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Review

China's air pollution crisis: Science and policy perspectives

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ABSTRACT

China's air pollution crisis, which has profound effects on the environment and human health, has attracted a great deal of scientific and media attention both domestically and internationally. Over the past few years, major policy initiatives for pollution abatement have been put in place, and air-quality monitoring data in many regions has actually begun to show marked and sustained improvement. This article serves as an introduction to the special journal issue entitled "China's air pollution crisis: Science and Policy perspectives," which brings together new empirical contributions on this important topic. The article outlines past trends in the air pollution crisis and examines emerging research to discuss what the future may hold. It also provides an in-depth analysis of the various measures – including scientific and technological innovation in key sectors such as energy, top-down policy initiatives, and citizen engagement – that are integral to the emissions reductions now being achieved. Finally, the article considers the implications of these trends for the control of air pollution in China today and into the future.

1. Introduction

In February 2018, readers of the South China Morning Post were greeted with an unusual headline: "Beijing Meets National Air Pollution Standard for First Time" (Zhen, 2018). The headline summed up the paradox confronting Chinese citizens on the topic of air pollution. On one hand, there was the dismal and absurd fact that the nation's capital, a metropolitan area of more than 20 million people, has failed for decades to meet air pollution standards that scientists and regulators know are crucial for protecting human health. On the other hand, there was the welcome news, greeted by residents with cautious optimism, that the skies were finally beginning to clear due to concerted government action at the intersection of science and policy.

For citizens of developing countries around the world, air pollution remains a major contributor to the burden of disease. According to a recent report released in Britain by the Lancet Commission on Pollution and Health (Landrigen et al., 2017), pollution-related deaths worldwide top more than 9 million per year – three times more than from infectious diseases such as AIDS, tuberculosis and malaria combined. Compounding the toll on human health, pollution slows economic growth due to health care costs and lost worker productivity and constitutes a major obstacle to well-being and quality of life.

China, the world's most populous country and its second-largest economy, behind the United States, plays a crucial role in current scientific and policy debates on the control and management of air pollution. After decades of rapid industrial growth driven by export-oriented manufacturing, rising domestic energy consumption, and an increase in automobile traffic and other emissions-intensive economic activities linked to a growing middle class, many regions of the country face chronic, unhealthy levels of air pollution. Hundreds of millions of Chinese citizens have been forced to cope with periodic "red alerts" during which the air quality index (AQI) far exceeds World Health Organization Guidelines for multiple consecutive days (Reuters, 2014; IHME, 2017). Air pollution, of course, traverses national borders, so China's air pollution crisis, which is associated with the world's highest emissions of greenhouse gases, has profound implications for the global crisis of climate change.

Yet, as the South China Morning Post headline suggested, air quality in many of China's urban centers is beginning to show marked and sustained improvement. Various initiatives within the central government, including a so-called "war on pollution" announced in 2014, suggest that Beijing's policy priorities, which have long emphasized economic growth over environmental protection, are becoming more balanced. New scientific evidence confirms that these policy initiatives are beginning to make a difference in environmental quality and human health. Zheng et al. (2017), for example, analyzed ambient levels of PM2.5, fine particles that are closely linked to severe health impacts such as cardiovascular and respiratory disease. Using a model of population-weighted PM2.5, which plots the geographic distribution of the pollutant and controls for population density, researchers demonstrated that nationwide exposures had declined by 22% within a very short time frame (2013-2015). It is perhaps too early to tell whether these new regulatory priorities will result in durable improvements in air quality, but they represent clear steps forward. The public health benefits, including reduced risk of premature mortality for vulnerable groups, are undeniable. Are we witnessing the beginning of clearer skies over China?

Our aim in this special issue of Environmental Science and Policyis to present the results of cutting-edge research on China's air pollution crisis. We address key questions at the intersection of science and

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policy, including: how policymakers use scientific air-quality monitoring to guide regulation, how different enforcement mechanisms, nationally and locally, influence pollution levels, how citizens and government officials face tradeoffs between economic growth and environmental protection, and what role public participation plays in air quality governance.

