Final report

Charting Pakistan's air quality policy landscape

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Charting Pakistan's Air Quality Policy Landscape

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Abstract

Air quality in Pakistan's major urban centers has considerably deteriorated over the past five years. Some Pakistani cities regularly feature in the list of the most polluted cities globally. Even though Pakistan has strong air pollution rules and regulations on paper—with a comprehensive set of ambient air quality and emission standards—monitoring and enforcement remain deficient. To support evidence-based research and policy work on Pakistan's air quality management, this paper: 1) describes the existing air quality regulatory framework; 2) identifies gaps in existing air pollution regulations; and 3) determines areas of policy research that would generate the most value to citizens and policymakers. This paper informs the International Growth Center's (IGC's) priorities to influence environmental policies and actions that strengthen regulatory frameworks and enable greater compliance.

Sections

1. The Air Pollution Problem 1
2. Air Quality Regulatory Framework 5
3. Regulatory and Compliance Challenges 17
4. Avenues for Policy Research 23
References 26

1. The Air Pollution Problem

Air quality in Pakistan's major urban centers has considerably deteriorated over the past five years. Lahore, the capital of Punjab province and the country's second most populated city with over 10 million residents, regularly features in the list of the most polluted cities globally (Nasim and Kashif 2021). 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).

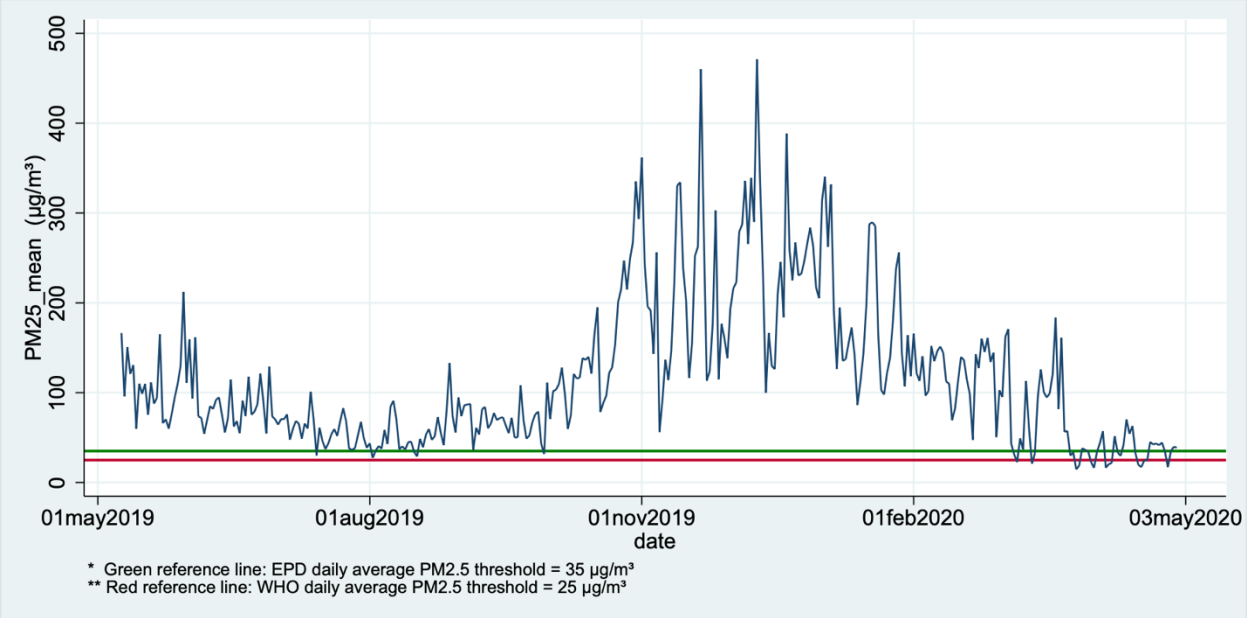

Figure 1: Lahore's daily average PM2.5 concentration, May 2019 – April 2020 (Nasim and Kashif 2021).

As Nasim and Kashif (2021) show (see Figure 1), "Lahore's daily average PM2.5 concentration significantly exceeded the World Health Organization's (WHO's) standard (25 $\mu g/m^3$) and the EPD's standard (35 $\mu g/m^3$) almost throughout the period. In winter, Lahore experienced daily average concentrations 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 $\mu g/m^3$)."

