Let Us Breathe![*]

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Abstract

Air quality in lower and lower-middle income countries has considerably deteriorated over the past many years, affecting human capital and welfare. Even though many developing countries have strong air pollution rules and regulations on paper—with a comprehensive set of ambient air quality and emission standards—their air quality outcomes continue to stagnate. Why? We deconstruct this problem using Pakistan—a developing country with a rich history of environmental regulation but acute air pollution—as a case study, demonstrating that regulatory deficiencies, resource and capacity constraints, and imperfect information prevent environmental institutions from achieving their objectives. Poorly designed standards—governed by a command-and-control approach—paltry budgets, and missing data on source emissions and ambient air quality inhibit environmental institutions' ability to monitor and enforce air quality regulations. Understanding how much citizens value better air quality (willingness to pay), employing source apportionment studies, and harnessing the "informal regulator" (civil society) offer opportunities to fill policy gaps and improve compliance.

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Poor air quality has become a perennial problem in many low income and lower-middle income countries. Even though many of these countries have strong air quality regulations—at least on paper—they experience extraordinarily high pollution levels. Experts warn that severe air pollution can lead to a systemic drop in human capital, offsetting the welfare gains from increased economic activity. Why do developing countries struggle with improving air quality? What constraints do policymakers face in mitigating pollution? What are the policy gaps that experts must plug to inform more robust air quality management? We address these questions in this paper by leveraging Pakistan—a developing country with acute air pollution—as a case study, offering evidence of institutional failures which inhibit cleaner growth.

In South Asia, major urban centers' air quality has considerably deteriorated over the past decade. Several South Asian cities—Including New Delhi, Lahore, and Dhaka—regularly feature in the list of the most polluted cities globally while Bangladesh, Pakistan, and India rank as the top three most polluted countries in the world (IQAir 2020). Pollution levels in these cities often persistently exceed acceptable thresholds by degrees of magnitude.

As an example, Figure 1 depicts the daily trend of Lahore's average particulate matter 2.5 (PM2.5) concentration in micrograms per cubic meter ($\mu g/m^3$) from May 2019 – April 2020. PM2.5 constitutes fine particles—with a size less than three percent the diameter of a strand of human hair—which the blood stream absorbs when inhaled, gravely risking health (USEPA 2020). Lahore's daily average PM2.5 concentration significantly exceeded the World Health Organization's (WHO's) standard (25 $\mu g/m^3$) and the local Environmental Protection Department's (EPD's) standard (35 $\mu g/m^3$) almost the entire period. In winter, the city experienced PM2.5 levels up to 13 times the EDP's threshold. Lahore's annual average PM2.5 concentration in this period stood at 117 $\mu g/m^3$, far higher than the WHO's standard (10 $\mu g/m^3$) and the EPD's standard (15 $\mu g/m^3$).

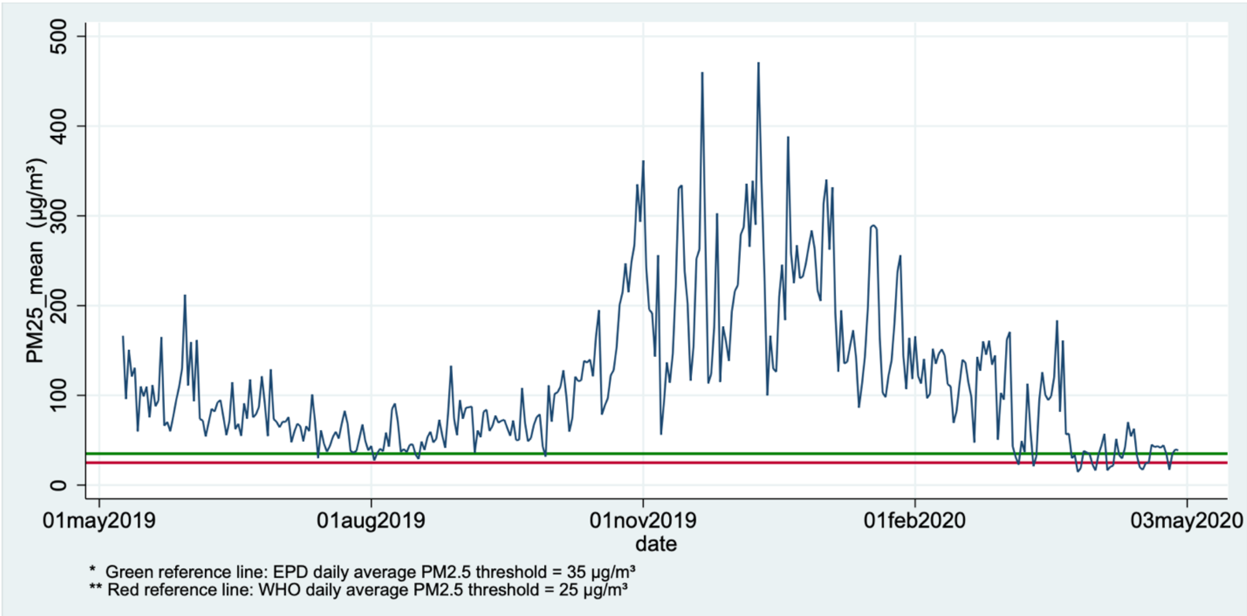

Figure 1: Lahore's daily average PM2.5 concentration, May 2019 – April 2020 (Nasim and Kashif 2021).

