease.

...causing productivity losses stemming from both physical and cognitive effects

- Air pollution **diminishes concentration and cognitive performance**, reducing productivity in the service sector.
- Air pollution also **increases rate of fatigue**, causing severe impacts to worker productivity and condition in the manufacturing sector.

Sources: Dalberg analysis

ASSET PRODUCTIVITY

B The impact of air pollution goes beyond people, reducing the productivity and lifespan of different categories of assets

Solar panels

*Pollutants **block sunlight** from reaching solar panels,[1] reducing efficiency of energy generation*

Revenue loss for solar companies as customers look for alternative energy sources

Unreliable power supply reduces productivity of factories and offices

Impacted sectors:
Renewables; industries reliant on solar power (e.g. manufacturing)

IT equipment

*Pollutants such as SO_2 **speed up degradation of circuitry** in electronic systems[2]*

Efficiency loss due to IT performance issues, unexpected system outages, etc.

More frequent costs for **replacement and repair** of IT hardware

Impacted sectors:
IT and dependent sectors (e.g. electronics, BFSI)

Agri inputs

*Ozone **damages flowering and growth** of crops such as wheat, reducing yields[3]*

Decreased agricultural revenues due to lower production

Increased procurement costs for food processors and other value chain actors

Impacted sectors:
Agriculture and dependent industries (e.g. food processing, retail)

Infrastructure

*Acid rain due to sulphur dioxide **corrodes buildings, machinery** and **historical monuments**[4]*

More frequent costs for **repair and renovation**

Decreased tourist visits to damaged historical monuments

Impacted sectors:
Infrastructure and real estate; tourism; heavy manufacturing

Transport

*Smog-induced **lower visibility** decreases the speed and efficiency of transport vehicles[5]*

Opportunity cost of time delays for both freight and commercial transport

Impacted sectors:
Transport and logistics; dependent industries (e.g. retail, tourism)

Sources: (1) Yeeles, "Solar power reduced by haze", 2018; (2) Hardcastle, "Air Pollution Hurts Computers, Intel Says", 2013; (3) Burney and Ramanathan, "Recent climate and air pollution impacts on Indian agriculture", 2014; (4) Rao, Rajasekhar and Rao, "Detrimental effect of Air pollution, Corrosion on Building Materials and Historical Structures", 2014; (5) Times of India article, 2019

Solar panels see a 13% reduction in productivity during bad air days, leading to lower savings and higher costs for consumers

Case Study

To understand the impact of air pollution on assets, we profiled one of India's leading rooftop solar companies, which operates in 75+ cities and leads the market in total number of rooftop solar installations.

What we did

Analyzed data from..

36 solar panels in Delhi-NCR

Across..

62 days

Controlling for..

- Location of panel
- Rainfall level
- Temperature

What we saw

13%

decline in productivity

- Every 100-unit increase in PM2.5 levels beyond 100 µg/m^3 **reduces solar panel productivity by ~13%.**
- As PM2.5 levels rise to hazardous levels, i.e., beyond 250 µg/m^3, the drop in panel productivity increases to **~23% per 100-unit increase** in PM2.5.

What this means

12%

increase in breakeven period

- Consumers of rooftop solar products in Delhi suffered an **11% drop in productivity in their appliances through the year** due to the city's high air pollution levels.
- At a micro level, this leads to lower savings from the use of solar panels each month, **increasing the breakeven period by 12%** and eroding a key USP for adopting residential solar.

67%

loss in cost advantage of solar vs coal

- The decline in productivity of solar panels drives up the per-kWh cost of solar power in Delhi from **INR2.62 to INR2.91 – an 11% markup**.
- A further **30% rise in Delhi's air pollution levels would equate the cost to produce solar and coal power**, potentially setting India back on its ambitious renewable targets to generate 450GW of renewable energy by 2030.

Sources: Dalberg analysis

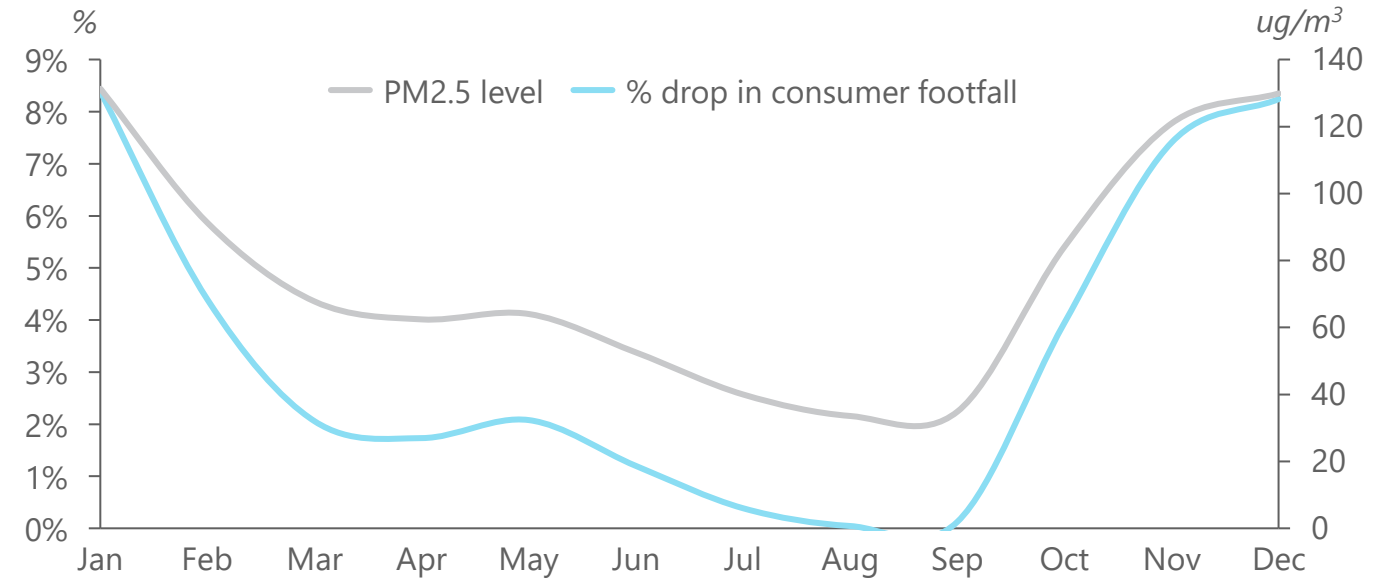
CONSUMER FOOTFALL

Decline in consumer footfall costs India ~1.3% of potential spending as consumers reduce outdoor activities

Consumers in India are highly sensitive to air pollution levels which leads to a significant dip in consumer footfall in markets during high pollution months..

Drop in consumer footfall due to air pollution vs PM2.5 levels in India

(%, ug/m^3, 2019)



- Winter months, i.e. **November to January** suffer 116% higher pollution levels vs rest of year and **see a 352% higher drop in consumer footfall due to air pollution**
- This is likely to get worse over the years with winter pollution on the rise.

..resulting in a sizeable impact on consumer spending in India

USD **22** billion

fall in consumption spending in India

- **North India**, having significantly higher air pollution levels, is disproportionately affected, contributing **74% of the total impact**, with a **217% higher drop in footfall** than the rest of India.
- This can act as a **roadblock to progress** made by business hubs in **Delhi, Haryana and Uttar Pradesh**, which have made significant efforts in the past few years to boost business growth.

Sources: Dalberg analysis

C

Categories of consumption that are discretionary, time-bound, or have fewer available online substitutes see a disproportionate impact

Overall, the sensitivity of consumption to air pollution is dictated by three parameters

Nature of purchase

- *Items that represent 'discretionary' spend – such as articles of clothing, leisure, etc., - are likelier to be foregone than necessities, such as food.*

Time-revenue linkage

- *Certain sectors are less sensitive to 'point-in-time' effects than others.*
- *For example, if a consumer forgoes a restaurant purchase due to air pollution, its unlikely that purchase gets made up.*
- *Alternatively, if a consumer forgoes purchasing a consumer durable, its likely that the purchase gets deferred to a later date vs. being completely foregone.*

Online substitutes

- *Certain product categories – such as clothing and food - can be more easily accessed through online channel*
- *This makes the need for in-person consumption redundant and reducing overall sensitivity to air pollution.*

Food and apparel categories saw the biggest fall in spending among consumers

1.5%

reduction in spending on food

Driven by sheer volumes, food consumption comprises **43% of the overall consumption lost due to air pollution**

*This is particularly alarming for the restaurant industry where **90% of restaurants shut within the first year** of launch.[2] Drop in consumer footfall due to air pollution will only add to the industry's woes.*

2.5%

reduction in spending on apparel

As a heavily impulse-driven category, clothing and footwear is sharply affected, facing **nearly 2x of the impact on other categories.**

*A significant portion of spending on these items comes from international tourism, which suffered a **7% loss in revenue** due to air pollution in 2019.*

Sources: (1) Dalberg analysis, (2) Economic Times article, 2017

C

CONSUMER FOOTFALL

Mumbai's Linking Road sees a 5% drop in footfall; this decline is less sharp than absenteeism effects, as the need to step out may outweigh pollution concerns

What we did

Analyzed movement of..

290,000+
consumers

Across..

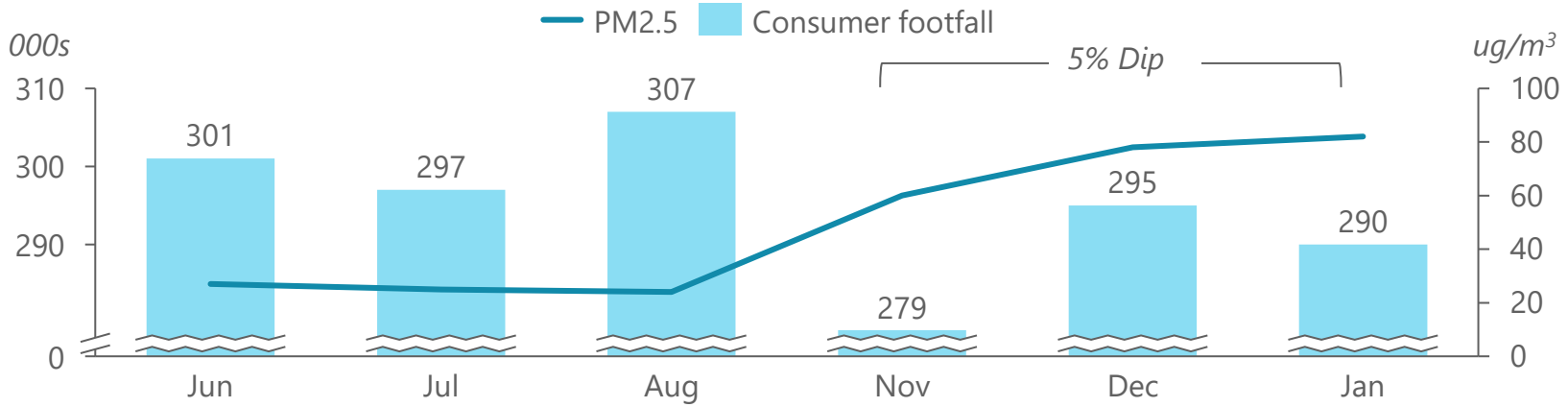
6
months

Controlling for..

- Holidays / Irregular events
- Rainfall level
- Temperature

What we saw

Weekly consumer footfall in Linking Road, Mumbai vs PM2.5 levels[1]
In 000s, ug/m³, 2019



Key highlights

- Linking Road Market suffers a **1.1% drop in consumer footfall for every 10 unit increase in PM2.5 levels.[2]**
- This translates to an overall **4.5% fall in consumer visits to markets** during high pollution winter months (November to January) vs low pollution months (June to August) when **PM2.5 levels jump nearly 3x.**
- The **drop in footfall is highest during the year's first PM2.5 spike** – usually in November – after which it recovers albeit not to the level during low pollution months, **indicating desensitization of consumers to increased PM2.5 levels as time passes**.

Sources: (1) Dalberg analysis, (2) Analyzed traffic levels in Linking Road, Mumbai as a proxy for consumer visits to markets in Mumbai

D

PREMATURE MORTALITY

Lastly, **premature mortality**, the direct consequence of pollution, affects both workforce of present & future

18%

contribution of air pollution to all deaths in 2019

- In 2019, **India saw 1.67 million deaths – 18% of the country's total mortality[1] –** due to air pollution.
- This represents an alarming **25% of the world's cases of premature mortality** due to air pollution.

3.8
billion

 # days of working life lost due to premature deaths in 2019[2]

- **Working age men are 62% more likely to die of air pollution-linked diseases than working age women**, due to prolonged exposure to unclean air.
- The state of **Delhi is disproportionately affected**, contributing to 3.3% of overall cost impact on the working age population despite having 1.4% of the population.[2]

34%

Of all loss borne by children below age of 1 year[2]

- Neo- and post-natal premature mortality contributed **1.3 billion lost days of working life** – driving 34% of the overall dollar impact of pollution-induced premature mortality In India [2].
- As the average age of India increases from **27 in 2019 to 30 in 2025 and 32 by 2030,[3]** the proportion of deaths and illness among the workforce could rise exponentially.

Sources: (1) The Lancet, Global Burden of Diseases, 2019; (2) Dalberg analysis based on data from Global Burden of Diseases; (3) Statista

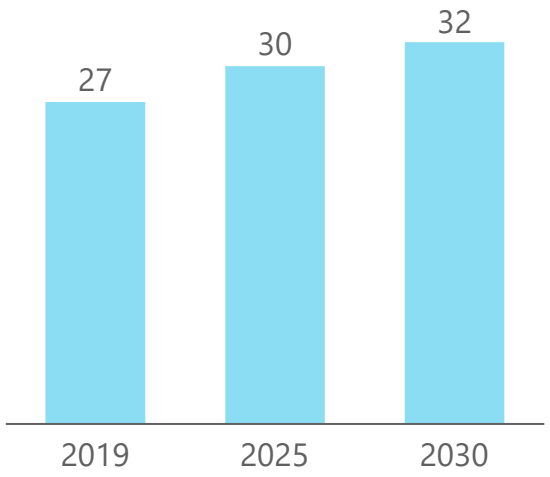
D

This impact is likely to get worse as India's average workforce age rises

As India's average age rises from 27 in 2019 to 32 by 2030..

Median age of India's population[1]

years



...mortality due to air pollution-linked COPD and lung cancer will grow at an accelerated pace

Age Band: 25-29

0.8

# of deaths per 100,000 due to air pollution-related COPD and lung cancer[2]

2X
rise in mortality

Age Band: 30-35

1.7

# of deaths per 100,000 due to air pollution-related COPD and lung cancer[2]

This could spell a potential workforce crisis for India in the future

Sources: (1) Statista; (2) Global Burden of Disease Study

CONTENTS

Case Study | How does air pollution impact India’s IT sector?

IT sector faces a 0.7% impact on its GDP due to air pollution, amounting to USD 1.3 bn.

Overview

India's IT sector is a key engine driving the country's growth agenda, and a strong representative for India's emerging service sector.

To understand how air pollution impacts the sector, we engaged ~65 IT sector enterprises across the country through surveys and interviews.

USD **191** billion — ***Value generated***[1] (9% of GDP)

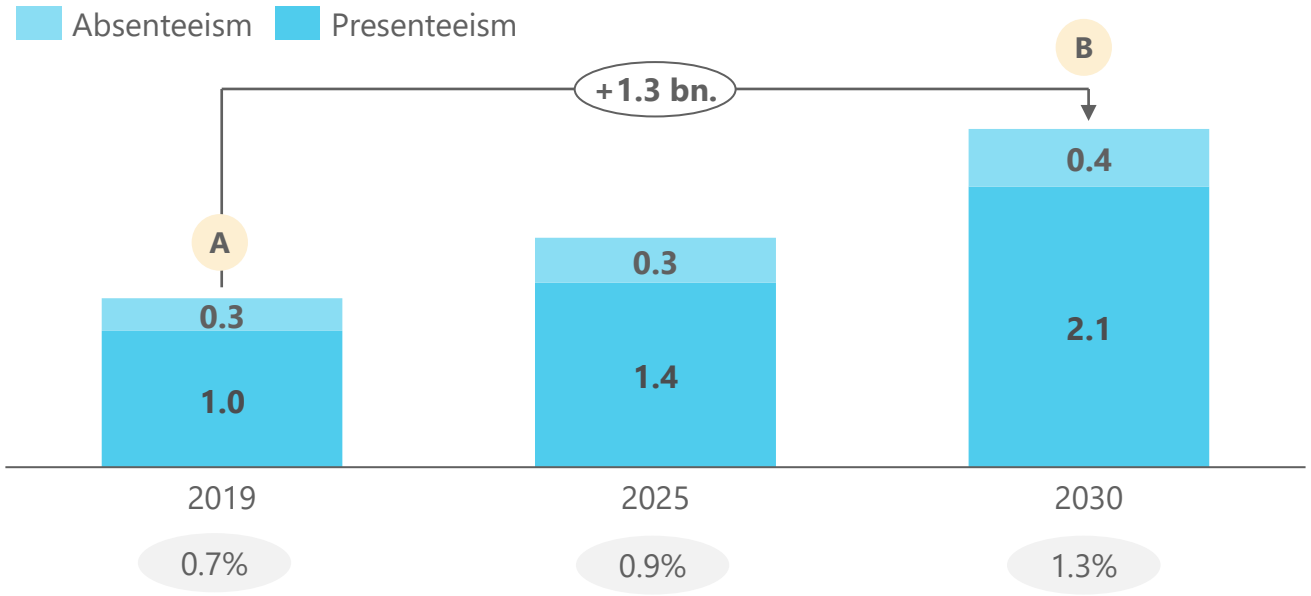
USD **7.7** billion — ***Foreign investment***[2] (15% of FDI)

3.9 million — ***Employment creation***[1] (1% of employment)

~70 percent — ***Importance of labor,*** *as a percentage of total costs*[3]

Economic impact of air pollution on the IT sector[4]

USD billion, assuming sector value to be constant at 2019 levels



A — **The economic impact of presenteeism is 5x that of absenteeism.** This is because many employees face financial and other constraints that prevent them from taking leave, even when air pollution rises to dangerous levels. Meanwhile, presenteeism is a passive effect that affects all working employees.

B — These **effects increase by more than USD 1 bn. (+100%) between 2019 and 2030**, as ambient PM2.5 levels increase by 13% nationally. **This will be driven by a 2x increase in presenteeism impacts over the same period**.

Sources: (1) InvestIndia, 2019-20; (2) India Department for Promotion of Industry and Internal Trade (DPIIT) data; (3) Dalberg analysis of annual statements of leading IT companies; (4) Dalberg analysis; assuming an 11% and 13% increase in ambient PM2.5 in 2025 and 2030, respectively, per TERI.

Loss of productivity coupled with recruitment and retention challenges, impact the stringent "performance timelines" for the IT sector

Short-term — *Absenteeism* — *Presenteeism* — *Other effects* — ***Long-term***

10%

*net reduction in **employee attendance** when air pollution crosses into hazardous territory (300+ AQI)*

- Financial constraints and desensitization to pollution mean that **employees are unlikely to take time off unless pollution levels reach extreme levels.**
- Employees largely need to be present at the workplace to utilize specialized infrastructure (especially in the BPO sector), suggesting **most absenteeism is truly 'zero productivity.'**

3%

*reduction in calls logged per day by **call center and BPO workers**, who represent the majority of the IT workforce*

- The depth of this impact is **up to 7x higher for more "skilled" IT services jobs,** such as software engineering, where the cognitive load placed on employees is higher.
- Productivity loss due to presenteeism is **more of an accrued effect**; on a day-to-day basis, the pressure to meet aggressive targets means that productivity may stay relatively intact.