Contributors to the special issue represent various nationalities and disciplinary backgrounds, drawing from innovative, empirical research in their fields. Taken together, the papers in the special issue analyze China's air pollution crisis across geographic scales—from indoor air pollution linked to household heating and cooking, to regional, national and international analyses. While each paper makes important contributions to disciplinary knowledge in the natural sciences, social sciences, and policy arena, our overall objective is to provide a synthesis across these fields, advancing the holistic approach necessary for producing new scholarly insights and for proposing new applications of science and policy for improving air quality.

This brief introductory essay provides context for reader, reviewing the state of the science in this growing field, illuminating past trends, outlining the current situation, and analyzing experts' assessments of what the future may hold. In what follows, I examine the sources and severity of China's air pollution crisis, emphasizing the historical legacy of policy choices and their ramifications for air quality today. I then examine the various measures – including top-down policy initiatives, technological innovation in key sectors such as energy, and citizen engagement – that are integral to the emissions reductions now being achieved. In the final section of the introduction, I provide a brief overview of each article in the special issue.

2. China's air pollution crisis: sources and severity

Since Chinese political leaders initiated market-oriented reforms in the late 1970s, massive economic and social changes have transformed the country, including agrarian reforms and widespread rural-urban migration, the privatization of industrial production, a manufacturing boom that has brought greater integration into the world economy, and the rise of the world's largest middle class. These reforms have now driven sustained, high rates of GDP growth for four decades. But such growth has come at a high price for the environment, throughout the reform era, the primary imperative for political leaders has been economic growth, while the approach to environmental protection has largely been one of "pollute first, clean up later" (xian wuran, hou zhili). In a 2006 speech, Pan Yue, who would later serve as the Deputy Minister of Environmental Protection, balanced China's remarkable economic achievements against a pessimistic environmental outlook:

> In twenty years China has achieved economic results that took a century to attain in the West. But we have also concentrated a century's worth of environmental problems into those twenty years. While becoming the world leader in GDP growth and foreign investment, we have also become the world's number one consumer of coal, oil and steel, and the world's largest emitter of CO_2. (Quoted in Tilt, 2010: 64)

China's Ministry of Ecology and Environment, formed in 2018 as a successor to the Ministry of Environmental Protection, monitors six "criteria pollutants" in ambient air, including particulate matter, sulfur dioxide, nitrogen oxides, ground-level ozone, carbon monoxide, and lead (Nielsen and Ho, 2013). Scientific scrutiny on $PM_{2.5}$, fine particles smaller than 2.5micrometers in diameter that are closely linked to cardiovascular and respiratory disease, has been growing for the past decade, and $PM_{2.5}$ was included for the first time in China's National Ambient Air Quality Standards (NAAQS) in 2012. Chronic exposure to these fine particles, which enter the blood stream via the lungs, is linked to increased risk of mortality, particularly for vulnerable populations such as the elderly or those with pre-existing health conditions (WHO, 2013).

Understanding air pollution's specific links to human health is a complex task requiring monitoring of emissions, modeling the atmospheric distribution and transport of pollutants, and measuring or estimating population exposures and associated health outcomes. Analyzing the potential health impacts of air pollution requires sophisticated modeling of population-weighted exposure based on actual monitoring data, satellite imaging, pollution dispersion models, and population data from censuses (Aunan et al., 2017; Zhang and Cao, 2015). The task is further complicated by the chemical composition of any given air mass, and the interactive and synergistic effects between compounds that result in negative health outcomes. In the most populous areas of Eastern China, where annual average concentrations of pollutants such as $PM_{2.5}$ are several times higher than in developed countries, the chronic health burden is severe. During acute air-pollution episodes, concentrations may be orders of magnitude higher than urban pollution levels measured in the United States and Western Europe (Aunan et al., 2017; Huang et al., 2014).