These alarming statistics demonstrate that millions of residents across developing country metropolises bear considerable costs of poor air quality. These costs translate into immeasurable health and human capital losses. PM2.5 exposure increases the incidences of cancer and cardiovascular and respiratory diseases such as ischemia, myocardial infraction, asthma, and bronchitis (Nasim and Sharif 2020). Other pollution-related morbidities include obesity, mental illness, and cognitive dysfunction, which raise an economy's health expenditure (Deschenes et al. 2020; Chen, Olivia, and Zhang 2018; Schikowski and Altug 2020). China spends over $22 billion annually to cover such expenses (Chen, Olivia, and Zhang 2018).

Since humans exposed to PM2.5 have a higher likelihood of suffering morbidities, they also live shorter lives on average. The Air Quality Life Index (AQLI) developed by the Energy Policy Institute at the University of Chicago (EPIC) causally relates PM2.5 to life expectancy. It shows that exposure to an additional 10 $\mu g/m^3$ of PM2.5 decreases life expectancy by roughly one year. Figure 2—a snapshot of Pakistan's AQLI—reveals that at current PM2.5 levels, an average Pakistani loses 2.7 years off their life while an average Lahori loses 5.3 years of their life (EPIC 2020). In 2010, premature deaths because of pollution resulted in welfare losses worth $3 trillion globally (OECD 2016).

Province	District	Population (Millions) [1]	$PM_{2.5}$ Concentration (µg/m³) 2016	$PM_{2.5}$ Concentration (µg/m³) After 32% Reduction	Life Expectancy Gain (Years) from Reducing $PM_{2.5}$ from 2016 Concentration: To WHO Guideline of 10 µg/m³	To National Standard of 15 µg/m³	By 32%[2]
All Pakistan		203.2	37	25	2.7	2.2	1.2
Sindh	Karachi City	22.4	16	11	0.5	0.1	0.5
Punjab	Lahore	9.4	64	43	5.3	4.8	2.0
Punjab	Faisalabad	8.1	59	40	4.8	4.3	1.8
Punjab	Gujranwala	5.1	58	40	4.7	4.3	1.8
Punjab	Rawalpindi	4.9	41	28	3.0	2.5	1.3

Figure 2: Potential PM2.5 reduction and its impact on life expectancy (EPIC 2020, as cited in Nasim and Kashif 2021).

Exposure to harmful air also increases infant mortality. Evidence shows that reducing particulate matter by 1 percent can lead to 0.35 percent fewer infant deaths (Chay and Greenstone 2003). Fetal exposure drives most of this effect, and it varies nonlinearly, with greater sensitivity of infant deaths in marginalized communities in response to changing particulate matter levels. Pollution-induced infant mortality amplifies the welfare losses from premature deaths.

Beyond direct health impacts, air pollution carries indirect economic and social costs. Recent literature demonstrates that air pollution: lowers labor supply and productivity (Hanna and Oliva 2015; He, Liu, and Salvo 2019); raises the incidence of violent crime (Herrnstadt et al. 2020); and forces disruptive migration—evidence from China suggests that pollution has driven skilled labor and talent out of important urban centers (Chen, Olivia, and Zhang 2017). Air pollution also poses risks to the financial sector. Exposure to polluted air impairs cognitive ability and drives mood changes, which affect investor behavior and can cause stock market returns to vary substantially (Heyes, Neidell, and Saberian 2016).

Persistent hazardous air quality in developing countries might suggest that they lack frameworks to mitigate pollution. However, many developing countries have created considerable institutions, laws, and mandates to manage air quality over time. For example, Pakistan and India have national- and state-level legislative acts establishing environmental protection agencies, delineating the agencies' governance structures and responsibilities, and mandating air quality and pollutant-specific standards. Despite such frameworks, these countries have struggled to clean their air.

Why? In this paper, we use Pakistan's experience with air quality management as a case study to demonstrate that regulatory deficiencies, resource and capacity constraints, and imperfect information prevent environmental institutions in developing countries from achieving their objectives. We identify poorly designed standards—governed by a command-and-control approach—paltry budgets, and missing data on source emissions and ambient air quality as the main mechanisms inhibiting environmental institutions' ability to monitor and enforce air quality regulations. We also describe policies and actions—which include measuring willingness to pay for better air quality, employing source apportionment studies, and harnessing "informal regulators" (civil society)—that could strengthen air quality regulatory frameworks and enable greater compliance.

We begin by contextualizing the problem (Section 2)—describing Pakistan's air quality challenges and charting the history of its regulatory framework. We then identify the regulatory challenges and constraints that hamper air quality management in the country (Section 3). In Section 4 we summarize lessons for developing countries and offer prescriptions to plug air pollution policy gaps.

1. Context and History

Pakistan's Air Pollution Problem

Pakistan's air quality data reveals that the government has struggled to regulate pollution, particularly the concentration of PM2.5—the most egregious pollutant. Pakistan's annual average PM2.5 concentration does not come close to the legal maximum allowable limit (15 $\mu g/m^3$) prescribed by its national and provincial standards for ambient air quality—in 2019, the national annual average concentration was four times the national standard (State of Global Air 2021). As shown earlier (Figure 1), major cities like Lahore—the capital of Punjab province and the country's second most populated city with over 10 million residents—experience hazardous levels of PM2.5 throughout the year.