28%

*of surveyed employers reporting **hiring challenges** in highly polluted cities*

- The effects of overworking - especially for employees contending with respiratory ailments - stack over time, resulting in **progressively more intense presenteeism impacts.**
- The resultant burnout and attrition can have dramatic consequences for IT businesses, **many of whom (63%) already report severe talent shortages.**[1]

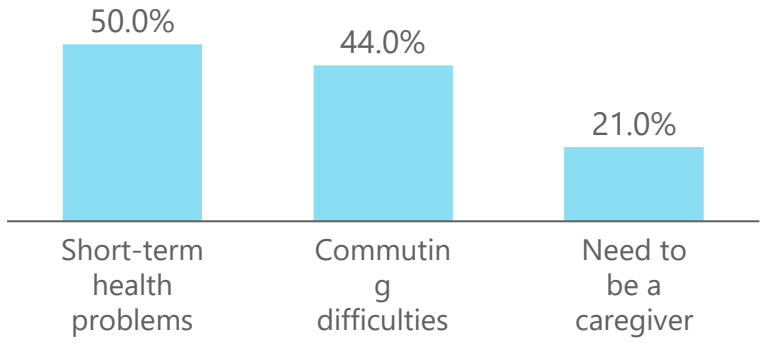
"Performance timeline" violations result in heavy penalties, how much of business does that take away from this sector?

Sources: (1) ManpowerGroup, "Talent Shortage 2020", 2019; Primary interviews with IT businesses; Dalberg analysis

These short-term impacts are compounded by the 'hidden' costs of employee retention and attrition, which may only become known in the longer term

Short-term *Absenteeism* *Presenteeism* *Other effects* ***Long-term***

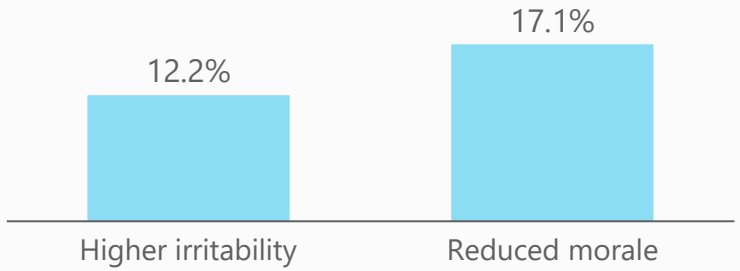
Causes of absenteeism on poor air quality days
% of employers responding, n = 27



"Employees struggle to commute. Even pre-COVID, I had to allow them to **stay home for those 3 horrible weeks of bad air**"

- IT HR head, Ghaziabad

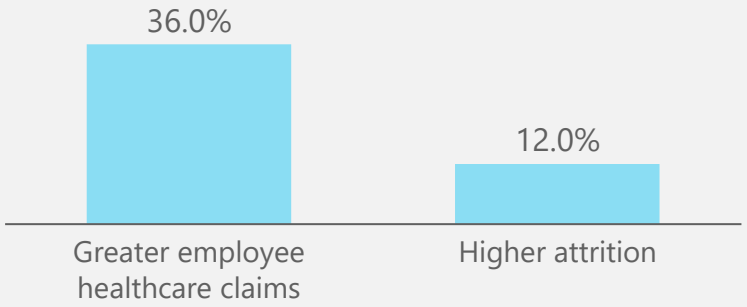
Effects of air pollution on employees
% of employers responding, n = 41



"People will continue to put in hours. **If they are sick, they step out to buy medicine and return to work. Productivity takes a hit**"

- BPO business head, Mumbai

Other long-term effects of air pollution on HR mgmt.
% of employers responding, n = 27



"People from other parts of country who come here suffer more and leave sooner, **as they aren't so used to the pollution**"

- IT HR head, Ghaziabad

Sources: Primary interviews with IT businesses; Dalberg analysis

In reality, these effects might be a lot higher

Employers may be underestimating the cost of presenteeism, due to desensitization in polluted cities and inability to identify air pollution as a cause…

"Productivity is not something I see decreasing too much… I have purchased an AC unit which makes sure that **the air inside our offices is as clean as possible**. "

- IT HR head, Ghaziabad

People's productivity may be a little slower to start for 30-40 minutes after they arrive on high air pollution days. But **they are putting in an extra 30-40 minutes to make it up**, so no output is really lost"

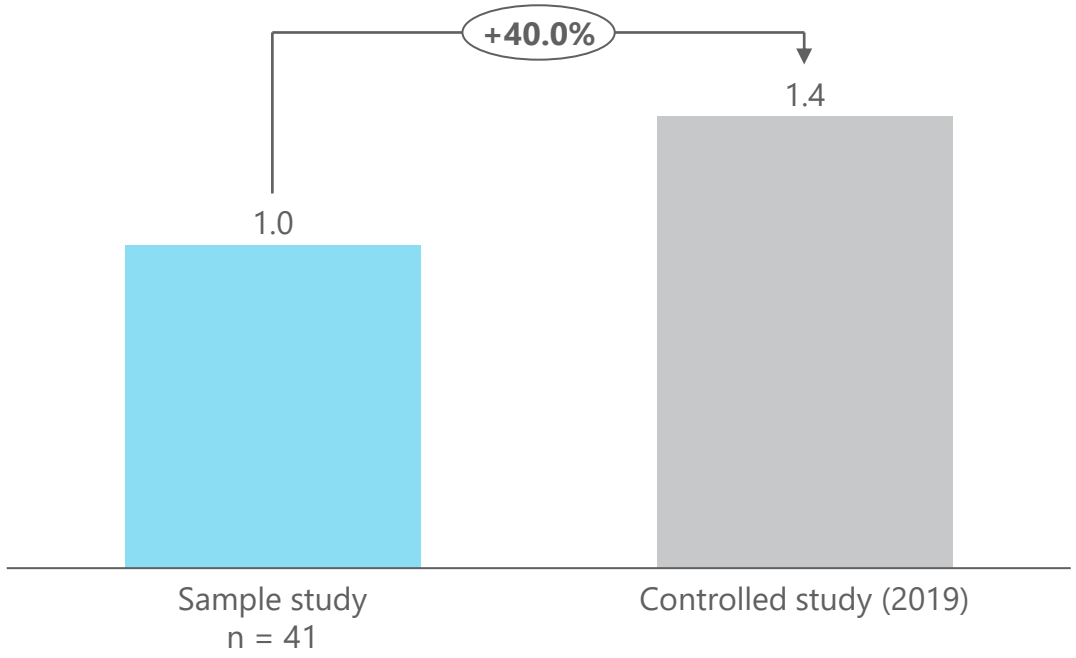
- IT business head, Mumbai

"Our employees are experienced professionals who know how to operate in adverse circumstances. **In my mind, their productivity would not be affected**"

- IT business head, Bengaluru

…with existing studies suggesting the impact could be as much as 40% higher[1]

Comparing estimates of economic loss due to presenteeism
USD billions, 2019

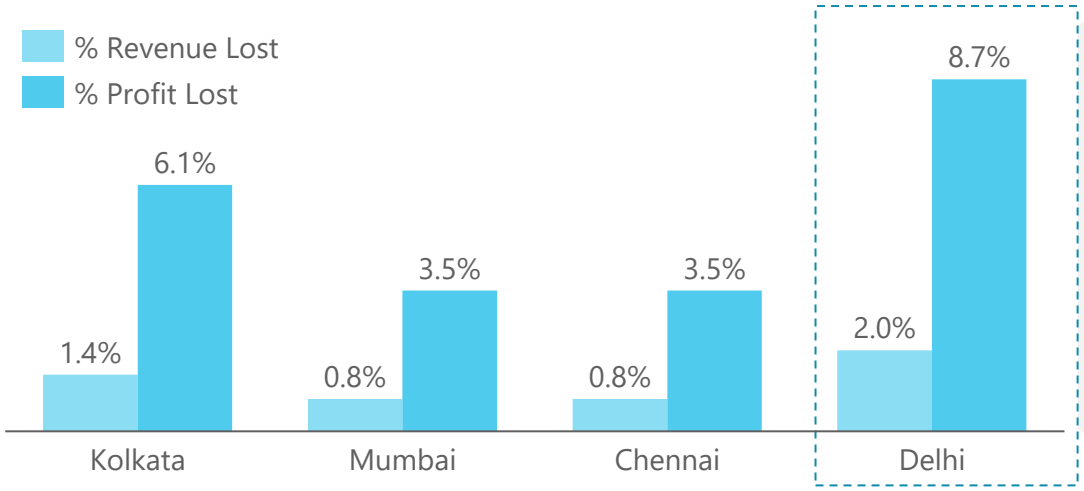


Sources: (1) Chang et al., "The Effect of Pollution on Worker Productivity", 2019; Stakeholder interviews; Dalberg analysis

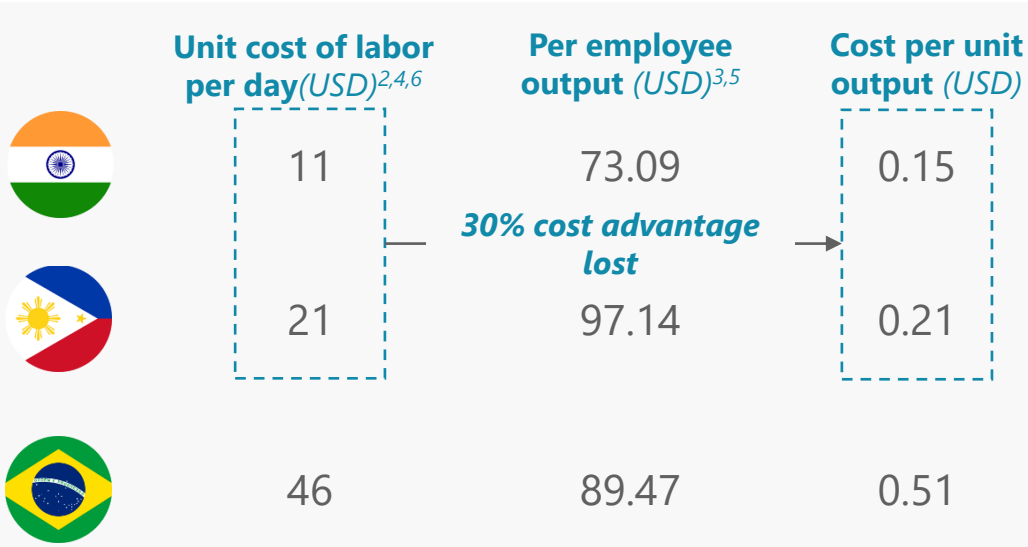
The risk that air pollution poses to the overall competitive advantage cannot be underestimated; for example, an IT firm in Delhi risks losing 33% of its cost advantage over a Filipino competitor

India's IT Sector becomes more regionally confined…

Economic impact of air pollution on the IT sector[1]
USD billion



…while losing competitive advantage internationally



Regional disparities

- **55% of overall economic impact on the IT sector is driven by North Indian businesses** – which contribute ~10% to overall sector value
- As Southern IT clusters reach saturation, major IT companies are shifting operations north; **even 10% of value shifting from South to North India could increase overall impact by as much as 80%**

- To recover its cost advantage, the Indian IT sector may **focus investments on hiring and building pollution-proof infrastructure**
- While these investments may offer short-term gains, they are likely to further drive costs up and profits down; **the most sustainable investment is, therefore, in reducing air pollution**

Sources: (1) IT sector average profitability was estimated by analysis of Annual Statements of leading IT companies. Our analysis assumes that costs in the IT sector remain constant, and that air pollution impacts only on the revenue side; (2) Payscale.com; (3) Dalberg analysis; (4) Payscale.com; (5) Dalberg analysis; (6) Annual Survey of Philippine Business and Industry; Dalberg analysis

Case Study | How does air pollution impact India’s tourism sector?

The tourism sector loses USD ~2 bn due to air pollution, amounting to ~1% of GDP

Overview

India's tourism sector is not only a driver of economic growth and employment in the country, but an indicator of the attractiveness of India's cities to consumers across the world.

To understand how air pollution impacts the sector, we engaged ~52 tourism sector enterprises across the country through surveys and interviews.

USD 240 billion — ***Value generated[1]*** (9% of GDP)

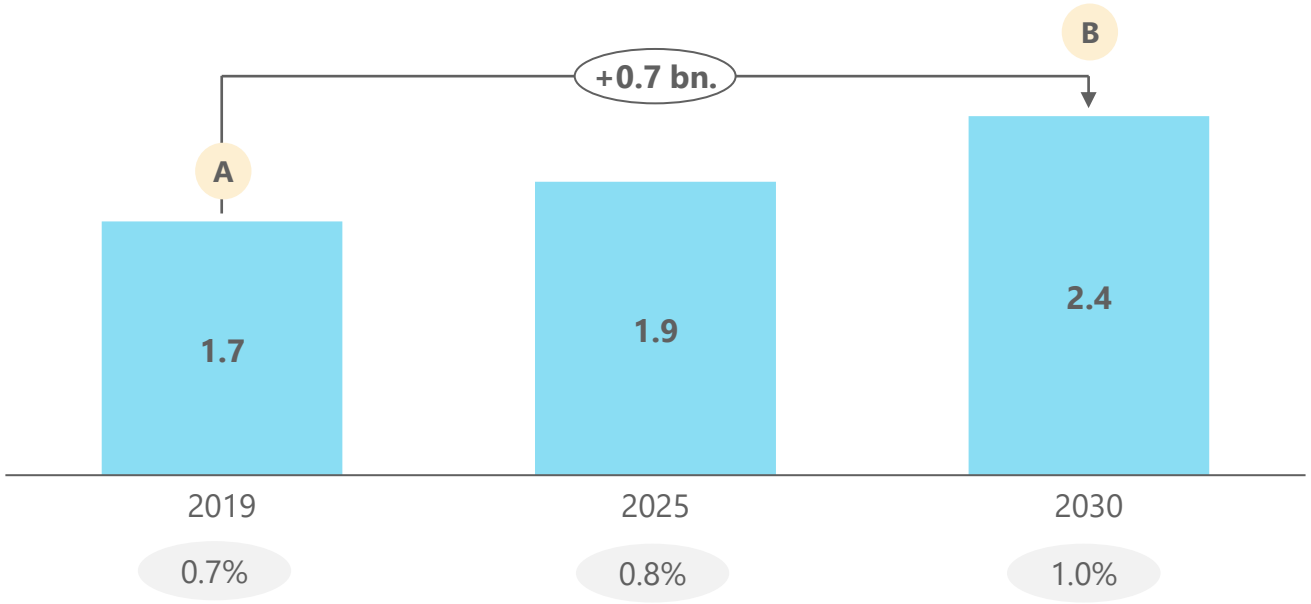
29 million — ***annual international tourist arrivals[2]*** (2% share of global volume)

38 — ***UNESCO World Heritage sites[1]*** (6th in the world)

~20 percent — ***of value from international tourism[2]***

Economic impact of air pollution on the tourism sector[3]

USD billion, assuming sector value to be constant at 2019 levels



A This loss in value is driven by an **overall 0.7% decrease in tourist arrivals** – particularly arrivals by foreign tourists visiting for leisure and sightseeing purposes, who are often **most sensitive to the impact of air pollution on health, visibility, and overall quality-of-life**.

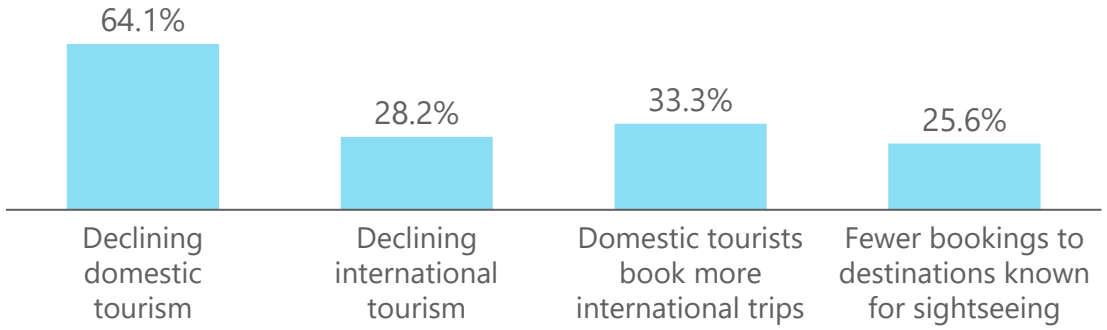
B Assuming currently projected estimates for air pollution in 2030, **this impact could increase by 40%,** driven in by an additional USD 0.4 bn. in foregone revenue due to lost international arrivals.

Sources: (1) InvestIndia, 2019-20; (2) Department for Promotion of Industry and Internal Trade (DPIIT) data; (3) Dalberg analysis; assuming an 11% and 13% increase in ambient PM2.5 in 2025 and 2030, respectively, per TERI.

The impact is two-fold: either tourist decide not to travel, or have a lower quality experience if they choose to travel

Tourist arrivals

Emerging trends caused by air pollution
% of businesses responding, n = 39



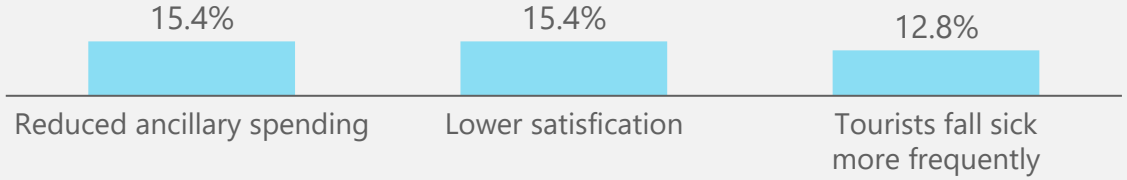
"A lot of people that come to sightsee and make outdoor trips are cancelling their itineraries, **especially older travelers and people from cities in and out of India who aren't used to the bad air**"

- Travel agent, Kolkata

- Increasingly, air pollution is pushing people away from India's major cities (e.g. Delhi, Kolkata) and Northern tourist attractions (e.g. Agra, Varanasi), **redirecting them either to 'cleaner' destinations or abroad.**
- While clients visiting for sightseeing and leisure purposes are most sensitive, **businesses are increasingly cognizant**; some corporates empanel only hotels that have air purifiers in each room, etc.