These alarming statistics imply that Pakistanis bear considerable costs of poor air quality. 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). Premature deaths and morbidities due to air pollution cost Pakistan up to 6.5 percent of its GDP annually (World Bank 2019).

			$PM_{2.5}$ Concentration ($\mu g/m^3$)		Life Expectancy Gain (Years) from Reducing $PM_{2.5}$ from 2016 Concentration		
Province	District	Population (Millions)[1]	2016	After 32% Reduction	To WHO Guideline of 10 $\mu g/m^3$	To National Standard of 15 $\mu g/m^3$	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).

Beyond direct health impacts, air pollution carries indirect economic and social costs: the literature "links poor air quality to lower labor supply and productivity, higher incidence of violent crime, and disruptive migration—evidence from China suggests that pollution has driven skilled labor and talent out of important urban centers. Poor air quality also poses risks to the financial sector. Impaired cognitive ability and mood changes because of exposure to polluted air affects investor

behavior and can drive substantial variation in the returns on the stock market" (Nasim and Kashif 2021).

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.

Pakistan's air quality data indicates 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). The lack of source-specific emission standards for PM2.5 and robust mechanisms to monitor and enforce regulations further compounds the problem.

To support evidence-based research and policy work on Pakistan's air quality management, this paper: 1) describes the existing air quality regulatory framework; 2) identifies gaps in existing air pollution regulations; and 3) determines areas of policy research that would generate the most value to citizens and policymakers. The paper informs the International Growth Center's (IGC's) priorities to influence policy and actions that strengthen regulatory frameworks and enable greater compliance.

The next section describes Pakistan's air quality regulatory framework. Section 3 explains the regulatory and compliance challenges that hamper air quality management in the country and summarizes other developing countries' experiences with addressing air pollution. Section 4 offers areas for policy research to understand and improve Pakistan's air quality management.

2. Air Quality Regulatory Framework

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, but 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.

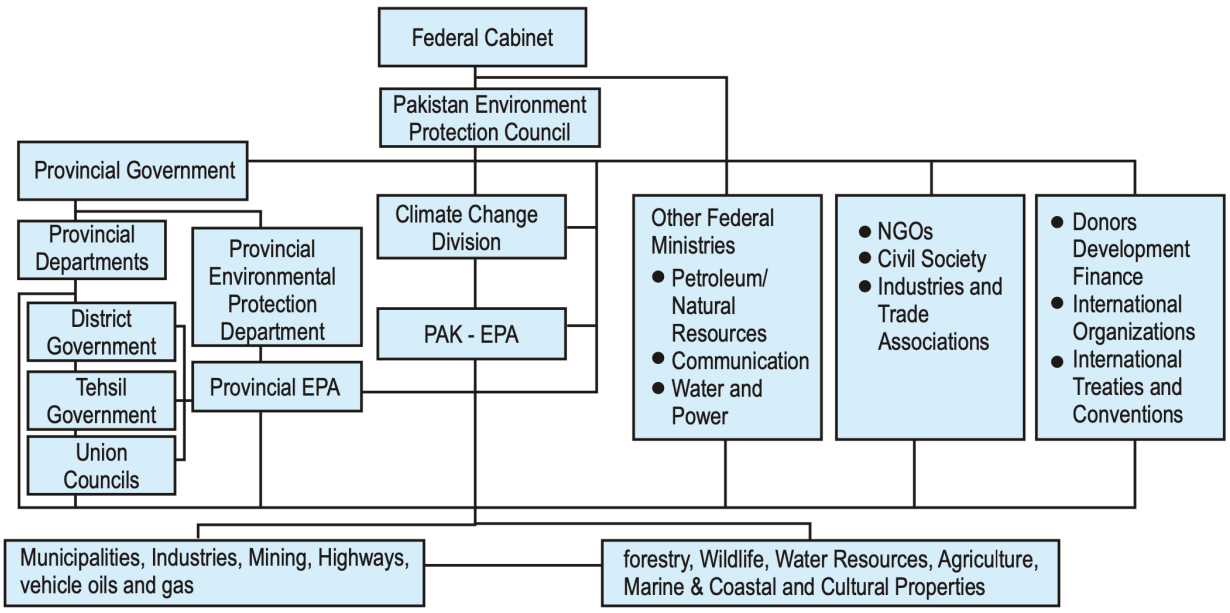

Figure 3: Administrative hierarchy and stakeholders under PEPA (UNEP 2013).