Dearth of data and research in Pakistan makes determining how much air pollution sources contribute to overall emissions difficult. In 2018, the Food and Agriculture Organization (FAO) conducted perhaps the only comprehensive source apportionment study in Pakistan with disaggregated data on several pollutants including PM2.5 (FAO 2018). It shows that the main polluting sectors include transport (43 percent share in total emissions), industry (25 percent), agriculture (20 percent), and power (12 percent). Vehicular and industrial emissions carry the highest aggregate share in overall emissions.

Poor fuel quality along with preponderance of older vehicles and two-stroke motorcycles and autorickshaws largely explain the large share of vehicular emissions. The fuel quality in Pakistan falls under the Euro 2 category of the European Union's standards, far behind the Euro 6 standard adopted by many high-income countries. Though the federal government has signaled suppliers to switch to Euro 5 compliant fuel, the transition has stuttered. Two-stroke motorcycles and autorickshaws have inefficient engines compared to modern cars, and thus generate considerably higher emissions (Vasic and Weilenmann 2006). The number of motorcycles in Pakistan has risen considerably over the years, comprising 74 percent of the total number of registered vehicles (PBS 2018).

Given the lack of source apportionment studies in Pakistan, the figures on how much each type of industry contributes to overall emissions remain contentious. However, environmental experts generally consider steel, cement, fertilizer, sugar, power, and brick industries egregious polluters (Sanchez-Triana et al. 2014). Recently, the Ministry of Climate Change, in a written response to a senator, held steel rerolling firms in the Islamabad Capital Territory responsible for deteriorating air quality in the city (Tanoli 2018). It also acknowledged that many of these firms violated environmental regulations.

Though pollution levels remain high year-round, they significantly exceed average levels in winter months, especially in Punjab. Two phenomena explain this sharp increase: 1) thermal inversion; and 2) crop residue burning. Thermal inversion—a meteorological phenomenon—occurs when the normal temperature gradient reverses, causing the air closer to the Earth's surface to have a lower temperature than the air at higher altitudes. This cooler, dense air traps pollution—especially particulate matter—which mixes with condensed water vapor to form smog.

Just when thermal inversion kicks in, Punjabi farmers in both Pakistan and India begin burning rice stubble—left over on their fields after the fall harvest—to prepare land for sowing wheat. Farmers find burning stubble relatively cheaper than hiring labor or machinery to remove it. Nasa detected over 87,000 fires—evidence of stubble burning—across northern India in mid-November 2020 (NASA, n.d.). Coupled with consistent emissions from other sources, crop residue burning amplifies pollution in winters, leading to prolonged smog episodes.

Stubble burning across Pakistan and India raises concerns about transboundary pollution flow. However, transboundary pollution depends on meteorological conditions, especially prevailing wind patterns and direction. Some evidence suggests that fire-related pollution primarily flows to the southeast—from Pakistan into India—but could reverse direction as meteorological conditions vary (Miro, Marlier, and Girven 2019). Current data and research do not support the argument that stubble-burning in northern India severely deteriorates air quality across the border. The complex task of determining how stubble burning in each country affects the other requires rigorous chemical transport models supported by fine-grained data—which recently launched satellites could deliver.

PEPA and NEQS

The Pakistan Environmental Protection Act (PEPA) of 1997 represents the most serious piece of legislation in the country's history. Not only did it create federal and provincial Environmental Protection Agencies (EPAs) to implement and supervise the rules and regulations under the Act, it also introduced the National Environmental Quality Standards (NEQS), which mandated limits on industrial emissions and ambient air quality. The Pakistan EPA—the federal regulator—falls directly under the Federal Ministry of Climate Change (MoCC).

PEPA also established the Pakistan Environment Protection Council (PEPC), an independent body to oversee the EPAs and the enforcement of the Act. To improve representation and governance, the PEPC includes members from the wider society. Besides officials from key federal and provincial ministries, the PEPC comprises representatives from civil society, non-governmental organizations, and industrial and trade associations—as depicted in Figure 3, which shows the administrative hierarchy and stakeholders under PEPA.