Tourist experience

Emerging trends caused by air pollution
% of businesses responding, n = 39



"I had one case with an elderly couple that was visiting from abroad during the winter; **within a day they were coughing heavily and telling me that they wanted to go back home**"

- Tour operator, New Delhi

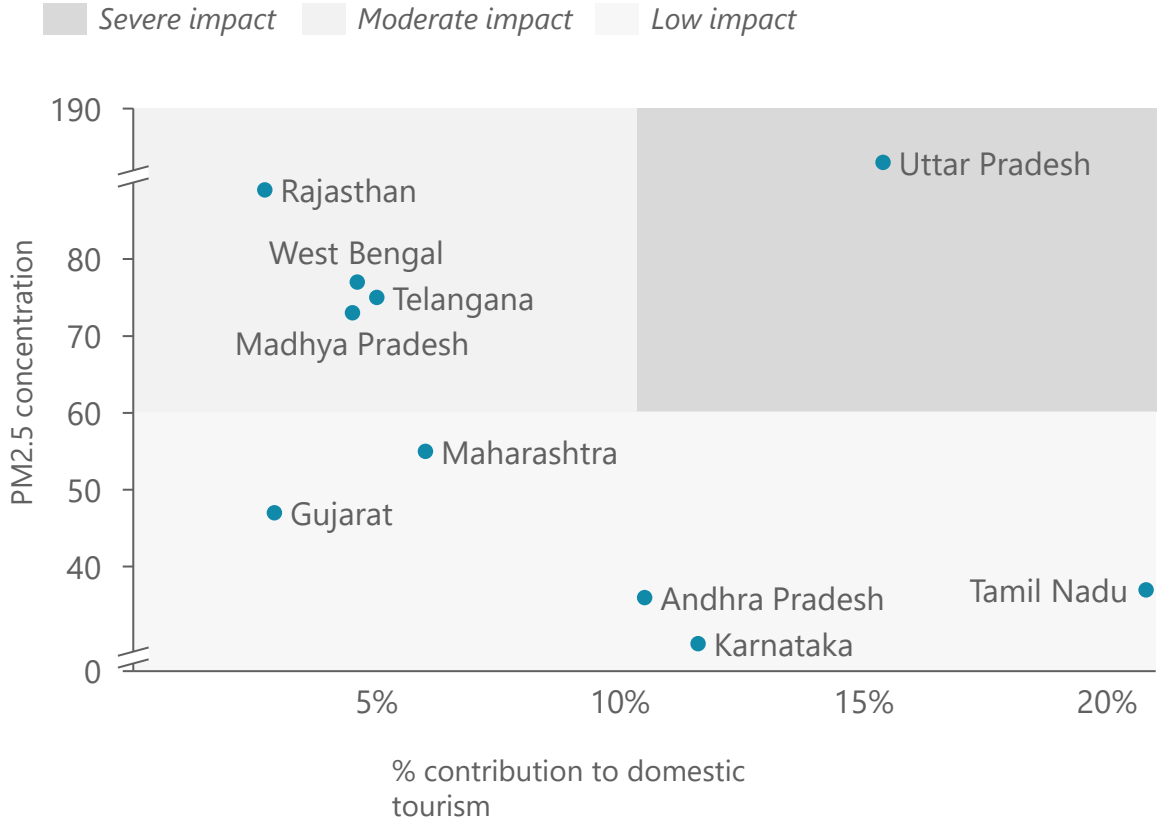
- Overall, when air pollution spikes, **outdoor attractions and historical sites may see as much as 10-15% lower footfall** – particularly from domestic tourists, who face fewer constraints around revisiting a site at a later date.

Sources: Dalberg analysis

These impacts expose India's economy to drastic short-term losses, as well as longer-term loss of competitiveness due to reputational risks

32% of India's domestic tourism industry is concentrated in 5 states where the impact of air pollution is most severe

State-wise PM2.5 levels[1] vs contribution to domestic tourism[2]
%, ug/m^3, 2019



The impact felt in these states will drive high revenue losses in domestic tourism and ultimately lead to drastic cost-cutting

USD **1.3** billion

Total revenue lost due to 12.5 million foregone domestic tourist arrivals

While domestic tourists' travel decisions are less sensitive to air pollution, they typically face stricter budget constraints than foreign tourists. Therefore, a tourist itinerary – once cancelled – is unlikely to be rebooked.

820k

Total employment loss due to losses in domestic tourism

Lower revenue for businesses in the tourism, hospitality and allied sectors (e.g. food & beverage) could prompt cost-cutting measures, resulting in increased unemployment in one of India's highest-employing sectors.

Sources: (1) Down to earth article; (2) India Tourism Statistics

The impact on international tourism could have further reaching consequences, incurring short-term economic loss as well as longer term reputational harm

USD **350** million

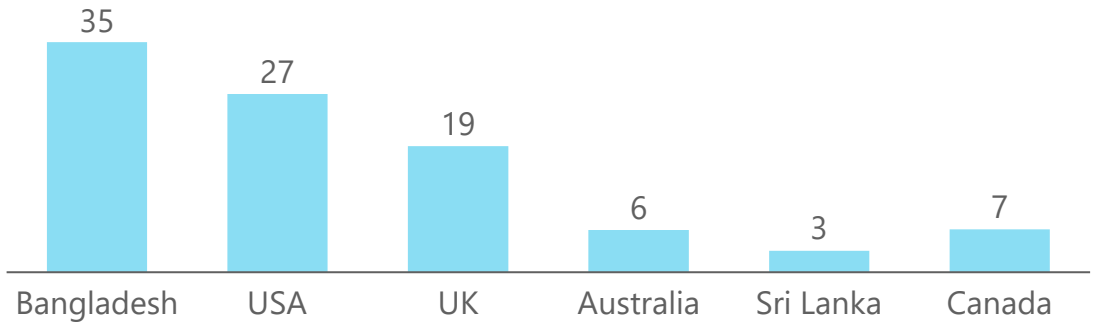
Total direct revenue loss due to lost foreign tourism
(0.1% of total sector GDP)

USD **2** billion

Total foreign exchange earnings from tourism lost
(0.7% of total forex earnings)

In the short term, air pollution could push away tourists from India's top 6 'client countries', **resulting in a total loss of USD ~100 mn. (~30% of total impact on foreign tourism)**

Value lost from key countries of foreign tourist origin[y]
USD million, 2019



- Tourists from highly polluted developing nations – such as Bangladesh – will **forgo travel to India in progressively greater numbers**, as traveling to India no longer means escaping high pollution levels at home
- While the absolute loss of footfall from developed nations is likely to be lower, **higher per-tourist value means the dollar impact is substantial**

In the long term, the word-of-mouth effects of cancelled trips and poor tourist experiences could cause **serious damage to India's reputation and attractiveness as an international tourist hub**

"I recall one client I had from abroad who was so shocked by the air quality that she took a video to show her friends back home. **I would be surprised if any of her friends were to visit India after seeing the video**"

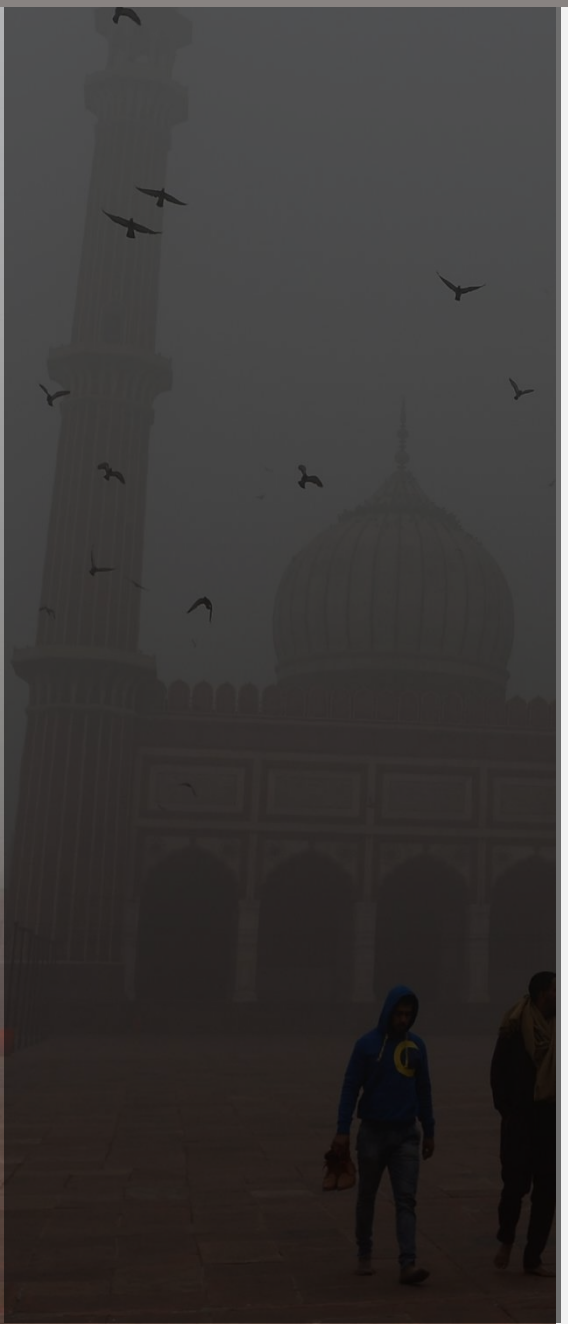
- Tour operator and travel agent, Delhi

""**Foreign clients are starting to understand what a big problem it is, and are now asking about air quality** when they contact us to make bookings. We hardly have any interest in our Delhi packages anymore"

- Travel agent, Delhi

Case Study | How does air pollution impact India’s capital?

CASE STUDY | New Delhi



3.5 *percent* — ***share of India's GDP (2019)***

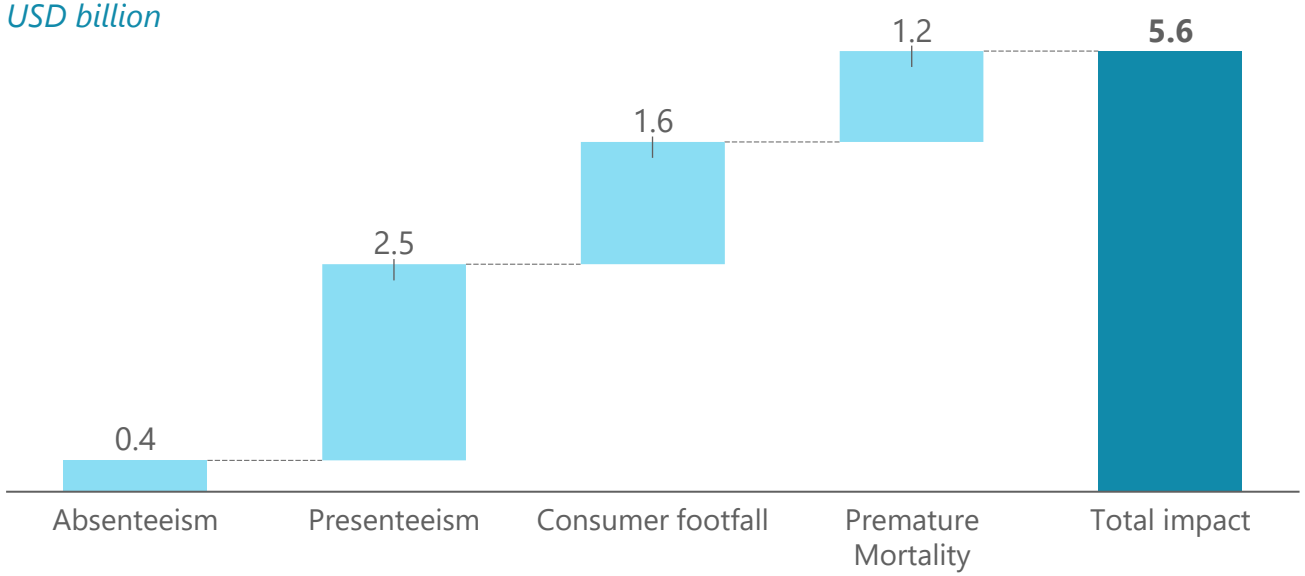
300k+ — ***companies formally registered in Delhi NCT***

152 — ***diplomatic missions located in New Delhi[1]***

5th — ***rank in world's most polluted cities, 2019[2]***

Economic impact of air pollution on New Delhi[3]

USD billion



A Delhi, among the most highly polluted cities in India, **suffers a disproportionate economic loss of USD 5.6 bn (~5.8% of city GDP)** – higher than the combined impacts suffered by Mumbai (~USD 2.1 bn.), Bengaluru (~USD 0.5 bn.), and Chennai (~USD 0.38 bn.).[3]

B The impact of direct health effects is substantial; in 2019, **Delhi saw 11,310 premature deaths due to air pollution and lost 12.2 million working days** to air-pollution induced absenteeism.[3]

Sources: (1) Delhi Ministry of Tourism; (2) IQAir Visual, "World Air Quality Report", 2019; (3) Dalberg analysis

Delhi's competitiveness is anchored to three dimensions, each of which is impacted to an extent by air pollution (1/2)

1

DECISION-MAKING HUB FOR THE PUBLIC AND PRIVATE SECTORS

2

ECONOMIC ENGINE FOR INDIA

3

TOURISTS' GATEWAY TO INDIA

Delhi's competitiveness is anchored to three dimensions, each of which is impacted to an extent by air pollution (2/2)

Decision-making hub for the public and private sectors

275 days of "Unhealthy" air quality or worse in 2019 (75% of all days)[1], **when presenteeism effects begin to occur**

550 **flights delayed in the first week of Nov. 2019,[2]** when air quality was nearly 3x worse than the yearly average

Delhi is the seat of India's political power. It is also home to >25% of India's registered companies,[3] making it a focal point for private sector decision-makers.

- Pollution has ~**10x higher impact on cognitively more demanding jobs,** creating costly impact in Delhi's senior corporate offices.
- India's political and judicial minds also suffer; **judges may take ~22% longer to reach a verdict.[4]**
- Further, flight and train delays not only cost carriers, but also **business travelers who face**

Would companies want to expand their decision-making centers to Delhi?

Economic Engine for India

40% of 17,000 surveyed Delhi residents reported they **would prefer to leave the capital** to preserve their health[5]

Delhi not only attracts talent from all over the country seeking to work at top companies, but also migrant labor from rural India.

- Members of the skilled workforce are increasingly empowered to make **relocation decisions based on quality-of-life.[6]**
- 'Unskilled' workers are rightfully also growing more frustrated; **~57% of migrant workers surveyed in Delhi felt their living conditions in their home-towns were superior** to those in Delhi, including due to air quality.[7]

Can Delhi's private sector expect to see continued growth if workers are unwilling to stay?

Tourists' Gateway to India

44% decrease in **online booking enquiries for Delhi** in Nov. 2019 when PM2.5 concentrations spiked to >2x the annual average[1]

Delhi is a key cog in India's tourism industry, not only as a destination, but as a hub for travel to other attractions in North India

- Air pollution affects tourists' ability to enjoy Delhi's many sites in the short-term, with low visibility and health risks **reducing the appeal of outdoor attractions, e.g. Red Fort, Qutub Minar.**
- In the longer term, this creates **reputational damage that is hard to recover from**, particularly with the high value foreign tourist market.

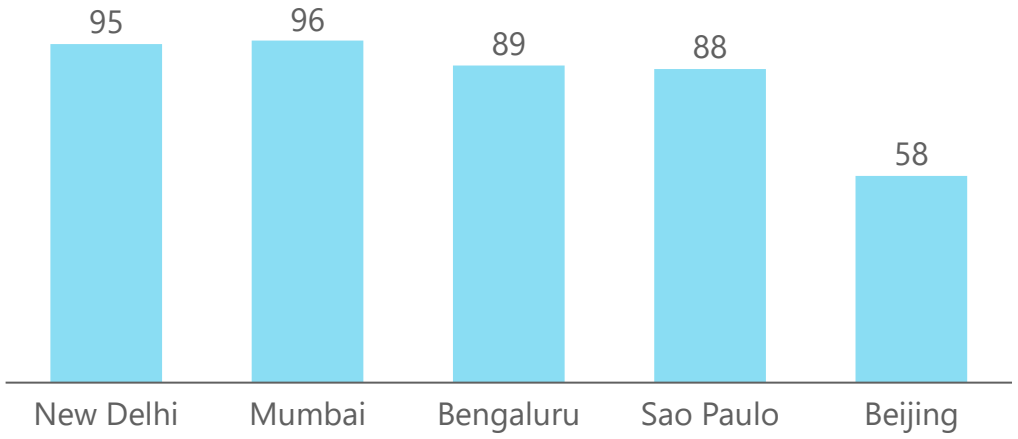
How will Delhi's tourism sector overcome the reputational harm that air pollution has caused?

Sources: (1) Dalberg analysis; (2) Reuters article, 2019; (3) ; (4) Kahn and Li, "Air pollution lowers high skill public sector worker productivity in China", 2020; (5) Local Circle, 2019; (6) Slater, "India's pollution refugees: People are fleeing Delhi because of the toxic air", 2018; (7)

Rising pollution levels are fast making Delhi a less attractive as a place to visit, work, and live

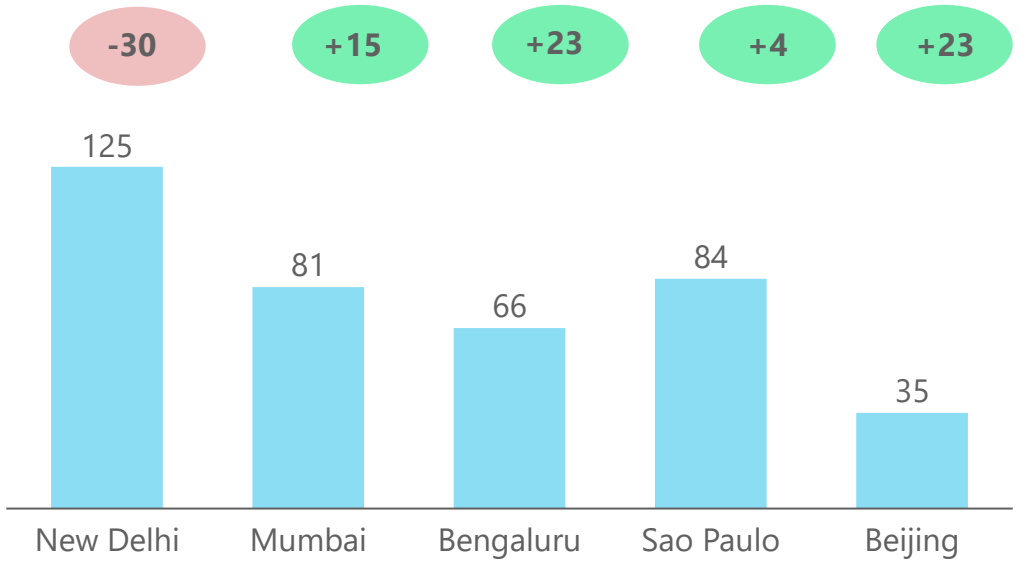
In 2019, Delhi ranked in the middle tier of cities from a livability perspective

Competitiveness of Delhi vs. Indian and global cities
Overall Ranking, 2019[1]



However, challenges in addressing pollution means that it is falling behind its peers

Competitiveness of Delhi vs. Indian and global cities
Overall Ranking, 2020[2]

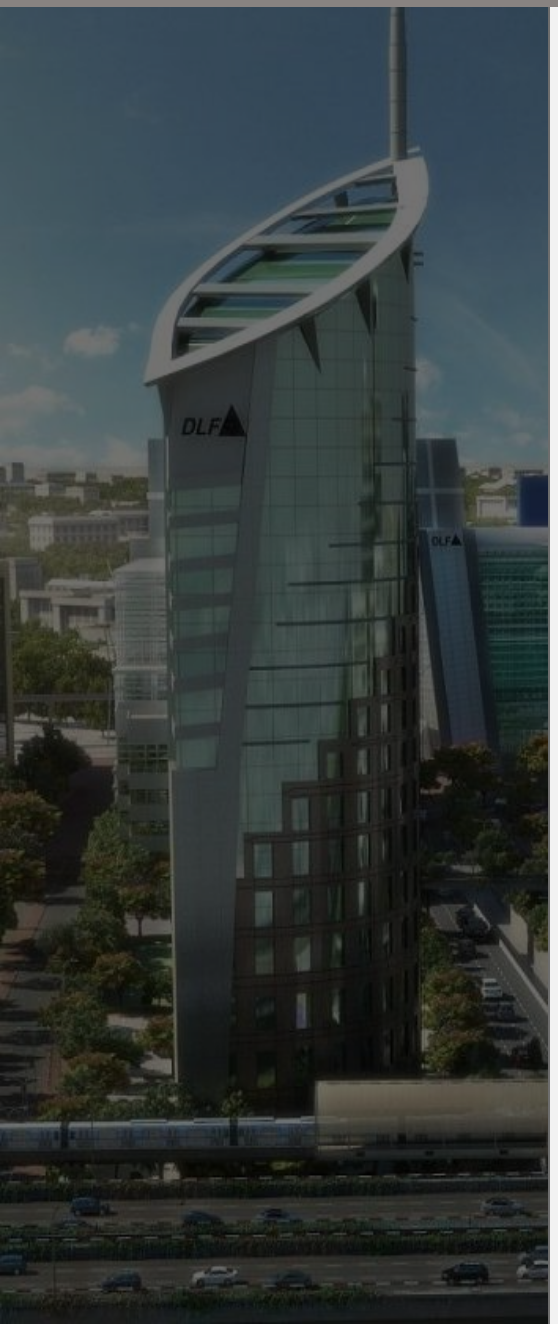


Rising air pollution – among other factors – has driven Delhi's competitiveness down relative to its domestic and global counterparts, compromising the attractiveness of the city to businesses and talent, alike

Sources: (1) Lanvin & Monteiro, "The Global Talent Competitiveness Index 2019 - Entrepreneurial Talent and Global Competitiveness", 2019; (2) Lanvin & Monteiro, "The Global Talent Competitiveness Index 2020 - Global Talent in the Age of Artificial Intelligence", 2020

Case Study | How does air pollution impact India’s Millennium City?