Scientific and regulatory advances in air-pollution control have been most significant in China's urban centers, where routine air-quality monitoring occurs in more than 300 cities. Air pollution levels, and the specific composition of pollution, vary considerably across regions. Densely populated areas such as the North China Plain, the Yangtze River Delta, and the Pearl River Delta, collectively home to hundreds of millions of residents, often exhibit the most severe chronic pollution and the most frequent acute spikes in ambient pollution levels (Zhang and Cao, 2015). However, scientists typically observe considerable seasonal variation in ambient pollution levels, as well as variation due to combustion sources, geography and topography, and atmospheric conditions (Wang et al., 2014). The Health Effects Institute, a non-profit research organization based in the United States, has worked to understand the link between coal combustion and ambient PM2.5, and the associated effects on mortality and morbidity. Coal combustion for both electricity generation and industrial production is a major culprit, resulting in an estimated half million premature deaths in China in 2013 (GBD MAPS, 2016).

Air pollution, of course, crosses boundaries, sometimes figuring prominently in international geopolitics. At the regional scale, China's neighbors in East Asia have long been affected by emissions from China. A group of South Korean activists, for example, recently filed a lawsuit against the government of Beijing, claiming that air pollution transported from China threatens their health and well-being (Time Magazine, 2017). At the global scale, scientists are now able to determine that pollutants from China (including carcinogenic compounds known as polycyclic aromatic hydrocarbons, or PAHs) are carried across the Pacific in high-atmosphere air masses, contributing to the pollution burden on the US west coast (Lang et al., 2008).

In terms of air pollution's geographic dispersion, cities get most of the headlines. But rural air pollution is also a crucial part of the burden of disease throughout China. To researchers unfamiliar with China's political and historical context, the idea of rural pollution sounds paradoxical. But China's countryside, which is home to some 800 million people, has long contended with air pollution levels that rival many urban areas. A recent article in the China Youth Daily (2014) provides a brief overview of the problem's scale. Although energy consumption in the countryside accounts for only about 15% of the nation's total, rural pollution – especially key pollutants like sulfur dioxide and nitrogen dioxide – account for about 40% of the nation's total.

For rural residents, air pollution is both an indoor and outdoor phenomenon. In fact, epidemiologists estimate that approximately 1.6 million people die prematurely each year in China due to air pollution, about one-third from indoor air pollution related to household heating and cooking (IHME, 2017). Millions of rural households still rely on solid fuel combustion, including coal and biomass such as wood or crop residues, for heating and cooking (Aunan et al., 2017). When ventilation systems are inadequate or nonexistent, indoor air pollution can easily exceed levels in the ambient environment. This also means that

actual pollution exposure, along with the long-term health risks such exposure entails, can be higher in rural areas than in cities. Women, who do more cooking and other kinds of household work, tend to bear the highest health burden, including increased exposure to fine particulate matter and carbon monoxide (Alnes et al., 2014; Aunan et al., 2018). Experts still struggle to understand the causal links between household air pollution exposure and health problems because there are a range of other factors – the variation in pollution by season, the type of heating and cooking technology used, and the mitigating effects of ventilation systems – that confound them.

In the ambient environment, many pollution sources remain loosely regulated compared to their urban counterparts. It is still legal in many rural regions, for example, to drive so-called "yellow-label vehicles," cars and trucks that fail to meet basic fuel-efficiency and emissions standards, although political pressure is mounting for a nationwide ban (Stanway and Chen, 2014). China's countryside is also home to millions of small-scale factories that play an important role in the national economy, producing agricultural fertilizers and pesticides, bricks, metal, paper products, and countless other goods. Lacking advanced environmental-mitigation technologies, these factories – some dating from the early years of China's economic reform period, others more modern – contribute to chronic, high levels of ambient pollution in many rural areas (Tilt, 2013; Hansen and Zhaohui, 2018).