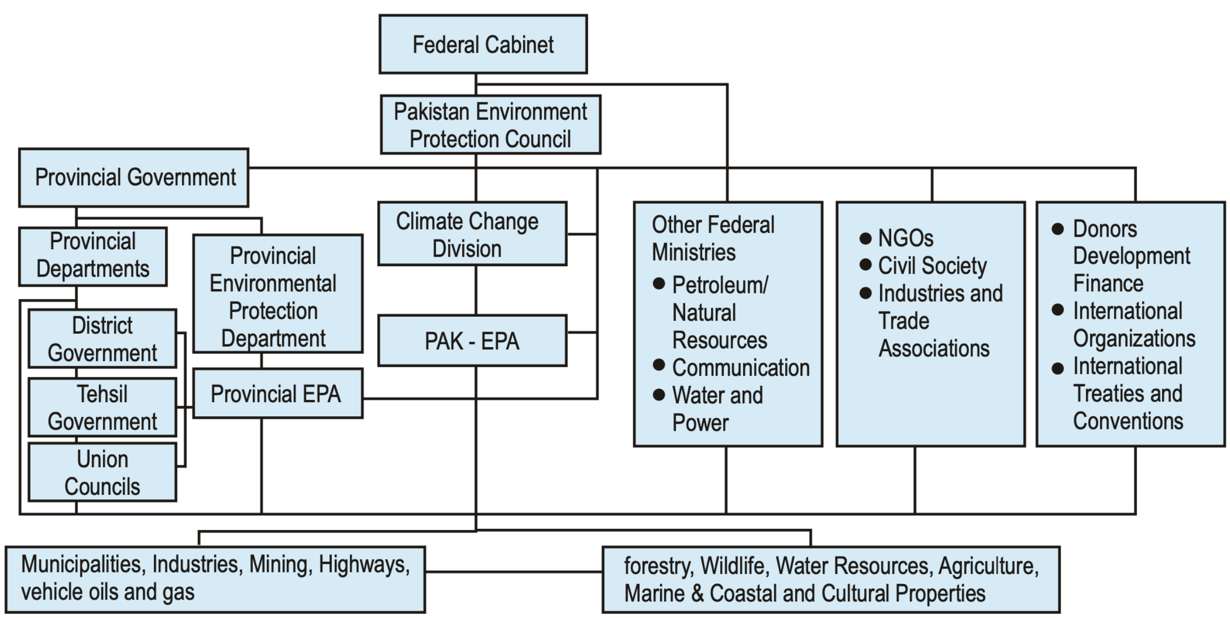

Figure 3: Administrative hierarchy and stakeholders under PEPA (UNEP 2013).

PEPA mandates that the PEPC convene at least twice a year. However, it has failed to meet for the past many years, a foundational failure of regulation in Pakistan. A new law in 2017—the Pakistan Climate Change Act—aggravates the failures. The Climate Change Act envisions a separate council and legally requires it to meet at least twice a year. But it does not clarify how the new council's role and responsibilities differ from those delineated under PEPA, effectively undermining the PEPC.

The Pakistan EPA has notified several rules and regulations to implement its responsibilities under PEPA. Table 1 lists the rules directly linked to air pollution. These rules involve the NEQS for Ambient Air, Motor Vehicle Exhaust, and Industrial Gaseous Emissions. They also include procedures for measuring and calculating pollution charges for industrial emitters. However, the rules regarding pollution charges have remained dormant since their inception, and the federal EPA and the provincial EPAs have refrained from administering these charges in letter and spirit.

Table 1: Pakistan EPA Rules on Air Pollution.

Rule No.	Description
3	NEQS for Ambient Air
4	NEQS for Motor Vehicle Exhaust
9	The Pollution Charge for Industry
12	NEQS Self-Monitoring and Reporting by Industries
14	NEQS for Industrial Gaseous Emissions

The federal EPA has revised the NEQS for Ambient Air several times since their inception. The current ambient air standards cover several major pollutants, including PM2.5, PM10, suspended particulate matter (SPM), sulfur dioxide (SO2), nitric oxide (NO), ozone (O3), lead (Pb), and carbon monoxide (CO). As an example, Table 2 shows the existing limits on PM2.5 under the NEQS for Ambient Air. The standards define annual, daily, and hourly averages for maximum allowable concentrations of PM2.5. While the EPA does not directly mandate an industrial emission standard for PM2.5, it indirectly covers PM2.5 emissions through its standards on allowable smoke based on opacity. The EPA further mandates emission standards for larger particulate matter (PM10) across different industrial processes. Under PEPA, the responsibility to coordinate and enforce the EPA's rules and regulations lies with the PEPC.

Table 2: NEQS for Ambient Air (PM2.5).

Period Average	**Allowable Limits ($\mu g/m^3$)**
Annual	15
24 hours	35
1 hour	15

Provincial Responsibilities

PEPA always intended to delegate the authority to implement air quality rules and regulations to the provinces through provincial EPAs. Originally, the Pakistan EPA set air quality and emission standards and defined the framework for their monitoring and enforcement while the provincial EPAs took on the responsibility to implement. After the 18th Amendment to Pakistan's Constitution in 2010, the provinces gained greater autonomy in environmental decision-making. Provinces can now define and legislate their own standards and develop their own system to monitor and enforce their rules and regulations—though the Federal Government still retains power to regulate environmental concerns in the areas of oil and gas, electricity, airports, shipping, and marine resources (Alam 2018).

In 2012, the Punjab Government amended the Punjab Environmental Protection Act—a provincialized version of PEPA adopted in 1997—to clarify existing and mandate new responsibilities. The Punjab Environment Protection Act laid out several rules, regulations, guidelines, and notifications concerning air quality. Other provinces also passed similar acts, including the Sindh Environmental Provincial Act 2013, Balochistan Environmental Protection Act 2013, and Khyber Pakhtunkhwa Environmental Protection Act 2014. Though the provinces can now set their own standards, they have largely retained the NEQS. The Acts present the provinces an opportunity to set industrial emission standards for PM2.5, which the NEQS neglected.