CASE STUDY | Gurugram



USD **8** billion

Nominal GDP[1]

300+

Fortune 500 companies housed[2]

17X

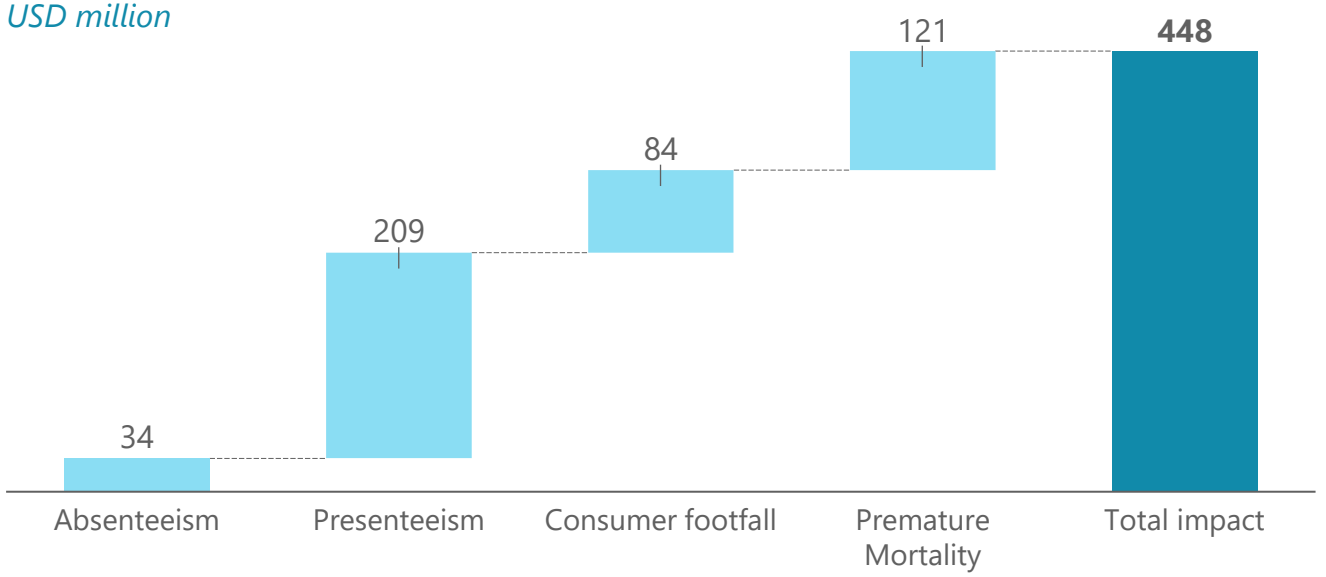
Poorer air quality than WHO limits[3]

70%

Of all economic investment in state of Haryana[4]

Economic impact of air pollution on Gurugram[1]

USD million



A **Gurugram loses ~5.5% of its GDP each year** to the various costs of air pollution, higher than other metropolitan areas, e.g. **Mumbai and Bengaluru, which suffer GDP losses of 1.9% and 1.3%**, respectively.

B The **impact of presenteeism in Gurugram is ~7X of absenteeism,** compared with a national picture where presenteeism is 4X costlier than absenteeism. This is due to the **high concentration of skilled professionals** whose jobs entail a higher cognitive burden and thus suffer the greater passive effects of air pollution.

Sources: (1) Dalberg analysis; (2) Business Standard article, 2016; (3) IQ Air: World's Most Polluted Cities 2018; (4) The Hindu article, 2015

Gurugram's competitiveness is anchored to three dimensions, each of which is affected by air pollution (1/2)

1

ATTRACTIVENESS AS A SERVICES HUB

2

VALUE PROPOSITION AS AN ENABLING STARTUP ECOSYSTEM

3

COMPETITIVENESS AS A MEDICAL TOURIST HUB

Gurugram's competitiveness is anchored to three dimensions, each of which is affected by air pollution (2/2)

ATTRACTIVENESS AS A SERVICES HUB

Gurugram is India's 2nd largest IT hub[1] and a flourishing finance hub in the country, attracting quality talent from across the country[2]

However, the impact of air pollution on productivity of Gurugram's workers reduces their willingness to stay and work in the city

6% **Fall in productivity of IT workers** on the job due to air pollution in Gurugram **vs 0% in Bengaluru** and **0.2% in Mumbai**

"If employees and businesses had this flexibility, they would **strongly prefer to work in other parts of the country**"

- HR Head, IT Firm, Gurugram

How will Gurugram's service sector attract the best talent when poor air quality prevents employees from performing to potential?

VALUE PROPOSITION AS AN ENABLING STARTUP ECOSYSTEM

Gurugram is ranked #5 among Asia's top global tech startup hubs due to its enabling environment, and has emerged as a critical lever for economic growth[1]

But air pollution affects entrepreneurs' willingness to relocate and start businesses in Gurugram in the short-term

"Gurugram's toxic air is a **big factor behind many a startup moving south**"

- Co-founder, Food Tech Startup, Gurugram

"I **moved my healthcare startup to Bengaluru** in 2018 because it is a **better place to live in**"

- Co-founder, Health Tech Startup, Bengaluru

How will Gurugram sustain its reputation for being a startup hub when air pollution discourages founders from living in the city?

COMPETITIVENESS AS A MEDICAL TOURIST HUB

Gurugram, with its growing luxury healthcare industry, is now a top medical tourist hub of India,[3] attracting patients from across the world

Yet the severe short-term health effects of air pollution deter vulnerable patients from seeking treatment in Gurugram

- Air pollution disproportionately impacts the elderly and those with heart or lung conditions in the shorter term,[4] **reducing the appeal of Gurugram for international patients** while choosing destinations for long term treatment.
- This has a **knock-on effect on other tourism-dependent industries** that medical tourists contribute to e.g. aviation, hotels, etc.

How will Gurugram's growing medical tourism industry react to the deteriorating effect air pollution has on tourist arrivals?

Sources: (1) CBRE, "Programming Asia Pacific Tech Cities as Global Tech Hubs", 2018; (2) KPMG, "Future of Finance Centres in India", 2020; (3) Quote by Gurugram Deputy Commissioner, 2020; (4) NYU Langone Health, "International travelers experience the harmful effects of air pollution", 2019

As air pollution continues to worsen and affect health of residents, businesses see merit in moving to other cities

Businesses are facing an unprecedented situation where their clients and employees wish to move to cities with cleaner air…

"Many of our **international clients have cancelled their trips** after reading the headlines. This will impact business. In the long run, **many of our clients want to shift their operations to smaller cities**"

- Senior Executive, Leading BPO, Gurugram

"Pollution now ranks higher than cost of living, safety and availability of public transport as a reason to relocate. Multiple survey show **a significant number of employees want to relocate to other cities to avoid this toxic mess**"

- Deep Kalra, CEO, MakeMyTrip

…which has led to some businesses initiating the shift out of Gurugram…

"Every year, we face the same problem in Gurugram. So, we are **giving our employees a choice to work from the Bengaluru office**, which will function as our second headquarters"

- Abhiraj Bahl, CEO, UrbanCompany

…driven by Gurugram's increasing pollution levels which have placed a significant health toll on the city's residents

1,180

Premature deaths in Gurugram due to air pollution-linked diseases[1]

100,000+

Asthma cases in Gurugram[2]

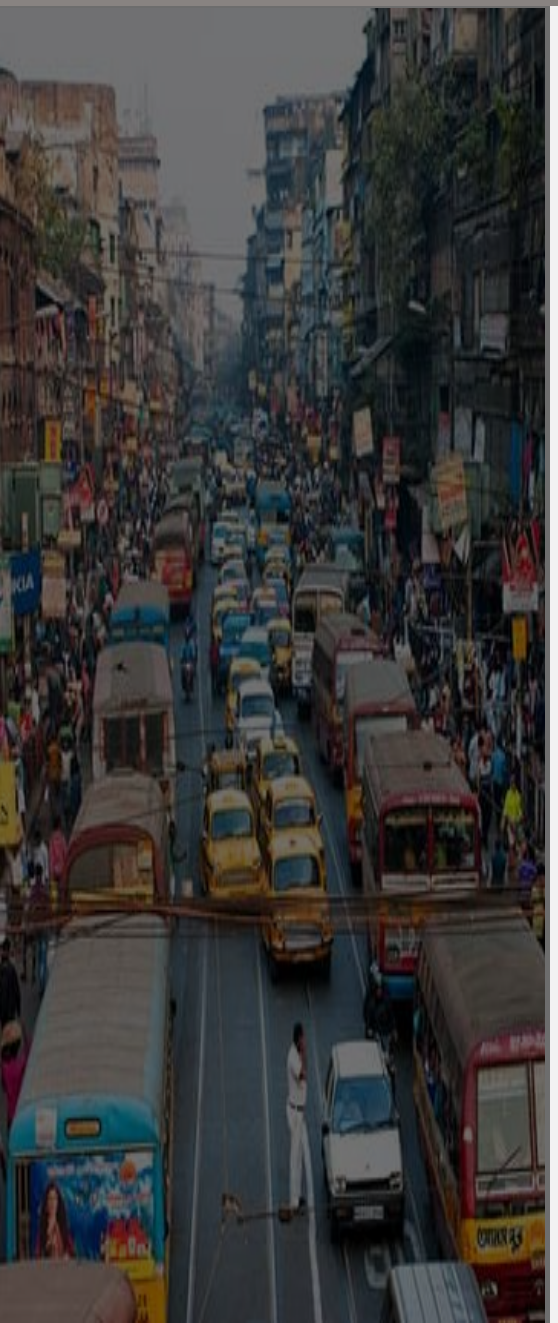
64,000+

Cases of respiratory ailments registered in a single hospital in Gurugram in 2015[2]

Sources: (1) Dalberg analysis; (2) Daily Mail article, 2015; (3) Times of India article, 2019

Case Study | How does air pollution impact the Gateway to East India?

CASE STUDY | Kolkata



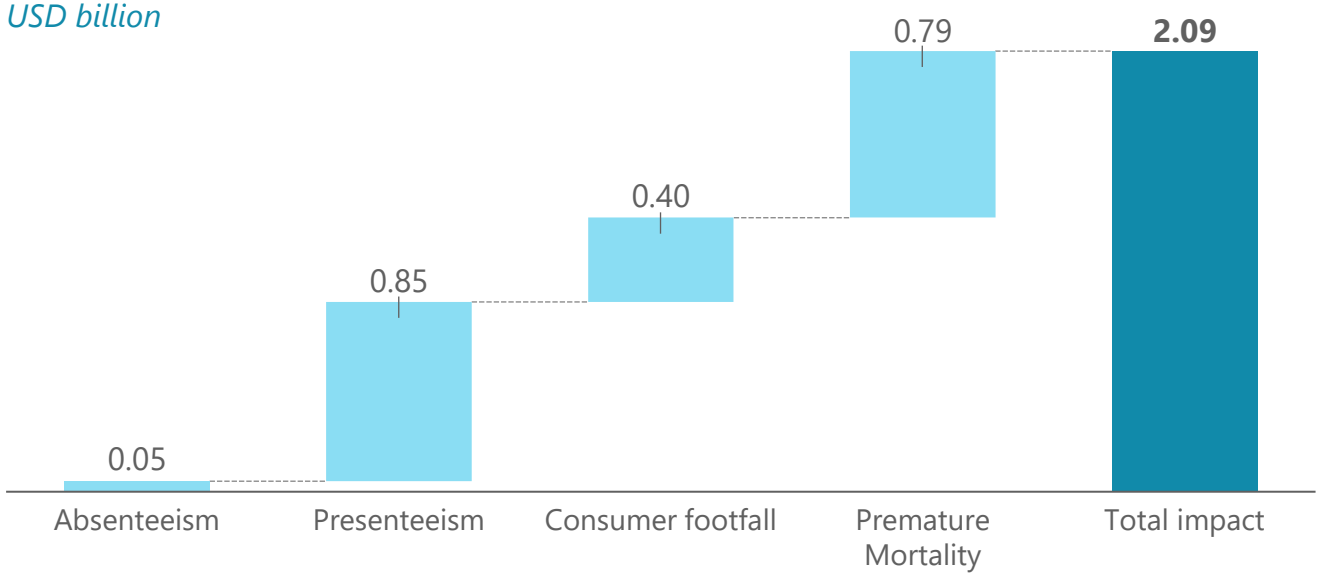
1.8 *percent* — ***share of India's GDP (2019)[1]***

2nd — ***Among Indian metros on economic performance[2]***

6X — ***Poorer air quality than WHO limits[3]***

Economic impact of air pollution on Kolkata[1]

USD billion



A **Kolkata loses 4% of its GDP each year,** driven largely by the productivity losses suffered by its large but vulnerable MSME sector. While this economic impact is less severe than that in more polluted Northern cities, it is still **~25% higher than the national figure**.

B **Kolkata lost 6,000 people through air pollution linked diseases** in 2019 at a mortality rate 33% higher than even Delhi, leading to a **disproportionately large impact from premature mortality**, representing **60% of overall impact on GDP** vs 46% for the rest of India.

Sources: (1) Dalberg analysis; (2) Brookings Institution Report, 2015; (3) IQ Air: World's Most Polluted Cities 2019

Kolkata's competitiveness is anchored to three dimensions, each of which is affected by air pollution (1/2)

1

ATTRACTIVENESS AS A HUB FOR MSME'S

2

VALUE AS THE EPICENTER OF STEEL MANUFACTURING

3

FEASIBILITY AS A COMMERCIAL TRANSPORT HOTSPOT

Kolkata's competitiveness is anchored to three dimensions, each of which is affected by air pollution (2/2)

Attractiveness as a hub for MSME's

Kolkata is home to the highest number of MSMEs in in India, with the sector contributing significantly to the city's overall economy[1]

However, air pollution causes consumers to step out less, leading to losses for consumer facing MSMEs, particularly apparel manufacturers

3.4% **Decline in consumer footfall due to air pollution in Kolkata[2]**

- **Apparel manufacturers,** who represent the largest chunk of MSMEs in Kolkata, **are disproportionately affected** as consumer discretionary spending drops first and in the greater degree for discretionary items.

How will Kolkata's small businesses deal with losses from air pollution given low affordability for adequate health equipment?

Value as the epicenter of steel manufacturing

West Bengal is India's 5th largest steel producer[3] with Kolkata being the center of the industry in the state, employing a large proportion of Kolkata's casual labor

But air pollution leads to a fall in worker productivity, leading to adverse business outcomes

2.4% **Decrease in productivity of steel manufacturing workers due to air pollution in Kolkata[2]**

- The effect of large pollution shocks on worker productivity is immediate, with **older workers facing a 35% higher impact** than their younger counterparts.[4]
- With **Kolkata ageing faster than other metros,[5]** the higher productivity drops will create a **workforce problem going forward**.

How will Kolkata's steel industry continue to grow when air pollution hampers workers from performing to potential?

Feasibility as a commercial transport hotspot

Kolkata, with its strategic location, having road, rail, air and port infrastructure, is a key cog in all trade to and from East and Northeast India

Yet, air pollution can pose a significant threat to the growth of Kolkata's title as the gateway to the east

- **Up to 30 flights are delayed daily (13% of total)** on low visibility days in Kolkata during winter months, when there is high pollution.[6]
- Low visibility due to air pollution and fog causes significant **delays in shipping and cargo-handling** at Kolkata's primary commercial port.[7]
- The significant delays in transport of goods in Kolkata can lead to adverse business outcomes through **greater logistical expenditure** and **reduced consumer satisfaction**, risking loss of sales.

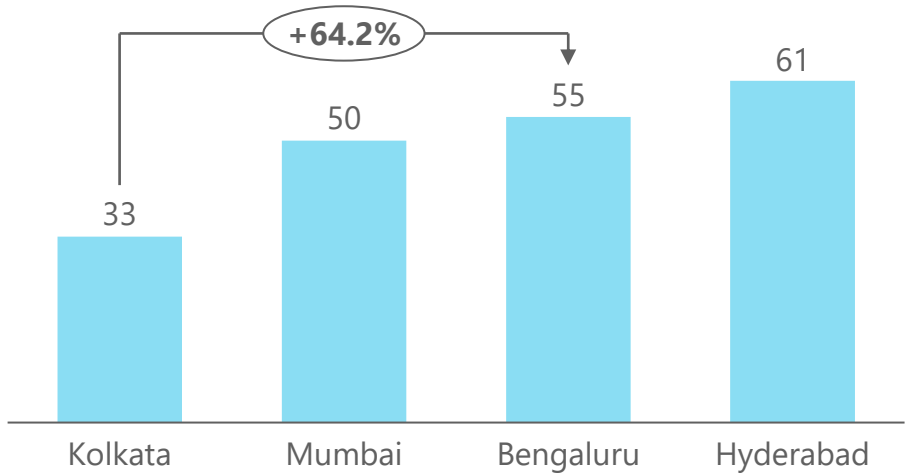
How will Kolkata dominance in logistics get affected by air pollution?

Sources: (1) India Today article, 2018; (2) Dalberg analysis; (3) World Steel report, 2018; (4) Adhvaryu et al, "Management and Shocks to Worker Productivity", 2019; (5) Times of India article, 2015; (6) Times of India article, 2020; (7) Haldia Dock Complex Trade Circular, 11 Dec 2020

Kolkata already lags other metros in terms of economic growth and high air pollution levels exacerbate the issue for the city further

Kolkata ranks far below its peer metros in terms of environmental quality…

Environmental quality score, Kolkata vs other cities
Quality Score, 2019[1]



- **Kolkata ranks 133rd of 155 cities globally** in the ability to grow, attract and retain talent,[1] far behind Bengaluru at 66th and Mumbai at 31st, indicating that **quality talent is likely to choose other metro cities** to work in.