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—Table 3 below summarizes the number of times the federal and provincial Environment Protection Councils have met since 2018.

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). 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 included the following rules, regulations, guidelines, and notifications concerning air quality:

1) Punjab Environmental Protection (Tribunal) Rules, 2012
2) Punjab Environmental Protection (BTS) Regulations, 2012
3) Punjab Environmental Protection (Administrative Penalty) Rules, 2013
4) Establishment of the Punjab Environmental Protection Council (3 September 2013)
5) Punjab Environmental Protection (Motor Vehicle) Rules, 2013
6) Punjab Environmental Protection Council (Procedure) Rules, 2016
7) Punjab Environmental Quality Standards for:
    a. Ambient Air
    b. Industrial Gaseous Emissions
    c. Motor Vehicle Exhaust and Noise

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 short of the mandated number of minimum meetings. Table 3 provides a summary of the federal and provincial Environment Protection Councils' composition and the number of meetings they have held from 2018 to 2020.

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.

Table 4 lists provincial government departments that have a regulatory or administrative role in managing air quality. The Environment Protection Agencies carry the regulatory role of setting and enforcing the provincial environmental quality standards. However, to enforce standards, they require administrative support from other official departments. The Industry Departments lend support to inspect facilities and monitor emissions. The Transport Departments possess the authority to inspect and certify vehicles while the Agriculture Departments, Parks and Horticulture Authorities, and Municipal Authorities monitor stubble, biomass, and waste burning.

Table 4: Government departments' roles and responsibilities in managing air quality.

Government Department	Regulatory Role	Administrative Role	Responsibilities
Environment Protection Agency	X		Set and enforce air quality standards
Transport Department		X	Conduct vehicle inspections
Industries Department		X	Support enforcement of industrial standards
Parks and Horticulture Authority		X	Monitor biomass burning in public parks
Agriculture Department		X	Monitor stubble burning and offer alternatives
Municipal Authority		X	Control municipal waste burning

With devolved powers, the provinces can define action plans to address air pollution. In response to deteriorating air quality in the province, the Environment Protection Department, Punjab (EPD)—the parent department of the Punjab Environment Protection Agency—developed the Punjab Clean Air Action Plan, which explores options for the government to address the significant costs that Punjab's citizens and economy bear because of increasing air pollution and winter smog. The Plan uses the available (scant) data to identify pollution sources in the province and suggests a suite of policy measures to control and eventually improve air quality.

To strengthen environmental governance and promote green investments in Punjab, the World Bank has committed $200 million to the provincial government under the Punjab Green Development Program (PGDP)—the government has committed an additional $73 million to the program. Table 5 summarizes the PGDP's main proposed actions. Its salient objectives include improving the EPD's capacity, installing more air quality monitors, disclosing pollution information, establishing vehicle emission standards, promoting green investments by polluting industries, and creating green financing opportunities.

When the seven-year program started in 2018, the Punjab Government dragged its feet on implementing its provisions. This forced the World Bank to rate the program's progress "Moderately Unsatisfactory." Since then, the government picked up pace, and besides creating the EPD's restructuring plan, it has established a program steering committee, a program coordination unit, and program delivery units at the Energy, Finance, Industries, and Transport Departments. In line with the PGDP's target to disseminate information, the EPD has also published the Guidelines for the Regulation of Disclosure of Environmental Information and Citizen Engagement, 2020. The World

Bank has now revised the program's rating to "Moderately Satisfactory," implying the government still has room to improve its progress.

Table 5: The Punjab Green Development Program's proposed actions.

Area	Proposed Actions
Capacity building	Restructure the EPD and increase its stack emissions inspection teams
Laws/policies	Adopt updated law, 3 new policies, and 2 regulations
Pollution standards	Introduce 9 new environmental quality standards and 58 industry-specific standards
Air quality monitors	Increase the number of installed air quality monitors
Civil society participation	Conduct annual information dissemination events, encourage NGO participation in events, and create interactive online platforms

Court Orders

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. Of the 16 cases in the category "Abduction of Women and Children and Environmental Pollution" listed on the Supreme Court's website, the court heard 11 through exercising its *suo moto* powers—4 out of these 11 cases concerned the environment.