Moreover, in today's China, where people, products and capital flow easily across political boundaries, the dividing line between city and countryside is increasingly blurry. Industrial parks and housing developments in most large urban areas continue to expand outward to gobble up farmland, while migrant workers from the countryside stream in to fill industrial and service-sector jobs. Pollution, too, crosses boundaries. The North China Plain is a case in point. Tangshan, a second-tier industrial city in the Hebei Province, is about 150 km east of Beijing. Home to a state-owned cement factory, several iron and steel factories, and numerous large coal mines, it has long been a center of industrial activity. The city, and rural areas of Hebei province around it, also happen to be downwind of the megalopolis of Beijing. In the years leading up to the 2008 Olympic Games, many of the most heavily polluting factories were moved to Hebei in order to clean up the capital's air during the three weeks of intense, worldwide media scrutiny. Though it is difficult to determine the precise number of factories that were relocated to Hebei, the figure likely runs in the hundreds, including companies in the steel, chemical and electronics sectors. Even Capital Steel, known asShougang Group, an industrial behemoth principally owned by the Beijing municipal government, left the capital and moved to Tangshan in the early 2000s.As a consequence, while environmental regulators in first-tier cities can applaud recent headlines such as "Beijing Closes Last Coal Plant" (Feng, 2017), much of the country's electrical grid remains powered by coal-burning thermal plants. Although the urban core of the Beijing-Tianjin-Hebei region, a dense area with a population exceeding100 million, may be getting cleaner, the rural areas along its periphery are facing increasingly worse air quality, at least in the short term (Geng Weixin and Chang Fangnan, 2015).

3. Fronts in the war on pollution: policy initiatives, technological innovation, and citizen engagement

Chinese and foreign experts have rightly been skeptical of Beijing's commitment to improving air quality, government policy documents, along with key speeches by political leaders, have paid lip service to environmental protection for decades, but meaningful action has generally not followed. That trend appears to have broken: unprecedented amounts of funding, both public and private, are now being spent on technical and policy-related solutions, and sweeping new laws and policies are taking hold. Understanding the current state of China's "war on pollution" requires an examination of top-down policy initiatives, technological innovation in energy and other key sectors, and citizen engagement.

3.1. Policy initiatives

In 2014, citing several prolonged periods of intolerable air pollution in northern Chinese cities, which political leaders deemed worthy of a "red alert" involving school closures and admonitions for residents to stay indoors, Premier Li Keqiang declared a "war against pollution" (Reuters, 2014), underscoring the government's seriousness about environmental protection. That same year, China's National People's Congress also passed amendments to the 1989 Environmental Protection Law, attempting to address some of the known gaps in environmental regulation. These amendments, which took effect in 2015, removed upper limits on fines for factories that fail to meet emissions standards, with the goal of encouraging factory owners to rethink the "pay to pollute" calculus. The amendments also allow factory personnel to be arrested and detained for failure to comply with environmental regulations (Kaiman, 2014; China NPC, 2014). These policy provisions are in line with new discourse and rhetoric from the highest levels of the Chinese government. Political leaders are also promoting the development of a so-called "ecological civilization" that would put environmental protection on equal footing with economic development as a national priority (Chinese State Council, 2015).

Some of the most far-reaching anti-pollution measures are taking place under the rubric of the National Action Plan for the Prevention and Control of Air Pollution, released by the State Councilin 2013.The action plan called for rapid and ambitious reductions in particulate matter, along with pollutants such as sulfur dioxide and nitrogen oxides, across key metropolitan areas and regions. More crucially, these emissions targets were linked with tangible steps that will be integral to achieving and maintaining emissions reductions over time: the development of more systematic monitoring regimes (including real-time emergency warnings for the public during severe incidents), restructuring in the industrial and energy sectors to improve efficiency, and stricter emissions standards for vehicles (Chinese State Council 2013).