…which can potentially set back the entire state of West Bengal from achieving its economic ambitions

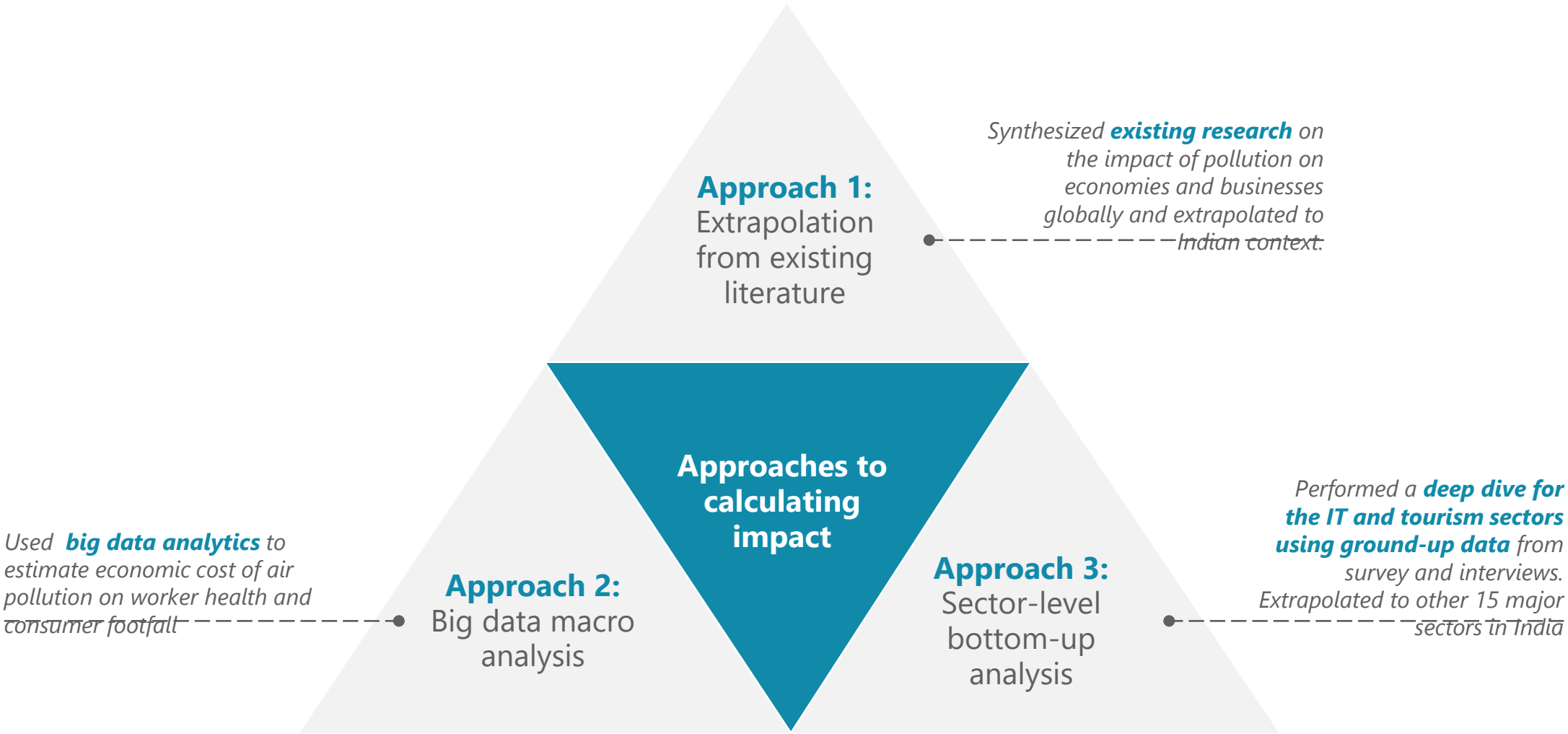
- With 18% of its revenue receipts coming from central government grants, **West Bengal government has among the largest shortfalls between expenditure and own receipts** in India.[2]
- **Kolkata contributes 32% to West Bengal's GDP**[3] and is hence, a significant part of the state's economic outlook and growth.
- However, **Kolkata's economic growth has been far slower than its peers**, growing at 5.2% p.a. while metros like Bengaluru and Hyderabad are growing at 9.3% p.a. and 8% p.a. respectively.[4]
- Investment in Kolkata and the rest of West Bengal has been decreasing, with **FDI inflows falling from USD 394 billion in 2011-12 to USD 380 billion in 2019-20,** while India's FDI grew from USD 35 billion to USD 50 billion in the same period.[5]
- As air pollution levels continue to rise in Kolkata and the city becomes more difficult to live in, it's **attractiveness as a destination for business activity will reduce**, setting it back on its goal to become a major financial center by 2030.

Sources: (1) Lanvin & Monteiro, "The Global Talent Competitiveness Index 2020 - Global Talent in the Age of Artificial Intelligence", 2020; (2) PRS India, 2020; (3) Dalberg analysis; (4) Statistics Times website; (5) RBI Website; DIPP Website; ET Article, 2019

CONTENTS

CONTENTS OF ANNEX

We followed a three-pronged approach to arrive at the impact of air pollution on businesses in India



CONTENTS OF ANNEX

We analyzed 50+ reports and identified 6 major cost elements of air pollution, having varying degrees of business impact

Our Approach

We followed a 'snowball' approach, covering 50+ relevant reports from peer-reviewed journals and grey literature/credible studies

Buzzwords: "Air pollution," "economic cost," "business impact," "productivity," "worker health," "sick leaves," "consumer footfall," "cognitive function" among others

Number of reports analysed: 56, 36 prioritized

Geographical distribution: 5 at global level, 7 from India, 13 from China, 10 from Europe, 15 from the Americas, and 4 from rest of the world

Major sources: Clean Air Fund, World Bank, OECD, Centre for Research on Energy and Clean Air, European Environment Agency, individual researchers

Types of Costs Identified

The report identified 6 types of economic costs of air pollution, which can have direct, indirect or no business impact

A. Opportunity cost of lost **labor productivity** (due to absenteeism and presenteeism)

B. Reduced **asset productivity** due to air pollution

C. Reduced revenue due to reduced **consumer footfall**

D. Value of total forgone labour output due to air pollution-caused **premature mortality**

E. **Health expenditure** due to pollution-induced illnesses

F. Increased **non-market welfare losses**

We scored each report on 4 parameters from a scale of 1-4 and selected the study with the highest score for each relevant cost

Parameter	Meaning	Rating Scale
I. Credibility	Credibility of author. Large credible organizations like World Bank, OECD, Clean Air Fund given higher score vs individual researchers	1 — *Individual researcher, not peer-reviewed*; 4 — *Large established organization (e.g. WB)*
II. Relevance to project objectives	Closeness of analysis to desired output in terms of geography and metrics analysed. Studies providing a quantitative economic impact of air pollution in India given higher score vs a non-India qualitative study	1 — *Non-India focused, qualitative impact*; 4 — *India-focused, relevant quantitative metric studied*
III. Extent of coverage of costs	No. of different cost elements covered by the study under a single pathway. A study covering both absenteeism and presenteeism rated higher than a study covering only absenteeism.	1 — *Single cost covered per pathway*; 4 — *Multiple costs covered per pathway*
IV. Robustness of analysis	Breadth of sample studied. Studies using a large representative sample given higher score vs studies with a small micro-sample	1 — *Small micro-level sample studied*; 4 — *Large representative sample studied*

Reports Evaluated (1/9)

S.No.	Report / Paper	Geography	Focus	Methodology	Key Findings	Quality Score
1	CBI UK, "Breathing Life into the UK Economy", 2020	UK	Health impact, Sector agnostic	Air quality data was tracked and combined with data in five potential areas of health impact - (1) Premature mortality, (2) Absenteeism, (3) Absenteeism for dependents, (4) Presenteeism (attending work while being ill), and (5) Early retirement; GVA data was used to translate health impact to economic impact	• The UK economy could benefit to the tune of GBP1.6 billion each year if it were to achieve the guidelines set by the WHO for air quality • Almost 17,000 premature deaths could be prevented each year • The UK could also stand to gain an additional three million working days	15
2	OECD, "The economic consequences of outdoor air pollution", 2016	Global	Health impact, Sector agnostic	PM2.5 concentration levels were mapped against different health consequences and a monetary value was attributed to each health impact separately, e.g. hospital admissions are translated into health expenditures	• Global air pollution-related healthcare costs are projected to increase from USD21 billion in 2015 to USD176 billion in 2060 • The business impact of outdoor air pollution is projected to gradually increase to 1% of global GDP by 2060, from 0.3% in 2015 • The number of premature deaths due to outdoor air pollution is projected to increase from 3 million people globally in 2010 to a global total of six to nine million people in 2060	15
3	OECD, "The economic cost of air pollution - evidence from Europe", 2019	Europe	Health impact, Sector agnostic	Satellite-based measures of air pollution were combined with statistics on regional economic activity throughout the European Union over the period 2000-15	• A 1µg/m^3 increase in PM2.5 concentration caused a 0.8% reduction in real GDP. Thus, Europe's annual improvement of 0.2 µg/m^3 in air quality from 2000-2015 boosted its GDP by 0.16% per annum, i.e. 15% of total GDP growth during that period	15
4	The World Bank, "The cost of air pollution: strengthening the economic case for action", 2016	Global	Health impact, Sector agnostic	Focused on premature mortality and not on non-fatal losses. Two approaches were adopted: (1) Welfare based approach - The expense individuals are willing to incur to reduce their chances of pollution-induced mortality was calculated; loss of things apart from paychecks due to pollution - consumption, leisure - was accounted for (2) Income based approach - The foregone income and wage amounts owing to premature deaths was calculated	Welfare based • Air pollution was responsible for USD5.11 trillion in welfare losses in 2013 globally • The losses were highest in East Asia and Pacific (7.5% of GDP) and South Asia (7.4% of GDP) Income based • Annual income losses were USD225 billion in 2013 • The losses were highest in South Asia (1% of GDP)	15

Report used in Approach 1

Reports Evaluated (2/9)

S.No.	Report / Paper	Geography	Focus	Methodology	Key Findings	Quality Score
5	Center for Research on Energy and Clean Air (CREA), "Quantifying the Economic Costs of Air Pollution from Fossil Fuels", 2020	Global	Health impact, Sector agnostic	Concentration of different fossil fuel generated pollutants (CO_2, NO_2) were mapped against the incidence of death / disease across the world using data from prior studies / reports and adjusted to different geographies using PPP data to arrive at global and region-wise figures	• Economic costs of air pollution from fossil fuels were estimated at 3.3% of global GDP (USD2.9 trillion) in 2018 • An estimated 4.5 million people died in 2018 due to exposure to air pollution from fossil fuels, average years lost estimated at 19 years • Fossil fuel pollution was responsible for 1.8 billion days of worker absence • China saw the highest economic costs at 6.6% of GDP, India faced costs amounting to 5.4% of GDP	14
6	Brandt, Hsu, Moroney and Janaskie, "Air Pollution Induced micro-migrations: Impacts on Consumer Spending", 2018	Spain	Footfall impact, Sector agnostic	Geospatial mapping was conducted using big data. Changes in consumer spending and how these relate to shifts in daily average air pollution was analyzed using dataset of 150 million credit card transactions from BBVA bank from over 170 postal codes over a two-year period	• With every 10% increase in particulate matter, consumers in Spain spent between 20-30 million euros less every day • With every 10% increase in ozone concentrations, consumers in that same area spent between 2.5-41 million euros less per day • A 10% increase in air pollution in Spain for a year could lead to a loss of as much as 1.5% of Spain's GDP.	13
7	DEFRA, "Valuing the Impacts of Air Quality on Productivity", 2014	UK	Health impact on workers, Sector agnostic	Five pathways of health impacts were analyzed: mortality in workforce, absenteeism in workforce, presenteeism in workforce, absence in workforce due to morbidity in dependents and health impacts in non-market productive activities by correlating with existing levels of air pollutants and calculating lost productive time for workers.	• Air pollution in 2012 caused an impact on productivity to the tune of GBP2.7 billion	13
8	International Food Policy Research Institute (IFPRI) & partner institutes, "Risk of acute respiratory infection from crop burning in India: estimating disease burden and economic welfare from satellite and national health survey data for 250000 persons", 2019	India	Health impact, Sector agnostic	Data on acute respiratory infections from India's fourth District Level Health Survey (DLHS-4) was merged and analyzed with satellite data on crop fire occurrence. Overall disease burden due to crop burning was estimated in terms of disability-adjusted life years	• Crop residue burning led to an estimated economic loss of over USD1.5 billion over five years. Eliminating crop burning would avert 149 thousand disability-adjusted life years lost per year, valued at USD1.53 billion over 5 years • Economic losses owing to exposure to air pollution from firecracker burning were estimated to be around USD357 million over five years • When rice farmers in north-western India burned their fields, PM2.5 concentrations in Delhi spiked to about 20 times beyond the World Health Organization's threshold for safe air	13

Report used in Approach 1

Reports Evaluated (3/9)

S.No.	Report / Paper	Geography	Focus	Methodology	Key Findings	Quality Score
9	Dong, Yu and Zhao, "The Impact of Air Pollution on Domestic Tourism in China: A Spatial Econometric Analysis", 2019	China	Footfall impact, Tourism	Data on PM2.5 levels, tourist arrivals, hotel stays and GDP for 337 Chinese cities from 2004-13 was merged and analyzed	• If the concentration of PM2.5 in one city increased by 1μg/m^3, the number of domestic tourists to the city declined by 0.7%. • There were also spillovers between cities: If the PM2.5 in other cities simultaneously increased by 1μg/m^3, the number of domestic tourists traveling to the local city rose by 4.1%	12
10	European Environment Agency, "Costs of air pollution from European industrial facilities 2008–2012", 2014	Europe	Health impact, Sector agnostic	The cost of damage to health and the environment in monetary terms from air pollution released by industrial facilities (2008-12) in Europe was analyzed. To calculate a monetary value, the study used (1) Value of a statistical life - amount people would pay to reduce the risk of death, and (2) Value of a life year - damages based on life expectancy loss in terms on consumption and income, giving higher weights to lower ages and vice versa	• The aggregated cost of damages over the period 2008–2012 caused by emissions from industrial facilities was estimated at EUR 329 billion - EUR 1.05 trillion	12
11	Hansen-Lewis, "Does Air Pollution Lower Productivity? Evidence from Manufacturing in India", 2018	India	Health impact on manufacturing workers	Satellite-based measures of air pollution were combined with panel survey data (composed of revenue, no. of workers, value of output, output per worker, labor cost etc) of Indian manufacturing firms (2000-09) from the Annual Survey of Industries (ASI)	• Bringing air quality to WHO standards would result in a 0.36% increase in variable profits for all industries (132 in total) and 1.18% rise for sensitive industries (86 in total)	12
12	Kumar et al, "Air quality mapping using GIS and economic evaluation of health impact for Mumbai City, India", 2016	India (Mumbai)	Health impact, Sector agnostic	Health impact assessments of Mumbai wards were carried out based on total population of the ward and air quality monitored data within the ward. Economic valuations of health impacts were carried out by using the estimated values of costs for different diseases from a previous study.	• The total health cost for Mumbai city for the year 2012 was estimated at USD8 billion, which is 4.24% of the Maharashtra state GDP • The maximum concentrations of all pollutants were found in the winter season, while the minimum concentrations were found in the monsoon season	12

Report used in Approach 1

Reports Evaluated (4/9)

S.No.	Report / Paper	Geography	Focus	Methodology	Key Findings	Quality Score
13	Maji, Dikshit and Deshpande, "Disability-adjusted life years and economic cost assessment of the health effects related to PM 2.5 and PM 10 pollution in Mumbai and Delhi", 2017	India (Delhi, Mumbai)	Health impact, Sector agnostic	The number of mortality and morbidity cases from 1991 to 2015 due to air pollution, and the subsequent disability-adjusted life years (DALYs) were estimated. The economic cost of the health damage was calculated for each type of health outcome.	• Economic cost of air pollution in 2015 was USD4.3 billion in Mumbai and USD6.4 billion in Delhi. This accounted for 0.71% of India's GDP in 2015. • Premature deaths account for ~76.60% and chronic bronchitis for 22.07% of this total economic cost	12
14	Archsmith, Heyes and Saberian, "Air Quality and Error Quantity: Pollution and Performance in a High-Skilled, Quality-Focused Occupation", 2015	USA	Health impact on baseball umpires	620,000 decisions by Major League baseball umpires across time and space were compared with ambient air pollution levels	• A 10 µg/m3 increase in 12-hour PM2.5 caused a 2.6% increase in the propensity of an umpire to make incorrect calls	12
15	A.M. Patankar and P.L. Trivedi, "Monetary burden of health impacts of air pollution in Mumbai, India - Implications for public health policy", 2010	India (Mumbai)	Health impact, Sector agnostic	Air quality data from the Environmental Agency was combined with a survey of 150 households in five areas of Mumbai to obtain information on the cost of treatment and lost wages due to restricted and total inactivity days related to the considered symptoms and diseases	• The total monetary burden of these impacts, including personal burden, government expenditure and societal cost, is estimated at 4.5 billion Indian Rupees (INR) or USD113.08 million for a 50µg/m^3 increase in PM10, and INR 8.7 billion or USD218 million for a similar increase in NO_2.	11
16	Anaman and Loi, "Economic Impact of Haze-Related Air Pollution on the Tourism Industry in Brunei Darussalam", 2000	Brunei Darussalam	Footfall impact, Tourism	The relation between monthly arrival data of tourists from January 1995 to September 1999 in Brunei Darussalam, and haze-related air pollution episodes caused by forest fires, was analyzed	• Haze-related air pollution (1995-99) caused a 3.75% reduction in the number of tourists and direct economic loss to the tourism industry of about one million Brunei dollars • Monthly arrivals were reduced by about 28.7% resulting in total direct loss of about 8 million Brunei dollars.	11

Report used in Approach 1

Reports Evaluated (5/9)

S.No.	Report / Paper	Geography	Focus	Methodology	Key Findings	Quality Score
17	Chiang-Ming Chen, Yo-Long Lin and Chien-Lung Hsu, "Does air pollution driveaway tourists? A case study of the Sun Moon Lake National Scenic Area, Taiwan", 2017	Sun Moon Lake National Scenic Area, Taiwan	Footfall impact, Tourism	Monthly tourist visitor data obtained from the Taiwan Tourism Bureau from 2004 to 2011 was combined with monthly PSI values provided by the Environmental Protection Administration. Monthly unemployment rates and CPI were used as macroeconomic indicators to serve as control variables.	• The effects of air pollution and rainfall on the demand for tourism depend significantly on the phases of business cycle, and, during the peaks, monthly numbers of tourists traveling at the Sun Moon Lake would fall by 25,725 people as the number of bad air-quality day increases by one	11
18	Holub, Hospido and Wagner, "Air pollution and labor supply: Evidence from social security data", 2016	Spain	Health impact on workers, Sector agnostic	A model was estimated that looks at the relation between sick leave days due to cardiovascular or respiratory disease and the air quality experienced at the place of the worker's residence, controlling for other factors such as weather and season. This study examined social security data in Spain which covered more than 95% of all employees in the country.	• A 10μg/m^3 increase in PM 10 caused a 1.64% increase in absenteeism due to sick leaves	11
19	Montt, "Too polluted to work? The gendered correlates of air pollution on hours worked", 2018	Chile (Santiago)	Health impact on workers, Sector agnostic, gender lens	The relation between air pollution data over 20 years and the daily hours worked for 2,500 citizens of Santiago (from Santiago Employment and Unemployment Survey) was examined	• Air pollution was associated with a reduction in overall hours worked for women, and particularly for women with children. Weeks with pollution at 100μg/m^3, common for Santiago, see double the gender difference in working hours • It was hypothesized by the authors that this is because children, unable to go to school, must stay home and be cared for by women	11
20	The Lancet Commission on Pollution and Health, 2017	Global	Health impact, Sector agnostic	Estimated the burden of disease attributable to pollution using WHO's GBD study	• Pollution-related diseases cause productivity losses that reduce GDP in low-income to middle-income countries by up to 2% per year • Pollution-related disease was responsible for 9 million premature deaths in 2015—16% of total global mortality • Unhealthy environments were responsible for 12.6 million deaths worldwide—23% of total global mortality	11

Report used in Approach 1

Reports Evaluated (6/9)