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 2003, the Lahore High Court appointed the Lahore Clean Air Commission after entertaining a writ petition filed by Justice Mansoor Ali Shah—he filed the petition as a citizen, six years before joining the judiciary. The Commission comprised high-level representatives from the city and national government and other stakeholders. After concluding its proceedings, the Commission recommended that the provincial government introduce 4-stroke rickshaw engines, expand public transport, and adopt Euro II, Euro III, and Euro IV fuel and emission standards for motor vehicles. The Lahore High Court accepted these recommendations—under the judgment in

Mansoor Ali Shah vs. Government of Punjab (PLD 2007 Lah. 403)—and directed the Punjab Government to implement them.

In November 2017, Justise Mansoor Ali Shah—the Chief Justice of the Lahore High Court at the time—accepted a writ petition (W.P No. 34789/2016) to investigate the provincial government's failure in controlling Lahore's air pollution and smog. As part of the proceedings, the court institutionalized the action plan given in Table 6. The plan lists the steps that government departments must take under different color-coded categories of PM2.5 levels. It further directed the EPD to act on the action plan under the supervision of the Chief Secretary and to upload daily PM2.5 readings on its website.

Table 6: PM2.5 color scheme and prescribed actions.

PM2.5 Level ($\mu g/m^3$)	Indicator Color (Description)	Prescribed Actions
0–35	Green (good–minimal impact)	No action required
36–70	Light Green (satisfactory)	Restrict industrial units and construction activities in affected areas
71–105	Yellow (moderately polluted)	Shut down air polluting industrial units; restrict motor vehicles
106–140	Orange (poor)	Shut down primary schools; issue warnings for children and the elderly to remain indoors
141–300	Red (very poor)	Shut down all educational institutions; close parks; mandate masks outdoors; distribute masks
300+	Maroon (severe)	Declare medical emergency; suspend all outdoor activities; evacuate if possible

A month later, after an extreme smog episode in Punjab, Justice Mansoor Ali Shah constituted the Smog Commission—under Order 26 of the Code of Civil Procedure, 1908—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 7 summarizes the salient actions that the Commission proposed. The voluntary actions include leveraging the Sustainable Rice Platform to increase green certifications—which prohibit waste burning—of rice produce; coordinating with the Brick Kiln Owners' Association Pakistan to

hasten the adoption of cleaner kiln technologies such as Zigzag kilns; and encouraging steel rerolling firms to adopt cleaner technologies—with the threat of eventual shutdowns—in liaison with the Lahore Chamber of Commerce and Industries.

Table 7: 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

The key mandatory actions include banning municipal waste burning, adopting the Punjab Clean Air Action Plan, publicly providing air quality data, and establishing digital smog response systems. The Commission further recommended the EPD engage with academia and civil society to invest in research and public awareness campaigns; the federal government include environmental concerns in bilateral and multilateral dialogues with India; and the court create a permanent Clean Air Commission.

Given that provinces—especially Punjab—have continuously struggled to reduce pollution, the courts have actively intervened to address how provincial governments can better govern and

regulate air quality. This raises concerns regarding the extent to which courts should intervene in matters of public policy. Dr. Parvez Hassan, an eminent lawyer and the Chair of the Smog Commission, has argued that though judicial commissions succeed in improving legal compliance, they increase the risk of "judicial activism." He further states that 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.

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). In Nepal, kiln owners aggressively adopted Zigzag kilns after the 2015 earthquake. After this, the International Center for Integrated Mountain Development (ICIMOD)—which led the effort in Nepal—engaged with Pakistani government and private stakeholders to introduce the technology in the country.

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. The government has also piloted the Happy Seeder—a device which assists farmers in mechanically removing rice stubble after harvest. So far, 500 select farmers have received the device. Attached to a tractor, it shreds rice stalks, mulches the pieces on the ground, and drills a hole for sowing wheat. The government hopes the pilot demonstrations will encourage more farmers to adopt the device and desist burning stubble.