Recent changes in the administrative structure of environmental protection also support better pollution control. During a central government restructuring process in 2018, the new Ministry of Ecology and Environment assumed responsibility for both pollution control and climate change mitigation, including the country's nascent Emissions Trading Scheme. This restructuring has arguably improved the agency's ability to successfully implement "co-control," the simultaneous enforcement of emissions standards for both the pollutants linked to adverse health outcomes and the greenhouse gasses linked to climate change. But the new structure also administratively distances pollution regulation from the one sector that matters most to emissions reduction – energy production – which remains the purview of the National Development and Reform Commission, China's highest economic planning body.

As the United States withdraws from multilateral commitments in a variety of arenas from trade to climate change, China is emerging as a*de facto* global leader. Its government remains committed to the Paris Climate Agreement, with all of its flaws and its questionable enforcement mechanisms, viewing the deal as an aspirational message about where governance and markets are headed in the near future. This is part of an overall strategy of "low-carbon development" that Beijing hopes will both improve the environment and position the country as a leader in emerging sectors such as renewable energy (Tambo et al., 2016).

3.2. Technological innovation

Massive increases in renewable energy have featured prominently in the last several five-year economic plans released by China's National Development and Reform Commission. While coal remains dominant in

the overall energy portfolio, China produces more energy from renewable sources—especially hydropower, solar and wind—than any other country, and the renewable portion of its energy portfolio grows larger each year (Lewis 2013), even while total energy consumption continues to grow. The near-term goal is to achieve significant reductions in the energy intensity of the national economy, usually measured in terms of GDP per unit of energy consumed (NDRC, 2011). At the same time, conventional energy technologies are also becoming cleaner, new coal-fired power plants, for example, are equipped with flue gas desulfurization and denitrogenization technologies, which greatly reduce key pollutants such as sulfur dioxide and nitrogen oxides.

Such steps rely on new advances in science and technology, and also on government regulations that make them financially viable. China's Renewable Energy Law, passed in 2005, requires electrical grid operators to purchase all available renewable electricity within their respective jurisdictions. This puts China in the category of what Mazzucato (2015) have called the "green entrepreneurial state," cases around the globe in which government entities are increasingly steering economic planning and lending practices toward forward-looking, environmentally conscious development (Kostka and Zhang, 2018). Of course, when the state plays a central role, bureaucratic barriers and inefficiencies inevitably arise. China's wind-power sector is an instructive example. Although wind-power production capacity has grown significantly in recent years, particularly in the northern and western regions, integration of wind-generated electricity into the grid system has been sporadic and unreliable. Technical solutions are underway, including the construction of the world's largest ultra-high-voltage (UHV) transmission network to connect electricity generating centers to the regions of highest demand. But recent reports also point to systemic problems in energy market governance: central and provincial governments, which remain heavily invested in the coal industry, have deliberately curtailed wind production, resulting in economic waste and missed opportunities for emissions reduction (Li, 2016).

3.3. Citizen engagement

As China's regulatory framework and technological sophistication have advanced, so too have the perspectives and actions of its citizens in response to the pollution crisis. In popular usage in China, the term "smog" (*wumai*) is now ubiquitous in public discourse and in the media, and residents routinely view a smog report on television or on the internet alongside the standard weather report and forecast. But that hasn't always been the case. In fact, the term is actually a neologism that has come into common usage within the last ten years by combining two previously unlinked Chinese characters – *wu* meaning fog, and *mai* meaning haze (Li and Svarverud, 2018). Public perceptions can have profound impacts on public policy, even in top-down governance systems such as China's. A growing body of research shows that air pollution is a key concern for members of the emerging middle class, and that people increasingly consider air quality as an important component of overall well-being and quality of life (Li and Tilt, 2018). Moreover, public perceptions and demands are driving more stringent policy controls at various levels of government (Mol and Carter, 2006; Shapiro, 2012; Zhang et al., 2014).