S.No.	Report / Paper	Geography	Focus	Methodology	Key Findings	Quality Score
21	Xu and Dong, "Evaluating the Impact of Air Pollution on China's Inbound Tourism: A Gravity Model Approach", 2020	China	Footfall impact, Tourism	The relationship between China's inbound tourism was analyzed with respect to the levels of air pollution in tourist destinations as well as the region the tourist was coming from	• Air pollution in tourist destinations and origin regions both had significant negative impacts on China's inbound tourism. If the concentration of particulate matter in China and foreign countries increased by 1g/m3, inbound tourist arrivals would decline by approximately 1.7% and 3.8%, respectively • The impact of air pollution in destination regions was larger for tourists coming from more polluted and Asian countries and visiting less polluted and more popular destinations.	11
22	Adhvaryu, Kala and Nyshadham, "Management and Shocks to Worker Productivity", 2019	India	Health impacts on workers, manufacturing	The relationship between air pollution data in the sewing floors of 2 garment factories and the productivity of each worker was analyzed	• A one standard-deviation increase in pollution decreased production efficiency in the ready-made garments sector by 1% of mean productivity • Impacts were about 60% larger for workers performing complex tasks, and about 35% larger for older workers (workers above the median age)	10
23	Ailshire and Clark, "Fine Particulate Matter Air Pollution and Cognitive Function Among U.S. Older Adults", 2015	USA	Health impact, Sector agnostic	Cognitive function was assessed with tests of working memory and orientation, and then the association between PM2.5 and the number of errors on the cognitive assessment was examined	• Older adults living in areas with high concentrations of PM2.5 had an error rate 1.5 times greater than those exposed to lower concentrations in a cognitive assessment	10
24	Aragon, Miranda and Oliva, "Particulate matter and labor supply: evidence from Peru", 2016	Peru (Lima)	Health impact, Sector agnostic	Data on hours worked in Lima, Peru (from the Peruvian National Household survey) was analyzed with respect to daily levels of PM2.5, controlling for factors like day of the week, year and municipality	• An increase in PM2.5 of 10μg/m^3 was associated to a reduction of almost 2 hours worked per week • The effect was concentrated among households with susceptible dependents, i.e., small children and elderly adults. This indicated that caregiving is likely a mechanism linking air pollution to labor supply	10

Report used in Approach 1

Reports Evaluated (7/9)

S.No.	Report / Paper	Geography	Focus	Methodology	Key Findings	Quality Score
25	Fu, Viard and Zhang, "Air Pollution and Manufacturing Firm Productivity: Nationwide Estimates for China", 2018	China	Health impact on workers, manufacturing sector as a whole	The relationship between satellite pollution data and the productivity of Chinese manufacturing firms (derived from a survey of all of China's manufacturing firms) was analyzed	• A 1μg/m^3 decrease in PM2.5 increased labor productivity by 0.85% • Lowering PM2.5 by 1% nationwide through methods other than reducing manufacturing output would generate annual productivity increases of CNY 57.7 thousand for the average firm and CNY 9.2 billion or 0.06% of GDP across all firms	10
26	Huang, Xu and Yu, "Pollution and Performance: Do Investors Make Worse Trades on Hazy Days?", 2019	China	Health impacts on workers, stock market	Data on stock trades by 87,054 individuals from 34 cities in China was analyzed with respect to air quality data, controlling for factors such as the year and weather conditions	• There was a negative relation between air pollution and trade performance. Air pollution made investors more susceptible to the disposition effect (reluctance to sell assets that have lost value and greater likelihood of selling assets that have made gains) and attention-driven buying behavior (purchasing attention-grabbing stocks)	10
27	Mayer and Pagel, "Fresh Air Eases Work – The Effect of Air Quality on Individual Investor Activity", 2017	Germany	Health impacts on workers, stock market	Daily trading patterns of 103,000 private investors (2003-15) from one of the largest retail brokerages in Germany was analyzed with respect to hourly air pollution levels	• When investors were working on high-pollution days, they sat down less at their workplace, logged in less often, and traded less in their brokerage accounts. A one standard-deviation increase in the air quality index reduced willingness to log in, or engage in other cognitively demanding activities, by 8.5%	10
28	Neidell et al, "The Effect of Pollution on Worker Productivity: Evidence from Call-Center Workers in China", 2012	China	Health impact on call center workers	The relationship between number of daily calls handled by BPO workers and the air pollution index was analyzed	• A 10-unit increase in the air pollution index (API) decreased the number of daily calls handled by a worker by 0.35% on average. These productivity declines were largely linear, and were most significant at an API above 100-150 • A 10-unit reduction in national pollution levels would increase worker productivity by USD2.2 billion per year	10

Report used in Approach 1

Reports Evaluated (8/9)

S.No.	Report / Paper	Geography	Focus	Methodology	Key Findings	Quality Score
29	Zhang, Chen and Zhang, "The impact of exposure to air pollution on cognitive performance", 2018	China	Health impact, Sector agnostic	The relation between cognitive test scores (from a nationally representative survey of Chinese families and individuals) and Air Pollution Index (API) levels was analyzed	• Polluted air may impedes cognitive ability as people become older, especially for less educated men • Reducing annual mean concentration of PM10 in China would move people from the median to the 63rd percentile (for verbal test scores) and the 58th percentile (for math test scores), respectively	10
30	Burney and Ramanathan, "Recent climate and air pollution impacts on Indian agriculture", 2014	India	Agricultural productivity	State-level wheat and rice yields in India were mapped with climate and emissions data. This was compared to an alternate scenario without taking long-run climate and pollution trends into account.	• Yields in 2010, using 1980 as a baseline, were 33.42% lower for wheat than they would have been absent air pollution trends (specifically black carbon and ozone), with some densely populated states like Uttar Pradesh experiencing 50% relative yield losses • Estimates for rice (22.48%) are similarly large, but not statistically significant	9
31	Chang et al, "Particulate Pollution and the Productivity of Pear Packers ", 2016	USA (California)	Health impacts on workers, pear packers	The effect of PM2.5 concentration levels on the daily productivity of employees in a pear-packing facility in Northern California was examined	• An increase in PM2.5 pollution of 10μg/m^3 reduces the productivity of workers by USD0.41 per hour, approximately 6% of their average hourly earnings • These effects first arise when PM2.5 exceeds15 μg/m3 and increase thereafter, suggesting a potential threshold effect. • Pollutants that do not travel indoors, such as ozone, have little, if any, effect on productivity	9
32	Hayes, Rivers and Schaufele, "Politicians, Pollution and Performance in the Workplace: The Effect of PM on MPs", 2016	Canada (Ottawa)	Health impacts on workers, Politics	Textual analysis was applied to all 119,225 speeches made in the Canadian House of Commons between 2006 and 2011, and quality of speeches was analyzed with respect to daily levels of PM2.5	• Exposure to fine particulate matter concentrations exceeding 15μg/m^3 causes a 3.1% reduction in the quality of MPs speech (equivalent to a 3.6 months of education) • For more difficult communication tasks the decrease in quality is equivalent to the loss of 6.5 months of schooling	9

Report used in Approach 1

Reports Evaluated (9/9)

S.No.	Report / Paper	Geography	Focus	Methodology	Key Findings	Quality Score
33	Kahn and Li, "Air pollution lowers high skill public sector worker productivity in China", 2020	China	Health impacts on workers, judicial system	A dataset of decisions made by 157 378 Chinese judges in 13 million criminal and civil cases (2014-17) was analyzed with respect to daily changes in air pollution data	• A 1% increase in PM2.5 leads to a 0.18% increase in the case handling time for a judge in China	9
34	Zivin and Neidell, "The Impact of Pollution on Worker Productivity", 2012	USA (California)	Health impacts on workers, Agriculture	The effect of average ozone concentrations during the typical workday on the productivity of agricultural workers on a large farm was examined	• Ozone levels well below federal air quality standards have a significant impact on productivity: a 10 ppb decrease in ozone concentrations increases worker productivity by 4.2%	9
35	Hales et al, "A Quasi-Experimental Analysis of Elementary School Absences and Fine Particulate Air Pollution", 2016	USA	Health impact on students	The relationship between data on school absences and pollution levels in 3 school districts was analyzed. Controlled for factors such as day of the week, holidays and weather.	• A 10µg/m^3 increase in PM2.5 was associated with an approximately 1.7% increase in daily elementary school absences	8
36	Anett C. Hansen and Harald K. Selte, "Air Pollution and Sick-leaves - is there a Connection?", 1997	Norway (Oslo)	Health impact, Sector agnostic	Sick leave data from large white collar company offices was combined with air quality and temperature data	• Significant relationship between concentration of particulate matter and sick leaves. An increase in the average level of PM10 by 1µg/m^3 leads to an increase in the number of sick leaves by about 0.6 per cent. Associations with SO_2 and NO_2 are more ambiguous	7

Report used in Approach 1

We prioritized buckets labor productivity, consumer footfall and premature mortality basis data availability and identified the most relevant study for each bucket

COVERAGE OF COSTS

	Cost	Coverage under Approach 1
A	Absenteeism	✓
A	Presenteeism	✓
B	Asset Productivity	*Data unavailable except agriculture*
C	Reduced consumer footfall	✓
D	Pre-mature mortality	✓
E	Health expenditure	*Non-business cost for India*
F	Non-market welfare loss	*Non-business cost*

STUDIES IDENTIFIED

- For **absenteeism**, the Centre for Research on Energy and Clean Air conducted a study estimating the **no. of workdays missed in India due to air pollution** and the economic impact thereof.
- For **presenteeism,** several studies in China and USA studied the **relation between PM2.5 levels and worker productivity**, both in the manufacturing and services sector, covering both high- and low-skill industries.
- For **consumer footfall**, a study in Spain estimated the **relation between PM2.5 levels and domestic spending** through credit card transactions while a study in China delved into the **impact air pollution had on tourist arrivals**.
- For **premature mortality**, the World Bank conducted a comprehensive study on the economic impact of air pollution from premature deaths using data from the Global Burden of Disease Study 2013.

A1 Absenteeism | Estimation approach

Objective: Estimation of economic impact of air pollution on India in 2019 through the cost pathway of absenteeism

Base study used: *Center for Research on Energy and Clean Air, "Quantifying the Economic Costs of Air Pollution from Fossil Fuels", 2020 (link)*

Base study output: India's economy lost ~**USD4.9 billion** in 2018 due to 490 million air pollution-caused work absence days

Calculation methodology: The calculation methodology uses the output from the base report and adjusts it from 2018 to 2019 by adjusting for pollution level and GDP. It further estimates safe pollution level basis the age distribution of population in India, existing co-morbidities and WHO recommended air quality levels

$$Cost\ of\ Absenteeism\ {}^{2019}_{India} = Cost\ of\ Absenteeism\ {}^{2018}_{India} \times (PM\ 2.5\ Annual\ average\ {}^{2019}_{India} / PM\ 2.5\ Annual\ average^{2018}_{India}) \times$$

Adjustment for actual pollution level

$$(GDP\ Nominal\ {}^{2019}_{India} / GDP\ Nominal\ {}^{2018}_{India}) \times (Safe\ Pollution\ Revised\ {}^{2019}_{India} / Safe\ pollution\ level\ in\ Study\ {}^{2019}_{India})$$

Adjustment for GDP *Adjustment for safe pollution level*

Sources

- India pollution levels – IQAir: World's Most Polluted Countries List
- GDP – World Bank Data: India GDP (Current US$)
- Safe pollution level – Airnow website: Home of US AQI , World Bank Data (1,2), HealthData article

A1 Absenteeism | Estimation approach

Assumptions:

- **Linearity Assumption –** Study assumes that the impact of increasing or decreasing pollution linearly translated into higher or lower level of absenteeism. This assumption has been taken as several academic papers (e.g. study by Neidell et al) mapped pollution levels across the range of 25 to 175 and found a linear relation to hold within these intervals.

- **Geographic consistency of pollution assumption –** Study assumes that pollution increased consistently across geographies from 2018 to 2019 such that the proportionate impact on different geographies to aggregate impact was the same.

- **Safe level of country pollution assumption –** Study assumes that the level of pollution till which there is no impact on workers is the weighted average of (i) ' Moderate' level of pollution (<100 AQI) and (ii) 'Unhealthy for sensitive groups' level of pollution, weighted by the proportion of India's population in sensitive groups. The CREA study assumes the safe level of pollution to correspond to (i) only.

- **Equal distribution of GDP assumption –** Study assumes that workers of all ages contribute an equal amount to GDP and thus, the value of a workday missed by a worker of any age group shall be the same.

- **Pollution sensitivity assumption –** Study assumes that workers' sensitivity to pollution would remain the same across years, i.e., in both 2018 and 2019 a given level of pollution would have the same impact on worker absenteeism.

- **Forecasts for 2025 –** Study projects PM2.5 levels for 2025 conservatively as the average pollution levels from 2015-2019. In reality, pollution is likely to worsen. India GDP for 2025 was estimated as per the Oxford Economics forecast.

A2 Presenteeism | Estimation approach

Objective: Estimation of economic impact of air pollution on India in 2019 through the cost pathway of presenteeism. This consists of the sum of costs in two sub-pathways: **(i) impact on manufacturing sector workers, (ii) impact on service sector workers** (a. high and b. low order skills)

Base study used for (i): *Fu, Viard and Zhang, "Air Pollution and Manufacturing Firm Productivity: Nationwide Estimates for China", 2018 (link)*

Base study output for (i): China's GDP decreased by ~**USD1.2 billion for every 1% increase in PM2.5** in 2007

Calculation methodology for (i): The calculation methodology uses the output from the base report and adjusts it from 2007 in China to 2019 in India using the pollution level and manufacturing sector GDP. It further estimates safe pollution level basis the age distribution of population in India, existing co-morbidities and WHO recommended air quality levels

$$Loss\ to\ manufacturing\ sector\ {}^{2019}_{India} = Decrease\ in\ GDP\ per\ 1\%\ increase\ in\ PM2.5\ {}^{2007}_{China}\ \text{x}$$

$$[(PM2.5\ Annual\ average\ {}^{2019}_{India} - PM2.5\ Safe\ level\ {}^{2019}_{India}) / (1\%\ x\ PM2.5\ Annual\ average\ {}^{2007}_{China})]\ \text{x}$$

Adjustment for pollution levels

$$(Manufacturing\ Sector\ GDP\ {}^{2019}_{India} / Manufacturing\ Sector\ GDP\ {}^{2007}_{China})$$

Adjustment for manufacturing GDP

Sources

- India pollution level – IQAir: World's Most Polluted Countries List
- China pollution level - Fu, Viard and Zhang, "Air Pollution and Manufacturing Firm Productivity: Nationwide Estimates for China", 2018
- Safe pollution level – Airnow website: Home of US AQI , World Bank Data (1,2), HealthData article
- Manufacturing Sector GDP – World Bank Data: India Manufacturing Value Added (Current US$), World Bank Data: China Manufacturing Value Added (Current US$)

A2 Presenteeism | Estimation approach

Base study used for (ii).a.: *Neidell et al, "The Effect of Pollution on Worker Productivity: Evidence from Call Center Workers in China", 2012 (link)*

Base study output for (ii).a.: Productivity of lower order skills workers decreases by ~**0.35% per 10-unit increase in Air Quality Index** in China

Calculation methodology for (ii).a.: The calculation methodology uses the output from the base report and applies it to India. It further estimates safe pollution level basis the age distribution of population in India, existing co-morbidities and WHO recommended air quality levels

$$Loss\ to\ service\ sector\ from\ lower\ order\ skills\ workers\ {}^{2019}_{India} =$$

$$(\%\ Decrease\ in\ productivity\ of\ lower\ order\ skills\ workers\ per\ 10\ unit\ increase\ in\ AQI\ {}^{2012}_{China})\ x$$

$$(AQI\ Annual\ average\ {}^{2019}_{India} - AQI\ Safe\ level\ {}^{2019}_{India})\ x\ Service\ Sector\ GDP\ {}^{2019}_{India}\ x$$

Adjustment for India pollution levels

$$\%\ Contribution\ to\ Service\ Sector\ GDP\ by\ lower\ order\ skills\ workers\ {}^{2019}_{India}$$

Sources

- India pollution level – IQAir: World's Most Polluted Countries List
- Safe pollution level – Airnow website: Home of US AQI , World Bank Data (1,2), HealthData article
- Service Sector GDP – World Bank Data: India Services Value Added (Current US$)
- India contribution to service sector GDP by lower-order and higher-order skills workers: Financial Express: Gap between Skill India goals and current status

A2 Presenteeism | Estimation approach

Base studies used for (ii).b.: *Kahn and Li, "Air pollution lowers high skill public sector worker productivity in China", 2020 (link); Archsmith et al, "Air Quality and Error Quantity: Pollution and Performance in a High-Skilled, Quality-Focused Occupation", 2018 (link)*

Base studies output for (ii).b.: Taking an average of the findings of both base studies, productivity of higher order skills workers decreases by ~**0.29% per unit increase in PM2.5.**

Calculation methodology for (ii).b.: The calculation methodology uses the average of the findings of the two studies and applies it to India. It further estimates safe pollution level basis the age distribution of population in India, existing co-morbidities and WHO recommended air quality levels

$$Loss\ to\ service\ sector\ from\ higher\ order\ skills\ workers\ {}^{2019}_{India} =$$

$$\%\ Decrease\ in\ productivity\ of\ higher\ order\ skills\ workers\ per\ unit\ increase\ in\ PM2.5_{average\ of\ studies}\ \text{x}$$

$$(PM2.5\ Annual\ Average\ {}^{2019}_{India} - PM2.5\ Safe\ level\ {}^{2019}_{India})\ \text{x}\ Service\ Sector\ GDP\ {}^{2019}_{India}\ \text{x}$$

Adjustment for India pollution levels

$$\%\ Contribution\ to\ Service\ Sector\ GDP\ by\ higher\ order\ skills\ workers\ {}^{2019}_{India}$$

Sources

- India pollution level – IQAir: World's Most Polluted Countries List
- Safe pollution level – Airnow website: Home of US AQI , World Bank Data (1,2), HealthData article
- Service Sector GDP – World Bank Data: India Services Value Added (Current US$)
- India contribution to service sector GDP by lower-order and higher-order skills workers: Financial Express: Gap between Skill India goals and current status

A2 Presenteeism | Estimation approach

Final impact calculation:

$$Cost\ of\ Presenteeism\ {}^{2019}_{India} =$$

$$Loss\ to\ manufacturing\ sector\ {}^{2019}_{India} + Loss\ to\ service\ sector\ from\ lower\ order\ skills\ workers\ {}^{2019}_{India} +$$

$$Loss\ to\ service\ sector\ from\ higher\ order\ skills\ workers\ {}^{2019}_{India}$$

A2 Presenteeism | Estimation approach

Assumptions:

- **Linearity Assumption –** Study assumes that the impact of increasing or decreasing pollution linearly translated into higher or lower level of presenteeism. This assumption has been taken as several academic papers (e.g. study by Neidell et al) mapped pollution levels across the range of 25 to 175 and found a linear relation to hold within these intervals.

- **Safe level of country pollution assumption –** Study assumes that the level of pollution till which there is no impact on workers is the weighted average of (i) ' Moderate' level of pollution (<100 AQI) and (ii) 'Unhealthy for sensitive groups' level of pollution, weighted by the proportion of India's population in sensitive groups.

- **Pollution sensitivity assumption –** Study assumes that workers' sensitivity to pollution would remain the same across countries and years for a given sector and skill level, i.e., in China, the USA and India, a given level of pollution would have the same impact on worker presenteeism across all years of study, for a given sector (e.g. services) and skill level (e.g. higher-order skills).

- **Forecasts for 2025 –** Study projects PM2.5 levels for 2025 conservatively as the average pollution levels from 2015-2019. In reality, pollution is likely to worsen. India GDP for 2025 was estimated as per the Oxford Economics forecast.