In line with PEPA, the provinces have established their own Environment Protection Councils as independent and diversely represented oversight bodies. The responsibility to monitor and enforce the provincial Environment Protection Agencies' rules and regulations rests with these provincial Councils. However, the number of annual Council meetings across provinces has fallen well short of the mandated number of minimum meetings. Table 3 below summarizes the number of times the federal and provincial Environment Protection Councils have met since 2018. Only the Punjab and Sindh provincial Councils managed to meet while the remaining provincial Councils and the federal Council failed to hold a single meeting.

Table 3: Environmental Protection Councils: Non-government members and meetings.

Province/Territory	Year	Number of Non-Government Members	Mandatory Council Meetings Per Year	Estimate of Meetings Held (Actual/Required, 2018 – 2020)
Federal	1997	At least 25	2	0/6
Punjab	1997	At least 25	2	3/6
Sindh	2014	Max. 25	2	1/6
KPK	2014	Max. 10	1	0/3
Balochistan	2013	Max. 6	2	0/6
AJK	2000	Max. 15	2	0/6
Gilgit-Baltistan	2015	2	2	0/6

Note: the federal-level Pakistan Environment Protection Council (PEPC) last convened in 2010.

Judicial Interventions

Regulatory failures in the provinces have created space for courts to take up matters of public policy. Since the 2000s, courts have actively intervened to enforce environmental regulations through either exercising their *suo moto* powers to hear cases of public interest or accepting writ petitions filed by civil society. Courts often establish commissions to investigate matters of public interest such as pollution. These commissions—headed by a prominent citizen—comprise civil society members and institutional representatives. The court accords the commissions powers to summon any stakeholder and submit recommendations, which the court can chose to enforce by passing orders to relevant authorities—the commissions' recommendations cannot legally bind authorities to act unless the court specifically directs the authorities to enforce them.

In December 2017, after an extreme smog episode in Punjab, Justise Mansoor Ali Shah—the Chief Justice of the Lahore High Court at the time—constituted the Smog Commission to formulate a smog policy for Punjab. The Smog Commission sought to identify the root causes of smog in Punjab and prescribe a plan to protect and safeguard the life and health of the province's citizens. To limit air pollution in Punjab, its report—issued in May 2018—recommended 17 measures, including voluntary and mandatory actions and steps to increase public awareness and to implement the measures. Table 4 summarizes the salient actions that the Commission proposed.

Table 4: Smog Commission's recommendations.

Voluntary Actions	Mandatory Actions
Encourage the Sustainable Rice Platform to enhance green certifications of rice produce—since many international importers do not procure rice from farmers who burn stubble	Prohibit municipal waste and urban biomass burning under the Punjab Local Government Act 2013
Coordinate with the Brick Kiln Owners' Association Pakistan to accelerate the adoption of Zigzag kilns or other cleaner technologies	Implement the Punjab Clean Air Action Plan
Provide steel rerolling firms a grace period to adopt cleaner technologies—shut down noncompliant firms after the grace period	Operationalize the emergency provisions of the Public Health Ordinance, 1944
	Link private hospitals and clinics with the Health Department to allow data sharing
	Establish smog response ICT applications
	Establish district-level smog response desks
	Implement the Standing Instructions for Management of Episodes of Poor Air Quality (2018)
	Execute the EPD's project titled "Enhanced Environmental Quality Monitoring Systems for Punjab's Air, Surface and Groundwater Resources"
	Initiate afforestation campaigns
	Implement the World Bank-funded Punjab Green Development Program
	Place updated environmental quality data on the EPD's website

Though the Punjab Government has dragged its heels in institutionalizing the Smog Commission's recommendations, it has made progress on some fronts. The government has collaborated with the Brick Kiln Owners' Association Pakistan to convert all conventional brick kilns in the province to cleaner Zigzag kilns—this comes with the caveat that though Zigzag kilns pollute less than conventional kilns, researchers do not consider them "clean" (Nasim and Sharif 2020). To limit stubble burning, the government has engaged with the Sustainable Rice Platform (SRP), a global organization that certifies rice produce cultivated sustainably and without stubble burning. Many European countries that import rice demand produce cultivated with minimal environmental impact and without stubble burning. The government has encouraged rice growers to join the SRP, incentivizing them to cease burning stubble and market their produce to larger international markets.

Judicial interventions in addressing how provincial governments can better govern and regulate air quality have raised concerns regarding the extent to which courts should intervene in matters of public policy. Though judicial commissions succeed in establishing actions plans by mobilizing experts and concerned citizens, they often fail to improve legal compliance. They also run the risk of increasing "judicial activism" given that the constitution and precedence already distinguish responsibilities of the judiciary and elected officials. But if environmental protection remains a low priority for governments, citizens will increasingly rely on courts to redress environmental concerns. To limit the courts from intervening in air pollution matters, the federal and provincial governments must prioritize pollution policies and demonstrate that their actions quantitively and visibly improve air quality.

2. Regulatory and Compliance Constraints

Command-and-Control

Provincial governments in Pakistan manage air pollution through what economists label a command-and-control (CAC) approach. The CAC approach to air quality entails mandating various standards through law and then harnessing state machinery—inspectors, police, courts, fines, and threats of shutdown—to enforce the standards. Though the provinces have prescribed rules to measure and levy pollution charges on sources, they have desisted from enforcing these rules since their inception. Broadly, regulators mandate three types of standards: ambient (hourly, daily, monthly, and annual average air quality in a particular region), emission or performance (hourly, daily, monthly, and average annual emissions from sources), and technology (technologies, practices, and procedures that sources must adopt).