Research and Private Initiatives

Academics have initiated several research projects to inform and support Pakistan's air quality management. Researchers with the International Growth Center (IGC) and the Lahore University of Management Sciences (LUMS)—led by Prof. Michael Greenstone at the University of Chicago's

Energy Policy Institute (EPIC)—have collaborated with the Environment Protection Department, Punjab to create a baseline repository of steel firms' PM2.5 emissions in Lahore. They propose to use the data to rate firms according to their emissions and share the ratings with the public to pressure firms to comply with regulations. Using a randomized controlled trial, they will experimentally test whether disclosing firms' ratings through the government or through informal channels (civil society or social media) forces greater compliance.

A recent IGC-funded study by researchers at LUMS and in the United States, implemented a randomized controlled trial in a lower-middle-income neighborhood of Lahore to investigate the behavioral impacts of receiving daily air pollution (PM2.5) forecast messages and a forecasting training (Ahmad et al. 2020). On average, subjects exposed to forecasts were willing to pay roughly 60 percent of the cost of mobile internet access to continue receiving them. Both interventions reduced air pollution forecast error, and receipt of forecasts increased demand for protective masks. The results demonstrate substantial demand for pollution forecasts among urban residents and suggest that modest educational interventions can improve pollution forecasting ability.

In another IGC-funded study on brick kilns in Punjab, researchers at LUMS and the Government College University, Lahore built a case for incentivizing brick kiln manufacturers to adopt a cleaner technology (Nasim and Sharif 2020). Using data on kilns near Lahore, the authors quantified the long-run environmental and economic benefits of replacing conventional brick kilns with Induced-Draft Zigzag Kilns. They found that the discounted social and private net benefits of the alternative technology far outweighed the adoption costs in the present. For policymakers, they outlined recommendations to facilitate the transition to the cleaner alternative. Their work gained considerable traction with the Punjab EPD, which collaborated with the Brick Kilns Owners' Association Pakistan to facilitate kiln owners in adopting the cleaner technology.

A few private initiatives complement the government's work on air pollution. The Pakistan Air Quality Initiative—founded by Abid Omar—focuses on collaborative citizen science. Under the initiative, citizens install low-cost air quality monitors in cities across the country and share the crowdsourced air quality data through an app (AirVisual) and social media. The initiative harnesses data to pressure the government to improve air quality management. Similarly, the United States Embassy in Islamabad and Consulates in Lahore, Karachi, and Peshawar have installed high-quality air quality monitors to track and disseminate the cities' pollution data through their websites and social media.

The World Wide Fund for Nature, Pakistan (WWF-Pak) has an ongoing project to assess economically viable alternatives to stubble burning. The IGC regularly supports research projects on air pollution under its Energy and Environment theme while the Foreign, Commonwealth, and Development Office (FCDO) of the United Kingdom Government plans to support research on pollution abatement and source apportionment in Punjab. The Mahbub ul Haq Research Center (MHRC) at LUMS has recently created an environment cluster to facilitate evidence-based policy research on air pollution in Pakistan.

Informal Regulator

Amid regulatory failures, alternative stakeholders ("informal regulator") offer a complementary channel to pressure polluters to comply with standards and the government to improve monitoring and enforcement. The federal and provincial laws already require the Environmental Protectional Councils to include several non-official members, enabling society to play an important role in implementing laws and overseeing regulators. Leveraging informal regulators such as civil society organizations, academic and research institutions, and industrial associations can create more transparency in air quality data sharing and motivate voluntary initiatives.

Identifying informal actors and their intersection with regulatory departments can strengthen how the country manages its air quality. As an example, Table 8 lists informal regulators in Punjab that can support, strengthen, and oversee the provincial government's air quality management—one can identify similar examples for the federation and other provinces. 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 data and 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.

As described earlier, some of these informal actors are actively supporting air pollution management in the country. Researchers at LUMS, the IGC, and the Institute of Development and Economic Alternatives (IDEAS) have several ongoing research projects to inform air quality policy through data and evidence. The Brick Kilns Owners' Association Pakistan has collaborated with the

Punjab EPD to introduce Zigzag kilns in the province. The Pakistan Air Quality Initiative has equipped citizens with low-cost air quality monitors and digitally disseminates pollution data. The US Embassy and Consulates report air quality data from their state-of-the-art monitors.

Table 8: Informal regulator examples and roles.