C Consumer Footfall | Estimation approach

Objective: Estimation of economic impact of air pollution on India in 2019 through the cost pathway of consumer footfall, consisting of the sum of costs in two sub-pathways: **(i) impact on domestic consumer spending, (ii) impact on international tourism**

Base study used for (i): *Brandt, Hsu, Moroney and Janaskie, "Air Pollution Induced micro-migrations: Impacts on Consumer Spending", 2018 (link)*

Base study output of (i): Daily consumer spending in Spain dropped by ~**EUR20 million per 10% increase in PM2.5** in 2016

Calculation methodology for (i): The calculation methodology uses the output from the base report and adjusts it from 2016 to 2019 by adjusting for pollution level and Spain and India's aggregate consumption levels. It further estimates safe pollution level basis the age distribution of population in India, existing co-morbidities and WHO recommended air quality levels

$$Decrease\ in\ Domestic\ Consumer\ Spending\ {}^{2019}_{India} = Daily\ Decrease\ in\ Consumer\ spending\ {}^{2016}_{Spain} \times 365\ days\ in\ a\ year \times$$

$$(PM2.5\ Annual\ average\ {}^{2019}_{India} - PM2.5\ Safe\ level\ {}^{2019}_{India}) / PM2.5\ Safe\ level\ {}^{2019}_{India} / 10\% \times$$

Adjustment for actual pollution in India

$$(Aggregate\ Consumption\ {}^{2019}_{India} / Aggregate\ Consumption\ {}^{2016}_{Spain})$$

Adjustment for aggregate consumption level

Sources

- India pollution levels – IQAir: World's Most Polluted Countries List
- Safe pollution level – Airnow website: Home of US AQI , World Bank Data (1,2), HealthData article
- Aggregate Consumption – World Bank Data: India Agg. Cons. (Current US$), World Bank Data: Spain Agg. Cons. (Current US$)

C Consumer Footfall | Estimation approach

Base study used for (ii): *"The Impact of Air Pollution on Domestic Tourism in China: A Spatial Econometric Analysis", 2019 (link)*

Base study output for (ii): Annual tourist arrivals in China dropped by ~**0.7% per unit increase in PM2.5** on average in years 2004-13

Calculation methodology for (ii): The calculation methodology uses the output from the base report and applies it to India's tourism industry and pollution levels. It further estimates safe pollution level basis the age distribution of population in India, existing co-morbidities and WHO recommended air quality levels.

$$Decrease\ in\ International\ Tourism\ Industry\ GDP\ {}^{2019}_{India} = Annual\ decrease\ in\ tourist\ arrivals\ {}^{2004-13}_{China}\ \text{x}$$

$$(PM2.5\ Annual\ average\ {}^{2019}_{India} - PM2.5\ Safe\ level\ {}^{2019}_{India})\ \text{x}\ Size\ of\ international\ tourism\ industry\ {}^{2019}_{India}$$

Adjustment for actual pollution in India

Sources

- India pollution levels – IQAir: World's Most Polluted Countries List
- Safe pollution level – Airnow website: Home of US AQI , World Bank Data (1,2), HealthData article
- India International tourism sector GDP – India Brand Equity Forum (IBEF): Tourism & Hospitality Industry in India (Current US$)

Final impact calculation:

$$Cost\ of\ consumer\ footfall\ {}^{2019}_{India} =$$

$$Decrease\ in\ Domestic\ Consumer\ Spending\ {}^{2019}_{India} + Decrease\ in\ International\ Tourism\ Industry\ GDP\ {}^{2019}_{India}$$

Consumer Footfall | Estimation approach

Assumptions:

- **Linearity Assumption –** Study assumes that the impact of increasing or decreasing pollution linearly translated into higher or lower level of absenteeism. This assumption has been taken as several academic papers (e.g. study by Neidell et al) mapped pollution levels across the range of 25 to 175 and found a linear relation to hold within these intervals.

- **Geographic consistency of pollution assumption –** Study assumes that pollution increased consistently across geographies from 2013 / 2016 to 2019 such that the proportionate impact on different geographies to aggregate impact was the same.

- **Safe level of country pollution assumption –** Study assumes that the level of pollution till which there is no impact on consumers is the weighted average of (i) ' Moderate' level of pollution (<100 AQI) and (ii) 'Unhealthy for sensitive groups' level of pollution, weighted by the proportion of India's population in sensitive groups.

- **Equal distribution of consumption assumption –** Study assumes that consumers of all ages contribute an equal amount to aggregate consumption and thus, the value of a missed consumption opportunity of any age group shall be the same.

- **Pollution sensitivity assumption –** Study assumes that consumers' sensitivity to pollution would remain the same across years and across geographies, i.e., in 2013, 2016 and 2019 a given level of pollution would have the same impact on consumer footfall in India, Spain and China.

- **Forecasts for 2025 –** Study projects PM2.5 levels for 2025 conservatively as the average pollution levels from 2015-2019. In reality, pollution is likely to worsen. Aggregate consumption and size of international tourism industry for 2025 were estimated as per the Oxford Economics forecast.

D Premature Mortality | Estimation approach

Objective: Estimation of economic impact of air pollution on India in 2019 through the cost pathway of premature mortality

Base study used: *World Bank, "The Cost of Air Pollution: Strengthening the Economic Case for Action", 2016 (link)*

Base study output: India's economy lost ~**USD55.39 billion** in 2013 due to the labor output that was forgone due to premature deaths

Calculation methodology: The calculation methodology uses the output from the base report and adjusts it from 2013 to 2019 by adjusting for pollution level and GDP. It further estimates safe pollution level basis the age distribution of population in India, existing co-morbidities and WHO recommended air quality levels

$$Cost\ of\ Premature\ Mortality\ {}^{2019}_{India} = Cost\ of\ Premature\ Mortality\ {}^{2013}_{India} \times$$

$$(PM\ 2.5\ Annual\ average\ {}^{2019}_{India} / PM\ 2.5\ Annual\ average\ {}^{2013}_{India}) \times$$

Adjustment for actual pollution level

$$(GDP\ Nominal\ {}^{2019}_{India} / GDP\ Nominal\ {}^{2013}_{India}) \times (Safe\ PM2.5\ Revised\ {}^{2019}_{India} / Safe\ PM2.5\ level\ in\ Study\ {}^{2013}_{India})$$

Adjustment for GDP *Adjustment for safe pollution level*

Sources

- India pollution levels – IQAir: World's Most Polluted Countries List
- GDP – World Bank Data: India GDP (Current US$)
- Safe pollution level – Airnow website: Home of US AQI , World Bank Data (1,2), HealthData article

D Premature Mortality | Estimation approach

Assumptions:

- **Geographic consistency of pollution assumption –** Study assumes that pollution increased consistently across geographies from 2013 to 2019 such that the proportionate impact on different geographies to aggregate impact was the same.
- **Safe level of country pollution assumption –** Study assumes that the level of pollution till which there is no impact on premature mortality is the weighted average of (i) ' Moderate' level of pollution (<100 AQI) and (ii) 'Unhealthy for sensitive groups' level of pollution, weighted by the proportion of India's population in sensitive groups. The World Bank study assumes the safe level of pollution to correspond to (i) only.
- **Pollution sensitivity assumption –** Study assumes that the population's health sensitivity to pollution would remain the same across years, i.e., in both 2013 and 2019 a given level of pollution would have the same impact on premature mortality.
- **Forecasts for 2025 –** Study projects PM2.5 levels for 2025 conservatively as the average pollution levels from 2015-2019. In reality, pollution is likely to worsen. India GDP for 2025 was estimated as per the Oxford Economics forecast.

CONTENTS OF ANNEX

We identified and acquired a variety of datasets on absenteeism, consumer footfall and premature mortality for our analysis

	Cost	Data Source	Data Description	Data Hypothesis	Data Acquisition Method
A	Absenteeism	• TomTom	• **Road traffic levels** in corporate zones across India	**Lesser road traffic around corporate zones** on higher pollution days due to higher absenteeism	• Compiled ~600 number of reports on **Tomtom data portal** for **1.9 million people** moving around 10 corporate zones across 10 cities
C	Consumer Footfall	• TomTom • Daily footfall data from Pacific Malls	• **Road traffic levels** in busy shopping zones across India	**Lesser road traffic around shopping zones** on higher pollution days due to lower footfall	• Compiled ~600 number of reports on **Tomtom data portal** for **1.3 million people** moving around 10 market zones across 10 cities
D	Premature Mortality	• Global Burden of Disease Study • World Bank	• **# of deaths** in India due to air pollution • Value of a **working year lost**	Rising economic cost of air pollution due to the **decreasing number of working years per person**	• Downloaded data on # of deaths from **Global Burden of Disease Study website** • Reached out to **Dr Urvashi Narain**, senior environmental economist at the **World Bank**, to understand their estimation methodology and data source to value a working year

Note: Presenteeism not analysed under approach 2 due to lack of availability of concrete datasets

We also identified and gathered data on control variables, which enable us to isolate the impact of air pollution on absenteeism and consumer footfall

Control Variable	Control Variable Hypotheses	Control Variable Acquisition Method
Average daily temperature	• **Footfall decreases** and **absenteeism increases** on **extreme temperature days** as people avoid stepping outdoors	• Weather data downloaded from **National Oceanic and Atmospheric Administration (USA)** and Indian Meteorological Department
Daily precipitation	• **Footfall decreases** and **absenteeism increases** on **high precipitation days** as people avoid stepping outdoors	• Weather data downloaded from **National Oceanic and Atmospheric Administration (USA)** and Indian Meteorological Department
Holidays / festival days	• **Footfall** and **absenteeism increase** on public holidays / festival days	• **Desk research** to compile list of annual holidays / festivals for the ten Indian cities analyzed
Irregular events (e.g. strikes, heat waves, floods, elections)	• **Footfall decreases** and **absenteeism increases** on irregular event days as people avoid stepping outdoors	• **Desk research** to compile list of irregular events for the ten Indian cities analyzed
Time of the year	• **Footfall** and **absenteeism increase** at specific times of the year (e.g. in December holiday season)	• Column on **month of the year** added to dataset
Day of the week	• **Footfall** and **absenteeism increase** on specific days of the week (e.g. Fridays, weekends)	• Column on **day of the week** added to dataset

A Absenteeism | Estimation approach

Objective: Estimation of economic impact of air pollution on India in 2019 through the cost pathway of absenteeism

Dataset used for analysis: *Global Burden of Diseases Study 2019 (link)*

Data procured: # of years lived with disabilities (YLDs)[1] in India in 2019 due to air pollution as a risk factor, cut by age groups of 5 years ranging from 1-4, 5-9 to 90-94, 95+. Data for only working age groups is used in the analysis.

Calculation methodology: For each age group, **(a) number of years lived with disabilities (YLDs) due to air pollution** is multiplied with **(b) economic value of a working year**. The impact of each age group is then aggregated to arrive at the overall impact on India.

$$Cost\ of\ Absenteeism\ {}^{2019}_{India} =$$

$$\sum_{\text{All age groups}} Number\ of\ YLDs\ due\ to\ air\ pollution\ {}^{2019}_{India} \times GDP\ {}^{2019}_{India} \times Labor's\ share\ of\ GDP\ {}^{2019}_{India} \times Labor\ force\ participation^{1}\ rate\ {}^{2019}_{India} \div Number\ of\ workers\ {}^{2019}_{India}$$

(a) Number of absentee days due to air pollution

(b) Economic value of a working year

Sources

- India GDP, number of workers, labor force participation rate – World Bank Data (1,2,3), Statista
- India Labor's Share of GDP – Fred Economic Data

Note: (1) Calculated from data on population of India in working age and number of workers

A Absenteeism | Estimation approach

Additional parameters calculated:

- # of working days lost due to absenteeism

$$\#\ of\ working\ days\ lost\ due\ to\ absenteeism\ {}^{2019}_{India} =$$

$$Number\ of\ YLDs\ due\ to\ air\ pollution\ {}^{2019}_{India}\ \text{x}\ Number\ of\ working\ days\ in\ a\ year\ {}^{2019}$$

Sources

- YLDs in India – Global Burden of Disease Study 2019
- Number of working days in 2019 – Working Days website

Note: (1) Calculated from data on population of India in working age and number of workers

A Absenteeism | Estimation approach

Assumptions:

- **YLDs as proxy for absenteeism assumption –** YLDs are defined as the years of productive life lost due to air pollution-related diseases. The analysis assumes that YLDs to be a good proxy for absenteeism, as the disease burden would directly translate into # of workdays missed.
- **Impact of future years assumption –** The analysis assumes that the impact of absenteeism on the current year includes the impact from all future years of productive life lost due to absenteeism. The rational here is that while the lost years after the current year would impact the future years, the impact must also be attributed to the current year to avoid double-counting across the person's life span.
- **Working age assumption –** The analysis assumes the working age to be from **15 to 79 years**. While the typical working age is 15-64 years, the ILO estimates that the labor force participation rate of people over 65 years was 33% in less developed regions and thus, the 65-79 age group has been considered, albeit with a lower labor force participation rate.
- **Constant labor force participation rate assumption –** The analysis a constant labor force participation rate across all age groups in the working age (except for 65-79 as mentioned above). Since the analysis accounts for all future years lost as well, applying the participation rate for the age group of deceased would be misleading as over the course of a working life, the average participation rate across years would converge at a common average.
- **Constant output per worker assumption –** The analysis assumes a constant output per worker irrespective of age or sex. This is due to the lack of availability of disaggregated data on average worker outputs by different demographic factors.
- **Loss restricted to labor share of GDP assumption –** The analysis assumes that the loss to the economy from the absenteeism of a worker would only be from the contribution of labor to national output and not from the contribution by capital holders, whose contribution will not be affected by the years of productive life of a worker lost.

C Consumer Footfall | Estimation approach

Objective: Estimation of economic impact of air pollution on India in 2019 through the cost pathway of consumer footfall

Dataset used for analysis: *TomTom Origin/Destination Analysis dataset[1]; Global Historical Climate Network – Daily (GHCN-D)[2]*

Data procured: Daily # of people visiting consumer zones, for 6 cities (Delhi, Mumbai, Kolkata, Gurugram, Bengaluru, Hyderabad) in 2019; Daily rainfall for each of the 6 cities in 2019; Data on holidays and irregular events for each of the 6 cities in 2019[3]

Calculation methodology

Step 1: For each of the 6 cities, identified the correlation between air pollution and weekly traffic level; controlling for rainfall level, holidays and irregular events[1]:

$$Weekly\ traffic\ level\ {}^{2019}_{City} = \beta_0 + \beta_1 \times Average\ weekly\ PM2.5\ level\ {}^{2019}_{City} +$$

$$\beta_2 \times Average\ weekly\ rainfall\ level\ {}^{2019}_{City} + \beta_3 \times Weekly\ number\ of\ holidays\ and\ irregular\ events\ {}^{2019}_{City}$$

Controlling for rainfall, holidays and irregular events

Interpretation of the equation: β_1 , β_2 and β_3 are coefficients of regression, indicating the change in traffic levels caused by a unit change in each variable, keeping all the other explanatory variables constant while β_0 represents the projected traffic level with no rainfall, PM2.5 or holidays / irregular events. β_1 thus, represents the projected change in weekly traffic in response to a 1-unit increase in weekly PM2.5.

Sources

- (1) Traffic Data – TomTom, a location technology provider
- (2) Rainfall Data – United States National Centers for Environmental Information (NCEI)
- (3) Holidays & Irregular Events – Office Holidays website

Note: (1) The regression equation controls for rainfall, holidays and irregular events as these are variables that were found to have a statistically significant correlation with weekly consumer footfall. Including them in the regression equation thus allows us to isolate the correlation between PM2.5 levels and consumer footfall and avoid spurious correlations.

C Consumer Footfall | Estimation approach

Step 2: Calculated the average % drop in footfall per unit increase in PM2.5 for each by dividing **(a) β_1 for each city** by the **(b) average footfall value for each city.** India average is calculated by averaging the above value for the 6 cities in analysis.

$$Average\ \%\ decrease\ in\ consumer\ footfall\ per\ unit\ increase\ in\ PM2.5\ {}^{2019}_{India} =$$

$$\left[\sum_{\text{All cities}} \left(\beta_1\ /\ Average\ weekly\ consumer\ footfall\right)^{2019}_{City}\right] \div 6$$

Step 3: For each region in India (North, South, East, West), multiplied (a) average $ decrease in consumer footfall per unit increase in PM2.5 with (b) No. of consumers in each region, (c) Amount by which the zone's PM2.5 level exceeds the safe PM2.5 level and (d) offline discretionary spending per consumer

$$Cost\ of\ consumer\ footfall^{2019}_{India} =$$

$$\sum_{\text{All regions}} Average\ \%\ decrease\ in\ consumer\ footfall\ per\ unit\ increase\ in\ PM2.5\ {}^{2019}_{India}\ \text{x}\ Number\ of\ consumers\ {}^{2019}_{Region}\ \text{x}$$

$$\left(Average\ PM2.5\ level\ {}^{2019}_{Region}\ -\ Safe\ PM2.5\ level\right)\ \text{x}\ Offline\ discretionary\ spending\ per\ consumer\ {}^{2019}_{India}$$

Adjusting for regional pollution levels

Sources

- Average annual offline discretionary spend per consumer in India, 2019 – NSS Survey on household expenditure 2011-12 ; World Bank (1, 2)
- Numbers of consumers per region, 2019 – Unique Identification Authority of India
- Average daily PM2.5 levels by region, 2019 – BreeZo Visualizer

Note: (1) The correlation coefficients were statistically significant within a 90% Confidence Interval for all the cities except Kolkata and Gurugram

C Consumer Footfall | Estimation approach

Assumptions:

- **Traffic in consumer zones assumption –** The analysis assumes that the % change in the # of people passing through a particular consumer zone is a good proxy of the % change in the total consumption expenditure in that zone. This is the best estimate of consumer footfall given the lack of availability of data on the total daily consumption expenditure in consumer zones.
- **Linearity assumption –** The analysis assumes that footfall decreases linearly as PM2.5 changes. This is because no statistically significant non-linear relations were found between air pollution and consumer footfall while conducting the analysis on R.
- **Causality assumption –** The analysis assumes a causal explanation behind the negative correlation observed between air pollution and consumer footfall. This is because the regression isolates the impacts of pollution by controlling for rainfall, holidays and irregular events.
- **Constant consumption per consumer assumption –** The analysis assumes a constant consumption per consumer irrespective of age, sex, income, or geographical location. This is due to the lack of availability of disaggregated data on spending by individual consumers.
- **Offline discretionary consumption assumption –** The analysis assumes that only the spending on discretionary items (i.e. items excluding food, education, medical, rent and tax & cesses) will be affected by air pollution. This is because expenditure on non-discretionary items cannot usually be forgone due to air pollution. The analysis also assumes that spending on e-commerce is unaffected by air pollution as online purchases do not require a consumer to step outside into the polluted environment.
- **Number of consumers assumption –** The analysis assumes that the number of consumers for each region of India is equal to the population of that region.
- **Pollution levels assumption –** The analysis assumes that the average pollution in each region in India is equal to the average pollution of the major cities located in that region.

D Premature Mortality | Estimation approach

Objective: Estimation of economic impact of air pollution on India in 2019 through the cost pathway of premature mortality

Dataset used for analysis: *Global Burden of Diseases Study 2019 (link)*

Data procured: # of deaths in India in 2019 due to air pollution as a risk factor, cut by age groups of 5 years ranging from 0-5, 5-10 to 90-95, 95+

Calculation methodology: For each age group, **(a) number of deaths due to air pollution** (obtained from GBD data) is multiplied with **(b) number of working years lost** and **(c) economic value of a working year**. The impact of each age group is then aggregated to arrive at the overall impact on India.

$$Cost\ of\ Premature\ Mortality\ {}^{2019}_{India} = \sum_{\text{All age groups}} Number\ of\ deaths\ due\ to\ air\ pollution\ {}^{2019}_{India} \times (Assumed\ retirement\ age - Median\ age\ of\ age\ group^{1}) \times GDP\ {}^{2019}_{India} \times Labor's\ share\ of\ GDP\ {}^{2019}_{India} \times Labor\ force\ participation^{2}\ rate\ {}^{2019}_{India} \div Number\ of\ workers\ {}^{2019}_{India}$$

(a) Number of deaths due to air pollution — *(b) Number of working years lost* — *(c) Economic value of a working year*

Sources

- India GDP, number of workers, labor force participation rate – World Bank Data (1,2,3), Statista
- India Labor's Share of GDP – Fred Economic Data

Note: (1) The number of working years lost is capped at *Assumed retirement age – Assumed start of working age* to account for children who would be younger than the start of working age (2) Calculated from data on population of India in working age and number of workers

D Premature Mortality | Estimation approach

Additional parameters calculated:

- # of working days lost due to premature mortality

Calculation methodology: For each age group, **(a) number of deaths due to air pollution** (obtained from GBD data) is multiplied with **(b) number of working years lost** and **(c) number of working days in a year**. The impact of each age group is then aggregated to arrive at the overall impact on India.

$$\#\ of\ working\ days\ lost\ due\ to\ premature\ mortality\ {}^{2019}_{India} =$$

$$\sum_{\text{All age groups}} Number\ of\ deaths\ due\ to\ air\ pollution\ {}^{2019}_{India} \times (Assumed\ retirement\ age - Median\ age\ of\ age\ group) \times$$

$$Number\ of\ working\ days\ in\ a\ year\ {}^{2019}$$

Sources

- # of premature deaths due to air pollution in India – Global Burden of Disease Study 2019
- Number of working days in 2019 – Working Days website

Note: (1) Calculated from data on population of India in working age and number of workers

D Premature Mortality | Estimation approach

Assumptions:

- **Impact of future years post death assumption –** The analysis assumes that the impact of premature mortality on the current year includes the impact from all future years of life lost due to death in the current year. The rational here is that while the lost years after death would impact the future years, the death is attributable to the current year and hence, the impact must also be attributed to the current year.