Following the CAC approach, provinces have set their own standards, which they regulate through provincial Environmental Protection Departments (EPDs). For example, the Punjab Government has mandated the Punjab Environmental Quality Standards, and the Punjab EPD bears the responsibility to monitor and enforce them. These mandates legally establish standards in seven domains, including ambient air quality, industrial gaseous emissions, and motor vehicle exhausts and noise.

The ambient air quality standards set maximum limits on the average concentrations of nine different pollutants at any locale in the province. These standards cap the annual and daily average concentrations for most pollutants—for PM2.5 and carbon monoxide, they further cap hourly average concentrations. Though one of the EPDs' primary objectives involves improving air quality, they cannot directly enforce ambient standards since air quality depends on emissions from various sources. The EPDs can only improve air quality directly by targeting polluters.

The industrial gaseous emission standards place maximum limits on the average concentrations of 16 different pollutants that industrial sources can emit. However, these limits remain ambiguous as they do not specify the period over which to measure the pollutants' concentrations, except sulfur dioxide's and nitrogen oxide's concentrations. This obscures whether firms must meet the standard annually with leeway on daily emissions or whether they must ensure they do not exceed the standard annually and daily. On the other hand, the motor vehicle exhaust and noise standards clearly state how to measure the pollutants.

Setting emission standards for sources (industries and motor vehicles) does not imply that ambient air quality would meet the ambient standards. Meteorological conditions dictate how emissions from the point of discharge accumulate or disperse in air, which affects ambient quality. Linking source emissions to ambient air quality requires scientific models which take meteorological factors such as temperature, humidity, and windspeed as inputs. The provincial EPDs have not publicly disclosed their scientific method of relating their emission standards and ambient air quality standards. This raises concerns about whether the EPDs created their standards through an informed process that actively considered the science behind air quality.

Motor vehicles can aggravate ambient air quality even if they meet the limits under the motor vehicle standards. Currently, for new vehicles, the EPDs place standards on emissions per kilometer or emissions per unit of fuel consumed. These limits do not restrict the number of vehicles on the roads nor the number of kilometers each vehicle can cover. As more vehicles enter roads and cover greater distances, aggregate emissions rise while ambient air quality deteriorates. The EPDs do not delineate how their motor vehicle standards correlate with the ambient standards. These standards alone cannot explain how meeting them will affect ambient quality.

Uniform Standards

The EPDs' emission standards apply uniformly to most sources, which raises the aggregate costs of abating emissions—the Punjab EPD has set some industry-specific standards, but they apply uniformly within those industries. Across industries, firms produce different outputs, while within industries, firms often employ different technologies. This implies that if all firms emit up till the uniform standard, the costs of abating additional units of the same pollutant will most likely vary across firms. Thus, reallocating abatement from firms with higher marginal abatement costs to firms that can abate more cheaply can decrease overall costs of reducing emissions.

Reducing total abatement costs through CAC entails setting source-specific standards. Devising source-specific standards requires data on abatement costs at each independent source, which the EPDs do not possess owing to information asymmetries—sources know more about their abatement technologies and costs than the regulator. Collecting abatement cost data across sources can get prohibitively expensive. Sources also have little incentive to accurately disclose their cost data if they expect the EPDs to set stringent standards. The EPDs will have to transition to incentive-based mechanisms such as emission taxes and tradable permits if they want sources to abate emissions cost-effectively—they can begin by leveraging their existing rules on pollution charges.

Technology Standards

As part of their mandates, the EPDs—along with the Industries Departments, Transport Departments, and business associations—must facilitate polluters to transition to cleaner technologies. They currently implement this charge through technology standards. The recent move by the Punjab Government to convert existing Bull's Trench Kilns in the province to Induced-Draft Zigzag Kilns offers an example. Zigzag kilns pollute less compared to traditional Bull's Trench kilns but other technologies such as Vertical Shaft kilns and Hoffman kilns pollute even less. Mandating an absolute technology standard—Zigzag kilns in this case—takes away kiln owners' flexibility to adopt better technologies beyond Zigzags. Experience with installing dry scrubbers by some steel firms, which enables them to export the "black carbon" by-product, presents another minimum technology standard worth investigating.

Budget

Given the large number of emission sources and their incentives to ignore official directives, the EPDs require considerable outlays to monitor and enforce their standards. Currently, the provincial governments allocate insufficient funds to EPDs to finance their expenditures. For example, in the current fiscal year, the Punjab Government has allocated 1.8 percent of its development budget (Rs. 337 billion) to environmental protection. The Punjab EPD devotes a share of these funds to regulating air quality since its role extends to managing other environmental media.

Paltry budgets weaken the EPDs' abilities to carry out their regulatory functions. Sources will comply with emission standards if the regulator can unambiguously monitor their emissions and credibly threaten them with penalties and sanctions. Monitoring sources requires stocking equipment to measure emissions and maintain a cadre of inspectors for audits and spot checks. Lack of funds curtails the EPDs' monitoring capacity, dampening their repercussive legal threats and encouraging sources to ignore the limits on their emissions. In Punjab, the World Bank's $200 million grant to the EPD—under the Punjab Green Development Program—to strengthen its capacity offers temporary relief from budgetary constraints.