Institutions	Examples	Roles
Non-governmental organizations	World Wildlife Fund, Pakistan (WWF-Pak); Sustainable Development Policy Institute (SDPI); International Union for the Conservation of Nature (IUCN); the United Nations Human Settlements Programme (UN-Habitat); Lahore Conservation Society	Assist courts as *amici curiae*; initiate and support public interest litigation; implement projects; establish voluntary monitoring committees
Academic and research institutes	Lahore University of Management Sciences (LUMS); Lahore School of Economics; University of Engineering and Technology (UET); Government College University (GCU); University of Agriculture Faisalabad (UAF); The International Growth Center (IGC); Institute of Development and Economic Alternatives (IDEAS); Center for Economic Research in Pakistan (CERP); Mahbub ul Haq Research Center (MHRC)	Conduct research; gather data and evidence; develop and pilot abatement technologies and monitoring networks; produce policy frameworks
Industry associations	Brick Kiln Owners' Association Pakistan (BKOAP); Pakistan Steel Rerolling Mills Association (PSRMA); All Pakistan Textile Mills Association (APTMA); Pakistan Readymade Garments Manufacturers and Exporters Association (PRGMEA)	Establish environment committees to monitor members' legal compliance; assist in identifying and adopting cleaner technologies; conduct trainings
Chambers of commerce	Federation of Pakistan Chambers of Commerce and Industry (FPCCI); Lahore Chamber of Commerce and Industry (LCCI); Overseas Investors Chamber of Commerce and Industry (OICCI)	Facilitate links with organizations that provide technical assistance (such as UN-Habitat, UNDP, and the World Bank); conduct seminars and training sessions
Civil society and private organizations	Pakistan Air Quality Initiative; US Embassy and Consulates	Install air quality monitors; collect and disseminate air quality data; create public information platforms

3. Regulatory and Compliance Challenges

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.

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.

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 a CAC approach 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 must 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.

India's and China's Experiences

Pakistan can learn from other developing countries' experiences with managing 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. Some of the policy initiatives adopted by both countries offer insights that can inform Pakistan's pollution strategy.

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 Pakistan consider designing its own emissions trading system.

4. Avenues for Policy Research

Pakistan's poor air quality and regulatory failures create opportunities to engage in policy research on understanding pollution's adverse impacts, incentivizing abatement, and improving the air quality regulatory environment in the country.

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. Pakistan requires 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 in Pakistan remains uncertain. As successive governments prioritize growth and take measures to alleviate poverty, economic development can aggravate air pollution. Chinese investments in power and industries under the China-Pakistan Economic Corridor (CPEC) will most likely increase emissions. The government can overestimate projected growth figures if it fails 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 the government to buffer the adverse shocks of CPEC and its own development policies.

Source Apportionment

As mentioned earlier, Pakistan lacks 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 and revise existing emission standards.

Willingness to Pay

To get a better sense of how much Pakistanis 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. Recent work by IGC researchers, which experimentally measure the willingness to pay for pollution forecasts and particulate filtering masks in Lahore, fills some of this research gap.

Implementation Hurdles

The reasons for Pakistan's weak capacity to implement air pollution policies constitutes another important theme worth investigating. Even though Pakistan has strong air pollution rules and regulations on paper—with a comprehensive set of ambient air quality and emission standards—monitoring and enforcement remain deficient. As an example, consider the fact that the federal and provincial Environment Protection Councils—the main statutory bodies to oversee environmental regulators—have met fewer times annually than legally mandated, and in some cases, not met at all. Many donor-funded programs to enhance regulatory capacity and improve compliance have also struggled to deliver results.

Which factors lead to air pollution regulatory failures? What constrains the government from implementing pollution regulations? How does political economy determine the extent to which the government prioritizes air quality? Why have past donor-funded programs failed to improve air quality management? What lessons have we learned from implementing these donor programs and how can they inform future projects? Does graft play a role in inhibiting compliance and how can policymakers intervene to redress this? Addressing these questions can support the government in strengthening its institutional capacity to control pollution.

Incentive-Based Strategies

The government 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

Given air pollution's high regulatory costs, leveraging the informal regulator (civil society, academia, business associations, and non-government organizations) offers the government a complementary channel to monitor and enforce compliance. Engaging the informal regulator creates transparency in policymaking and signals a sense of ownership in the regulatory process. Examining the extent to which the informal regulator can support the government, oversee its actions, pressure polluters to improve compliance, and disseminate air quality data and information can strengthen the country's air pollution regulatory environment.

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