Chinese citizens now have access to better information than ever before about the extent of the nation's air pollution crisis. One of the most influential actors in the information disclosure arena is a non-profit organization called the Institute of Public and Environmental Affairs (Gongzhong Huanjing Yanjiu Zhongxin), which was founded in 2006 by Ma Jun, one of China's most celebrated environmental journalists and activists. The timing of IPE's emergence was fortuitous: the very next year China's State Council released new regulations on information disclosure (State Council 2007), which provided a government-sanctioned space for public engagement in environmental decision-making. Now backed by the efforts of other researchers, and equipped with funding from the Natural Resources Defense Council and other high-profile organizations from China and abroad, IPE has become a clearinghouse of environmental information for investors, corporate executives, and government policymakers. Their web site features a pollution map linked to a database with emissions data for more than 300 cities, a "Blue Map App" with real-time monitoring data from thousands of industrial enterprises, and a Pollution Information Transparency Index, which tracks the public disclosure of information regarding pollution monitoring (Wang and Bernell, 2013).

However, while domestic organizations working on environmental protection have seen some major successes, international organizations have been less fortunate. During the first decade of the twenty-first century, all signs seemed to indicate that civil society organizations, including environmental NGOs, were enjoying greater freedom to pursue their objectives and greater power to influence the policy process (Mol and Carter, 2006; Yang 2005; Tilt, 2010). This has changed dramatically under the Xi Jinping government. The 2016 *PRC Law on the Management of Foreign Non-Governmental Organizations' Activities in China*, for example, has placed new legal and regulatory burdens on international NGOs, including those working on environmental science and advocacy. Such organizations are required to register with the Ministry of Public Security and to find a suitable sponsoring organization within the government, a potential liability that few governmental units are willing to assume. Countless NGOs that previously worked on science, data-sharing, and advocacy related to pollution control are now struggling simply to survive.

4. Contributions of the special issue

Formulating effective and durable solutions to China's air pollution crisis will remain a challenge for at least a generation. Researchers seeking to understand the crisis, and its gradual but steady resolution, face an array of challenges, from a constantly changing energy landscape, from economic incentives that vary across regions and sectors, and from shifts in governance and in the structure of the environmental protection bureaucracy. The authors whose work comprises this special issue are all engaged in an effort to bring new empirical analyses to bear on this important topic.

Monitoring particulate matter and polycyclic aromatic hydrocarbons (PAHs) in three megacities and one rural area in the North China Plain region, Shen et al. observe seasonal and geographic variation in pollution levels. Their data show improvements in air quality over time (from 2014 to 2017), but persistent levels of these pollutants that exceed China's Ambient Air Quality Standard and WHO guidelines. PAHs are both potentially carcinogenic (cancer-causing) and mutagenic (associated with increased frequency of genetic mutations). Their work raises key questions about how to advance the state of science in order to gain a fuller understanding of population exposures and associated health effects, while also developing a robust regulatory framework to protect human health.

Working at the other end of the geographic scale, Aunan et al. examine the threat of household air pollution (HAP) produced by biomass-fueled heating and cooking in both urban and rural households in Zhejiang Province. This interdisciplinary team, comprising both physical and social scientists, finds evidence of routine hazardous exposure from household air pollution. Local residents, however, show minimal concern about household air pollution, focusing instead on more obvious sources of pollution, such as nearby petrochemical factories, in the ambient environment. HAP thus remains a largely "hidden hazard" with profound implications for human health. They remind us that household fuel choices are driven by economic, historical and cultural factors, and that policy solutions for improving the situation will need to take public perceptions and attitudes into account.