Ambient Air Quality Data

The Punjab EPD has gradually begun to publicly report ambient air quality data—especially after its new public disclosure rules—but these data and their reporting are fraught with serious problems. The EPD lists the data only on its websites, putting it out of reach of the digitally illiterate and those without digital access. It can reach a larger share of the population by disseminating data through alternative channels such as text messages, radios, and television. The EPD operates six air quality monitors, which cover only Lahore, though several other Punjabi cities also experience poor air quality. It also struggles to consistently report data with large chunks of daily readings missing. This underreporting commonly stems from malfunctioning equipment, with many monitors going offline because of power outages or expired internet packages.

The data that the EPD does disclose often contradict data from private sources—such as the US Consulate's AirNow monitor and citizen-operated monitors. Since the EPD struggles to report data regularly and reliably—an important part of its mandate—citizens have turned to private sources to consume pollution-related information. This will likely deepen citizens' mistrust in the EPD and reinforce beliefs about its incapacity to manage air quality. To counter these perceptions and encourage citizens to trust and value their information, all EPDs will have to expand their networks of air quality monitors and regularly report daily readings.

Air Quality Index

The Punjab EPD uses data from its air quality monitors to construct and report an Air Quality Index (AQI)—a weighted average of various pollutants. However, this AQI deviates from internationally accepted standards and can deceive citizens. It omits a safety margin, which environmental agencies often include in their indices. As Figure 4 shows, the Punjab EPD labels AQI values between 301 and 400 as "poor" and values above 500 as "severe" (highest category). On the other hand, the United States Environmental Protection Agency (USEPA) labels any value above 301 as "hazardous."

Though all EPDs should report an AQI to keep citizens informed, they must ensure the AQI categories follow the templates of globally reputable environmental agencies.

AQI	Air Quality (USEPA)	Air Quality (EPD)
0 - 50	Good	Good
51-100	Moderate	Good
101-150	Unhealthy for Sensitive Groups	Satisfactory
151-200	Unhealthy	Satisfactory
201-300	Very Unhealthy	Moderately polluted
301-400	Hazardous	Poor
401-500	Hazardous	Very poor
500+	Hazardous	Severe

Figure 4: Differences in the Air Quality Index advisories (Nasim and Kashif 2021).

Source Apportionment

Source apportionment studies allow air quality regulators to identify pollution sources and the share of their contribution in total emissions. Since source emissions can vary geographically and between seasons, regulators must generate source apportionment figures across space and time to better understand how different sources affect air quality. In 2018, the Food and Agriculture Organization (FAO) conducted perhaps the only comprehensive source apportionment study in Pakistan.

Though the FAO study provides some evidence on emission sources, it lacks scale and rigor. First, it covers only Punjab, leaving other provinces without data on their emission inventories. Second, the analysis relies on remote sensing techniques, which can yield imprecise measures of existing emissions. More robust methods such as the top-down approach involve sampling, testing, and modelling emissions. Third, as the number of sources often change over time, the FAO study will soon become outdated. All the provincial EPDs must regularly gather new and fine-grained evidence on sources so they can better target their policies.

3. Filling the Gaps

Pakistan's experience with managing air pollution—as investigated above—offers insights into how developing countries that chronically experience environmental regulatory failures can create opportunities to understand pollution's adverse impacts, incentivize abatement, generate better data and evidence, and improve compliance.

Economic and Social Costs

The literature extensively documents the harmful link between pollution and health but results from specific locations often cannot generalize to other contexts. Developing countries require more robust work on quantifying the full costs of long-term exposure to air pollution. The work must not only focus on mortality, morbidity, and cognition but must also cover pollution's impacts on behavioral decisions such as fertility, migration, time-use, and defensive expenditures. Such evidence on impact will underscore air pollution's potential costs and motivate policymakers to act.

The tradeoff between economic growth and air pollution remains uncertain. As successive governments prioritize growth and take measures to alleviate poverty, economic development can aggravate air pollution. For example, investments in power and industries will most likely increase emissions. Governments can overestimate projected growth figures if they fail to consider the deleterious effects of worsening air quality on growth. Projecting the flow and stock of emissions and quantifying their effect on growth will allow policymakers to buffer the adverse shocks of development policies.

Source Apportionment

As mentioned earlier, developing countries often lack source apportionment studies. We do not know enough about the spatial and temporal dynamics of emission sources and require continuous research to understand these dynamics. The apportionment studies must employ established techniques involving lab testing and diffusion modeling to generate precise and accurate data. Identifying sources and their industrial composition, location, and contribution to overall emissions will enable policymakers to better target polluters, revise existing emission standards, and set clearer objectives.

Willingness to Pay

To get a better sense of how much citizens in developing countries value better air quality, researchers must focus on willingness to pay measures. We currently know little about how much people are willing to pay for improved air quality and how this willingness to pay changes with information and across heterogenous factors such as income, education, and gender. Revealed preference methods that involve measuring the demand for pollution avoidance—particulate filtering masks, air purifiers, and air quality information such as forecasts and real-time readings—offer a way to approach these questions. Ongoing work by Ahmed et al. (2020), which experimentally measure the willingness to pay for pollution forecasts and particulate filtering masks in a developing city, will fill a part of this gap.