- **Children in analysis assumption –** While children are not a part of the active workforce, the analysis includes children as per the 'Impact of future years post death assumption'. Since they will be a part of the workforce in the future, the economic value attributed to their working life is included in the estimate.

- **Working age assumption –** The analysis assumes the working age to be from **15 to 79 years**. While the typical working age is 15-64 years, the ILO estimates that the labor force participation rate of people over 65 years was 33% in less developed regions and thus, the 65-79 age group has been considered, albeit with a lower labor force participation rate.

- **Constant labor force participation rate assumption –** The analysis a constant labor force participation rate across all age groups in the working age (except for 65-79 as mentioned above). Since the analysis accounts for all future years lost as well, applying the participation rate for the age group of deceased would be misleading as over the course of a working life, the average participation rate across years would converge at a common average.

- **Constant output per worker assumption –** The analysis assumes a constant output per worker irrespective of age or sex. This is due to the lack of availability of disaggregated data on average worker outputs by different demographic factors.

- **Loss restricted to labor share of GDP assumption –** The analysis assumes that the loss to the economy from the death of a worker would only be from the contribution of labor to national output and not from the contribution by capital holders, whose contribution will not be affected by the death of a worker.

CONTENTS OF ANNEX

We surveyed stakeholders in the IT and tourism space to understand the impact of air pollution in those sectors and identified a list of sectors and consumption categories to extrapolate the impact to the rest of India

Table of Stakeholders Surveyed

Cost Pathway	Stakeholders Interviewed	Desired Outcome Metrics
Absenteeism	• HR representatives from **25 IT services** and **BPO services** companies across 12 cities in India	• A quantitative **estimate of worker attendance** in both high and low air pollution days
Presenteeism	• HR representatives from **27 IT services providers** and **33 BPOs** across 12 cities in India	• A quantitative **estimate of** key metrics of employee productivity such as **hours logged**, **calls completed** etc on both high and low air pollution days
Consumer Footfall	• Representatives from **25 tour operators**, **17 hotels** and **10 travel agencies** across 7 cities in India	• A quantitative estimate of **tourist arrivals on high and low air pollution days** or **actual tourist arrivals vs potential**

Sectors for extrapolation – absenteeism and presenteeism

- *Agriculture & forestry*
- *Food processing*
- *Fintech and financial services*
- *Retail & e-commerce*
- *Construction*
- *Tourism & hospitality*
- *IT & BPM*
- *Automobile*
- *Telecom*
- *Electronic systems*
- *Biotechnology*
- *Textile & apparel*
- *Aviation*
- *Media & entertainment*
- *Pharmaceuticals*
- *Capital goods*
- *Chemicals & petrochemicals*

Consumption categories for extrapolation – consumer footfall

- *Food*
- *Pan, tobacco & intoxicants*
- *Fuel & light*
- *Clothing & footwear*
- *Education*
- *Medical*
- *Conveyance*
- *Consumer services*
- *Misc. goods, entertainment*
- *Rent*
- *Taxes & cesses*
- *Durable goods*

A1 Absenteeism | Estimation approach

Objective: Estimation of economic impact of air pollution on India in 2019 through the cost pathway of absenteeism

Data used for analysis: Findings from primary survey conducted among 25 IT and BPO Services providers

Insights drawn from survey: **10.8% fall in worker attendance among IT workers** on high pollution days

Calculation methodology

Step 1: Estimating impact on IT sector. The cost of presenteeism on the IT sector in India is calculated for each region multiplying **(a) % fall in worker attendance on high pollution days** with **(b) % of high pollution days in the region** and **(c) IT sector GDP in the region.** The impact on each region is aggregated to arrive at the impact on the entire IT sector.

$$Cost\ of\ Absenteeism\ on\ IT\ sector\ {}^{2019}_{India} =$$

$$\sum_{\text{All regions}} \%\ fall\ in\ IT\ worker\ attendance\ on\ high\ pollution\ days \times \%\ high\ pollution\ days\ in\ the\ region\ annually \times IT\ sector\ GDP\ in\ the\ region\ {}^{2019}_{India}$$

Sources

- % high pollution days by region – BreeZo Air Quality data
- IT sector GDP by region – Balasubrahmanya & Rao, "The Rise of IT Services Clusters in India: A case of growth by replication", 2017

A1 Absenteeism | Estimation approach

Step 2: Extrapolating impact to other sectors. The % impact of air pollution on each sector is estimated by multiplying **(a) cost of absenteeism on IT sector as a % of IT sector GDP** with **(b) GDP of each sector, (c) ratio of sensitivity factor of each sector vs IT sector to air pollution** and **(d) ratio of average % high pollution days in each sector vs IT sector**[1]. Sensitivity is based on two factors – (i) importance of labor to the sector, and (ii) occupational exposure to air pollution. Impact across sectors is aggregated to arrive at the overall cost of absenteeism for India.

$$Cost\ of\ Absenteeism\ {}^{2019}_{India} =$$

$$\sum_{\text{All sectors}} (Cost\ of\ Absenteeism\ on\ IT\ sector\ {}^{2019}_{India} \div IT\ sector\ GDP^{2019}_{India}) \times i^{th}\ sector\ GDP^{2019}_{India}$$

$$(Sensitivity\ factor\ of\ i^{th}\ sector\ to\ air\ pollution \div Sensitivity\ factor\ of\ IT\ sector\ to\ air\ pollution) \times$$

$$(Average\ \%\ high\ pollution\ days\ across\ India, i^{th}\ sector \div Average\ \%\ high\ pollution\ days\ across\ India, IT\ sector)$$

Sources

- Other sectors' GDP– Invest India,
- Sensitivity factors – Allocated through first principles, financial statements of leading companies in each sector analyzed

Note: (1) While the average pollution across different regions (North, South, East, West India) is the same, the GDP contribution of each sector from these regions is different, hence while extrapolating the IT sector impact to other sectors, we factor in the difference in such contribution using the ratio of average % high pollution days, weighted by the % GDP contribution of each sector from each region

A1 Absenteeism | Estimation approach

Assumptions:

- **Perceptions-based survey assumption –** Study assumes that self-reported estimates by business managers of the impact of air pollution on presenteeism is a reliable and largely unbiased reflection of the true impact of air pollution on absenteeism.
- **Air pollution thresholds assumption –** Study assumes that the effects of presenteeism kick in at 200 ug/m^3 PM2.5 concentration, which is the start point of the 'hazardous' band of pollution as per the US AQI air pollution bands. This is higher than the threshold for presenteeism since presenteeism is a more passive effect which is felt earlier, vs absenteeism which involves taking an active decision to avoid traveling to work.
- **Equal contribution to sector GDP assumption –** Study assumes that workers of a given sector of all ages across all regions of the country contribute an equal amount to the sector's GDP, and thus, the decrease in productivity of a worker of a given sector due to a given amount of pollution is the same for workers of any age group and any region of the country.
- **Importance of labor to sector assumption –** Study assumes that labor costs as a percentage of total costs for representative companies in each of the 17 top-contributing sectors is an accurate proxy for the importance of labor to that sector. The study also assumes that the more labor-reliant the sector, the worse it will be affected by air pollution through the pathway of absenteeism. This assumption has been taken as a study by Hansen Lewis (2018) found that the productivity of more labor-intensive sectors in India is worse affected by air pollution.
- **Occupation exposure to air pollution assumption –** Study assumes that workers in polluted outdoors are the most exposed to pollution, and workers in air-conditioned indoors are least exposed. This assumption has been taken after interviews with experts and first principles.

A2 Presenteeism | Estimation approach

Objective: Estimation of economic impact of air pollution on India in 2019 through the cost pathway of presenteeism

Data used for analysis: Findings from primary survey conducted among 27 IT and 33 BPO Services providers

Insights drawn from survey: **3.4% fall in BPO worker productivity** and **25% fall in IT services worker productivity** on high pollution days

Calculation methodology

Step 1: Estimating impact on IT sector. The cost of presenteeism on the IT sector in India is arrived at by adding the cost of presenteeism on the BPO and IT services sub-sectors individually. In each case, **(a) % fall in the sub-sector's worker productivity** is multiplied with **(b) % of high pollution days in the region** and **(c) IT sector GDP in the region**

$$Cost\ of\ Presenteeism\ on\ BPO\ sub\ sector\ {}^{2019}_{India} =$$

$$\sum_{\text{All regions}} \%\ fall\ in\ BPO\ worker\ productivity\ on\ high\ pollution\ days \times \%\ high\ pollution\ days\ in\ the\ region\ annually \times BPO\ sub\ sector\ GDP\ in\ the\ region\ {}^{2019}_{India}$$

$$Cost\ of\ Presenteeism\ on\ IT\ services\ sub\ sector\ {}^{2019}_{India} =$$

$$\sum_{\text{All regions}} \%\ fall\ in\ BPO\ worker\ productivity\ on\ high\ pollution\ days \times \%\ high\ pollution\ days\ in\ the\ region\ annually \times IT\ services\ sub\ sector\ GDP\ in\ the\ region\ {}^{2019}_{India}$$

A2 Presenteeism | Estimation approach

$$Cost\ of\ Presenteeism\ on\ IT\ sector\ {}^{2019}_{India} = Cost\ of\ Presenteeism\ on\ BPO\ sub\ sector\ {}^{2019}_{India} +$$

$$Cost\ of\ Presenteeism\ on\ IT\ services\ sub\ sector\ {}^{2019}_{India}$$

Step 2: Extrapolating impact to other sectors. The % impact of air pollution on each sector is estimated by multiplying **(a) cost of presenteeism on IT sector as a % of IT sector GDP** with **(b) GDP of each sector, (c) ratio of sensitivity factor of each sector vs IT sector to air pollution** and **(d) ratio of average % high pollution days in each sector vs IT sector[1]**. Sensitivity is based on two factors – (i) importance of labor to the sector, and (ii) occupational exposure to air pollution. Impact across sectors is aggregated to arrive at the overall cost of presenteeism for India.

$$Cost\ of\ Presenteeism\ {}^{2019}_{India} =$$

$$\sum_{\text{All sectors}} (Cost\ of\ Presenteeism\ on\ IT\ sector\ {}^{2019}_{India} \div IT\ sector\ GDP^{2019}_{India}) \times i^{th}\ sector\ GDP^{2019}_{India}$$

$$(Sensitivity\ factor\ of\ i^{th}\ sector\ to\ air\ pollution \div Sensitivity\ factor\ of\ IT\ sector\ to\ air\ pollution) \times$$

$$(\%\ of\ sector\ value\ exposed\ to\ air\ pollution, i^{th}\ sector \div \%\ of\ sector\ value\ exposed\ to\ air\ pollution, IT\ sector)$$

Sources

- % high pollution days in each region annually – BreeZo Air Quality data
- BPO and IT services sub-sector GDP by region – Balasubrahmanya & Rao, "The Rise of IT Services Clusters in India: A case of growth by replication", 2017
- Other sectors' GDP – Invest India
- Sensitivity factors – Allocated through first principles, financial statements of leading companies in each sector analyzed

Note: (1) While the average pollution across different regions (North, South, East, West India) is the same, the GDP contribution of each sector from these regions is different, hence while extrapolating the IT sector impact to other sectors, we factor in the difference in such contribution using the ratio of average % high pollution days, weighted by the % GDP contribution of each sector from each region

A2 Presenteeism | Estimation approach

Assumptions:

- **Perceptions-based survey assumption –** Study assumes that self-reported estimates by business managers of the impact of air pollution on presenteeism is a reliable and largely unbiased reflection of the true impact of air pollution on presenteeism.
- **Air pollution thresholds assumption –** Study assumes that the effects of presenteeism kick in at 103 ug/m^3 PM2.5 concentration, which is the mid point between the 'Unhealthy' and 'Very unhealthy' band of pollution as per the US AQI air pollution bands. This is lower than the threshold for absenteeism since presenteeism is a more passive effect which is felt earlier, vs absenteeism which involves taking an active decision to avoid traveling to work.
- **Equal contribution to sector GDP assumption –** Study assumes that workers of a given sector of all ages across all regions of the country contribute an equal amount to the sector's GDP, and thus, the decrease in productivity of a worker of a given sector due to a given amount of pollution is the same for workers of any age group and any region of the country.
- **Importance of labor to sector assumption –** Study assumes that labor costs as a percentage of total costs for representative companies in each of the 17 top-contributing sectors is an accurate proxy for the importance of labor to that sector. The study also assumes that the more labor-reliant the sector, the worse it will be affected by air pollution through the pathway of presenteeism. This assumption has been taken as a study by Hansen Lewis (2018) found that the productivity of more labor-intensive sectors in India is worse affected by air pollution.
- **Occupation exposure to air pollution assumption –** Study assumes that workers in polluted outdoors are the most exposed to pollution, and workers in air-conditioned indoors are least exposed. This assumption has been taken after interviews with experts and first principles.

C Consumer Footfall | Estimation approach

Objective: Estimation of economic impact of air pollution on India in 2019 through the cost pathway of consumer footfall

Data used for analysis: Findings from primary survey conducted among 25 travel agents, 17 hotels and 10 tour operators

Insights drawn from survey: **3.2% fall** in bookings with tour operators, **2.8%** fall in hotel bookings and **3.5% shortfall** in bookings vs potential with travel agents[1] **on high pollution days**

Calculation methodology

Step 1: Estimating the % fall in tourist arrivals through the year. For each region, **(a) average % fall / shortfall in tourist arrivals on high pollution days** as per the three different respondents is multiplied with (b) **% high pollution days in each region**. The region-wise averages are then weighted by GDP contribution of each region to tourism to arrive at the national % fall in tourist arrivals

$$\%\ fall\ in\ tourist\ arrivals_{India}^{2019} = \underset{\text{All regions}}{Weighted\ average\ (weighted\ by\ GDP\ contribution\ of\ each\ region\ to\ tourism):}$$

$$Average\ \%\ fall/shortall\ in\ tourist\ arrivals\ to\ on\ high\ pollution\ days\ from\ tour\ operators, hotels\ and\ travel\ agents$$

$$x\ \%\ high\ pollution\ days\ in\ the\ region\ annually$$

Sources

- % high pollution days by region – BreeZo Air Quality data

Step 2: Estimating the impact on fall in consumer footfall on tourism. For each region, **(a) % fall in tourist arrivals** is multiplied with **(b) # of tourist arrivals** and **(c) economic value per tourist**

Note: (1) The findings from travel agents represent the shortfall vs capacity, This is because monthly data was captured from travel agents, and actual bookings were compared with potential bookings by taking the actual bookings during low pollution months and projecting the potential bookings in high pollution winter months with estimates of projected increase based on data from the Ministry of Statistics.

C Consumer Footfall | Estimation approach

$$Cost\ of\ consumer\ footfall\ on\ tourism\ {}^{2019}_{India} = \%\ fall\ in\ tourist\ arrivals\ {}^{2019}_{India}\ \text{x}\ \#\ of\ tourist\ arrivals\ {}^{2019}_{India}\ \text{x}$$

$$economic\ value^{1}\ per\ tourist\ {}^{2019}_{India}$$

Step 3: Extrapolating impact to other consumption categories. The % impact of air pollution on each category is estimated by multiplying **(a) cost of consumer footfall on tourism as a % of tourism sector GDP** with **(b) GDP from each category,** and **(c) ratio of sensitivity factor of each category vs tourism to air pollution**. Sensitivity is based on three factors – (i) discretionary nature of purchase, (ii) time-revenue linkage of purchase and (iii) availability of online substitutes. Impact across categories is aggregated to arrive at the overall cost of consumer footfall for India.

$$Cost\ of\ Consumer\ Footfall\ {}^{2019}_{India} =$$

$$\sum_{\text{All categories}} (Cost\ of\ consumer\ footfall\ on\ tourism\ {}^{2019}_{India} \div Tourism\ sector\ GDP^{2019}_{India})\ \text{x}\ i^{th}\ consumption\ category\ GDP^{2019}_{India}$$

$$(Sensitivity\ factor\ of i^{th}\ consumption\ category\ to\ air\ pollution \div Sensitivity\ factor\ of\ tourism\ to\ air\ pollution)$$

Sources

- # of tourist arrivals – Ministry of Tourism, "India Tourism Statistics 2019", 2020
- Economic value per tourist – Keelery, "Domestic Tourism in India", 2020
- Tourism sector GDP – Keelery, "Domestic Tourism in India", 2020
- GDP contribution of consumption categories – National Sample Survey Office, "Household Consumer Expenditure across
- Socio-Economic Groups," 2012; World Bank, "Private Final Consumption Expenditure India", 2019
- Sensitivity factors – Allocated through first principles, Dalberg analysis

Note: (1) The economic value per tourist in India was arrived at by taking the weighted average of the value of international and domestic tourists, weighted by the # of tourist arrivals. Value of every international and domestic tourist was arrived at by dividing the value of domestic and international tourism sector by the # of domestic and international tourists respectively

C Consumer Footfall | Estimation approach

Assumptions:

- **Perceptions-based survey assumption –** Study assumes that self-reported estimates by business managers of the impact of air pollution on presenteeism is a reliable and largely unbiased reflection of the true impact of air pollution on absenteeism.
- **Air pollution thresholds assumption –** Study assumes that the effects of presenteeism kick in at 103 ug/m^3 PM2.5 concentration, which is the mid point between the 'Unhealthy' and 'Very unhealthy' band of pollution as per the US AQI air pollution bands.
- **Equal contribution to sector GDP assumption –** Study assumes that consumers of all ages across all regions of the country contribute an equal amount to a given consumption category, and thus, the loss of any consumer to a given amount of pollution is the same for consumers of any age group and any region of the country.
- **Scope of impact to consumption spending assumption –** The impact assessment of this analysis on consumer footfall is only limited to the final consumption economy and not the interim consumption economy and hence is applicable only to ~60% of India's GDP.
- **Discretionary spending assumption –** Study assumes that consumption items that are discretionary will be more affected than consumption items that are non-discretionary in nature, e.g., apparel will get more affected than groceries when air pollution is high.
- **Time-revenue linkage assumption –** Study assumes that items which require a length of time for purchase will be more impacted than items which can be purchased in a single point of time the purchase of which can, hence, be postponed, e.g., a visit to a restaurant is more likely to be affected than the purchase of a television, which can be postponed.
- **Availability of online substitutes assumption –** Study assumes that items which can easily be purchased online will be less impacted by air pollution than items which cannot be as on a high air pollution day, a consumer can still purchase the item from home.