Examining $PM_{2.5}$ levels in the city of Hangzhou during the 2016 G20 Summit, Shen and Ahlers outline a campaign-style pollution

enforcement regime that has become fairly common around large, high-profile international events hosted in Chinese cities. This attempt at "blue sky fabrication," achieved through forced factory closures and reduced automobile traffic, has become a feature of China's hierarchical, command-and-control enforcement style. As a result, residents in many Chinese cities—from Beijing during the 2008 Summer Olympics to Hangzhou during the 2016 G20 meetings—are increasingly afforded brief glimpses of how drastic enforcement measures could bring dramatically cleaner skies. However, Shen and Ahlers cast doubt on whether such short-term measures, requiring significant economic cost and coordination across different levels of government, can achieve durable emissions reductions.

Stensdahl, meanwhile, examines greenhouse gas emissions control at the municipal level, focusing on two governance mechanisms in Shanghai. The first, an emissions trading scheme (also known as a carbon market), is guided and incentivized by China's National Development and Reform Commission but implemented at the city level, where Shanghai has been at the vanguard. The second, the so-called 10,000 Program, targeted the highest energy-consuming enterprises for mandated improvements in energy efficiency. Stensdahl analyses how the structure and implementation of these programs result in different outcomes in terms of pollution control.

Cao, et al. approach the topic of pollution control through the lens of local political leaders who are subject to a cadre evaluation system in which economic development is heavily weighted. Examining ambient levels of $PM_{2.5}$ across Chinese prefectures, these authors observe that political leaders are in a position to practice "selective policy implementation," loosening environmental oversight in order to maximize economic output at crucial moments in their tenure, thereby enhancing their own career prospects. While scholars have long described a political economy of environmental enforcement in China (Tilt, 2007), this paper provides some of the strongest and most innovative evidence to date on how this process actually unfolds.

Pollution enforcement ultimately depends on public demand for cleaner air. Li and Tilt, drawing on qualitative interviews and a quantitative survey of residents in the northern city of Tangshan, examine public knowledge and perceptions about air pollution as well as personal actions that residents take to avoid or mitigate exposure to pollution. They also underscore the importance of understanding the trust that residents place in different institutions, such as government agencies, NGOs, domestic and international media, and the scientific community. The authors also explore the opportunities and challenges involved in incorporating public views into environmental decision-making in China, where top-down governance is the norm.

5. Conclusion

Are we witnessing a turning point, the crucial first steps toward clearer skies over China? Anecdotal evidence suggests that residents in metropolitan areas have noticed a change, from living continually in the "hazardous" range of the AQI scale, with visibility a mere few hundred meters, to actually being able to see blue skies by day and view the stars by night. Photographer and activist Zou Yi, for example, has chronicled air quality improvement with daily photographs of central Beijing's skyline over the past five years, creating a mosaic of thousands of photos on his web site that show a gradual shift from grey to blue (Strait Times, 2018).

Emerging empirical research supports residents' perceptions of dramatically improved air quality. Zheng et al. (2017), for example, modeled population-weighted $PM_{2.5}$, which plots the geographic distribution of the pollutant and controls for the exposed population, and found that the nation as a whole saw a 22% reduction from 2013 to 2015. Related research shows that $PM_{2.5}$ levels have been declining throughout most of China since 2005 (Wang et al., 2017). In addition to the benefits for human health, various research institutions have noted a decline in the greenhouse gas emissions that cause global warming: Guan et al., (2018), for example, observed that China's annual CO_2 emissions peaked in 2013, declining year over year since then due to major structural changes in the energy sector away from coal and to decreasing energy intensity and emissions intensity nationwide.

Time will tell whether the air quality improvements of the past few years, with major implications for the health and well-being of hundreds of millions of people, will be buttressed by the political will necessary for long-term emissions reductions. A range of actors – from citizens, to political leaders, scientific researchers, journalists and activists – are engaged in this important work, using a variety of market mechanisms, technological innovations and policy advocacy. The articles in this special issue help advance our understanding of how China's progress on pollution control is currently unfolding, and what opportunities and constraints may arise in the near future.

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