Incentive-Based Strategies

Developing countries should also explore options to transition from command-and-control regulations to incentive-based abatement strategies such as emission charges and tradable permits. These strategies incentivize polluters to abate cost-effectively and provide them greater flexibility in determining the best abatement measures. Emission charges (also known as emission or pollution taxes) hinge on the "polluters pay" principle which places the onus to compensate for damages directly on polluters.

If the charge on each unit of emission exceeds the costs of reducing additional units of emissions, abatement will benefit polluters. Since the charge disincentivizes polluters to emit, they can choose how they want to abate without conforming to stringent mandates. The government gains additional revenue from emission charges—the "double dividend"—and can divert it towards financing other air quality initiatives, including technological research and innovation.

Under an emissions trading system, the regulator caps emissions at the desired level and then distributes permits—defining maximum emission allowances—to polluters, which they can trade in a market. The cap limits emissions while market dynamics ensure cost-effective abatement. Permits flow from polluters who can reduce emissions cheaply to polluters who incur higher costs to abate—bargaining between the buyers and sellers determines the optimal price of the permits. The gains from trade lead polluters to reduce emissions at a lower cost to society than command-and-control measures.

Price-based abatement strategies come with a host of challenges, especially in weak institutional settings. Since emission charges lead to a tax bill for polluters, they require the regulator to accurately measure emissions and establish legal forums where polluters can contest charges. Emissions trading systems work only if the regulator can ensure polluters do not exceed their permit allowances and the market has enough participants to make it thick—thus immune to price volatility. Understanding the regulatory costs and the capacity demands of these strategies can help the government determine whether it can feasibly implement them. India's Gujarat State is currently piloting an emissions trading program for particulate matter. The results of this program could inform the design of Pakistan's own permit trading system.

Informal Regulator

Amid regulatory failures, alternative stakeholders ("informal regulator") offer a complementary channel to pressure polluters to comply with standards and governments to improve monitoring and enforcement. Leveraging informal regulators such as civil society organizations, academic and research institutions, and industrial associations can create more transparency in air quality data sharing, signal a sense of ownership in the regulatory process, and motivate voluntary initiatives. In countries like Pakistan, laws already require environment oversight bodies to induct non-official members, enabling society to play an important role in enforcing regulations.

Identifying informal actors and their intersection with regulatory departments can strengthen how the country manages its air quality. Non-governmental organizations can assist courts in a legal capacity, support public interest litigation, implement projects, and establish voluntary monitoring and oversight committees. Academic and research institutes can harness research to develop and pilot abatement technologies, generate evidence, and produce policy frameworks. Industry associations can monitor whether their members legally comply with regulations and assist them in identifying and adopting cleaner technologies. Chambers of commerce can facilitate its members to engage with organizations that provide technical assistance and conduct seminars and training exercises. Civil society and private organizations can collect and disseminate air quality data and create information-sharing platforms.

India's and China's Experiences

Recent reforms and policy experiments in India and China offer important lessons that other developing countries can draw on to managing their air quality. In India, though many cities experience severe smog, some states have begun to initiate evidence-based policy measures to improve air quality. China witnessed some of the worst ambient air quality globally a decade ago but has since made remarkable strides in reducing emissions.

India's and China's push to publicly disclose air quality information and make emissions reporting more transparent forms the backbone of their pollution management. In collaboration with the University of Chicago's Energy Policy Institute (EPIC), the Indian states of Maharashtra, Odisha, and Jharkand have instituted the Star Rating Program (Greenstone and Lee, n.d.; TCD 2019). Under the program, each state discloses information about how much firms emit through a star rating scheme—firms that pollute the most receive a 1-Star rating while firms that perform best receive a 5-

Star rating. The program puts pressure on polluting firms and recognizes the efforts of firms that comply with emission regulations.

In China, after its air quality management came under intense public scrutiny, authorities have vastly expanded their air quality monitoring network and regularly report air quality statistics to the public (Greenstone and Schwarz 2018; Wong 2013). They have also aggressively pushed power plants and firms to move from coal to natural gas. Similarly, they have encouraged residents to replace coal boilers with electric or gas heaters. In large urban centers, authorities have restricted the number of vehicles on the road. These assertive measures have increased the average life expectancy of 70 percent of the population by 2.3 years relative to 2013 (Greenstone and Schwarz 2018).

Evidence from the Indian state of Gujrat reveals that increasing random plant inspections leads firms to modestly comply with emission standards (Duflo et al. 2018). These random inspections fail to target egregious polluters. However, the regulator's discretionary inspections capture more extreme violators, improving its power to enforce standards and leading firms to abate three times more than under random inspections.

New technologies have also helped some Indian states strengthen their monitoring capacities. The Continuous Emissions Monitoring System (CEMS) allows regulators to track firm emissions in real-time, reducing monitoring and enforcement costs (Greenstone et al. 2020). Coupled with the Star Rating Program, CEMS allows regulators to publicly disseminate more accurate industrial pollution information. CEMS has also prepared regulators to experiment with incentive-based mechanisms for reducing emissions. Gujarat has implemented the world's first PM2.5 emissions trading system, which can plausibly control pollution more cost-effectively than the existing command-and-control approach (Tripathi 2019). The pilot is still ongoing, and its results, once evaluated, can help other countries design their own emissions trading systems.

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