AIR POLLUTION IN CHINA: AN INTERDISCIPLINARY PERSPECTIVE

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Air pollution is a crucial issue for China: reducing it will have enormous benefits for human health within the country, and because many air pollutants flow beyond national boundaries, and their sources are in many cases also major contributors of greenhouse gasses, pollution control in China is also vital for protecting global public health.

In the face of mounting evidence of the negative health effects of pollution and public demand for cleaner air, the government has declared a "War on Pollution (Li Keqiang 2014)." Since 2013 it has rolled out a series of measures to address air pollution through stronger enforcement, tightened technical standards and industrial restructuring. Unprecedented levels of funding are being invested in what is the possibly the most ambitious and costly air pollution prevention and control effort in the history of the world. Many other actors, from bi-lateral government partners to international organizations, NGOs and private foundations are also providing funds and technical support for China’s air control pollution agenda.

This is an exciting time for all who are concerned with reducing pollution and improving public health. But translating this commitment into action will not be easy. It will entail scientific, political and administrative challenges, hard choices and difficult tradeoffs. It also has important repercussion for research, calling for a shift in focus in many specific areas of research and greater collaboration across natural, medical and social science disciplines. While it is often regarded as an environmental policy issue, and a problem that can be solved merely by greater investment in environmental protection, controlling air pollution in China will in fact require the engagement of almost all policy sectors, from industry, transportation and agriculture to health, social protection and education.

First, if maximum benefits for health are to be achieved, policies will have to take account of the complexity of the composition and flows of air pollution. Pollution is often discussed as if it were a singular phenomenon but it is in fact composed of many substances from numerous sources, which interact in complex ways under different environmental conditions. These pollutants have different health effects over different temporal and geographic scales. In a country of China’s enormous size, with a highly diverse climate and terrain, and uneven economic development, the composition and transport of air pollution varies considerably across contexts and has different health effects. Understanding these complexities and their variation to provide a sound evidence base for policy remains a significant scientific challenge.
Second, translating these new and ambitious policies and plans into action presents complex challenges for governance. Effective implementation of environmental protection policies in China has long been hampered by the inadequate capacity and insufficient independence of regulatory agencies and by interdependence between industry and local government. Research shows that these problems persist. At the same time, the rapid introduction of so many new laws, policies and measures by different levels of government, and the creation of new regulatory bodies, is generating fresh challenges for governance that have implications for the development of China's legal system and the rule of law.

There is also the increasingly pressing question of who will pay. Over the long term, the benefits of reducing emissions of pollutants and greenhouse gases for public health will outweigh the economic costs, and some policies may be cost-neutral or positive over shorter time frames. But many policies will have costs associated with higher technical standards and stronger enforcement, which will be borne by different actors, including not only enterprises but also government and ordinary citizens in their roles as workers, tax payers, and consumers of goods and services. These costs and their distributional effects need to be understood in order to choose policies that achieve the maximum benefits for health in the most cost-effective and fair way.

On a more fundamental level, stronger policies to prevent and control air pollution are part of a larger effort to push China's whole economy through a transition to a cleaner and more environmentally sustainable model of production and consumption through the restructuring of industry. This is a laudable but also an ambitious and challenging goal. China is attempting to force this transition at a lower level of development than the early industrializing nations and with a very different economic and demographic structure. The nation's uneven development means that different regions, and cities and rural areas within them, face very different constraints and opportunities in making that transition. Air pollution control policies will affect their economic structure, employment opportunities and public revenue sources in different ways.

While some wealthier cities and regions of the country can quite easily accelerate economic restructuring, in others it will be far more difficult. Many poorer parts of China have yet to make the transition out of agriculture or are still strongly dependent on polluting industries. They are not well positioned in terms of their physical infrastructure and human capital base to shift easily to a higher value or service-based economy. To avoid placing an excessive burden on poorer regions and populations, and win the local support necessary for effective implementation, it will be important to assess the economic effects of environmental protection policies and ensure that other policies, including investments in social protection and education, are in place to prevent the exacerbation of existing inequalities, including those in public health.
This report seeks to initiate a more integrated analysis of what we know about these challenges, drawing on research from across the natural, medical and social science disciplines. It is based on the work of the FORHEAD Working Group on Air Pollution and Regional Development over the last two years. The first section of the report discusses what we know from natural and medical science about the nature and severity of air pollution in China and its health effects. It explains the strengths and weaknesses of different data sources and models; and considers the implications of the limited and uncertain nature of our knowledge for policy. The second part of the report focuses on governance. It details air pollution prevention and control policies and discusses their effectiveness and ongoing challenges.

While it cannot offer detailed reviews of all the pertinent literatures, the report aims to provide a broad summary of the state of our knowledge and identify areas where an interdisciplinary approach is needed to provide a better evidence base for policy. It includes a discussion of the challenges of air pollution generally and some comparison across regions and cities, but we focus on the specific example of the Beijing-Tianjin-Hebei (BTH) region. The area has some of the worst pollution in China and has recently been the target of the most stringent pollution control measures in the country. At the same time, BTH suffers from an unbalanced industrial structure and severe intra-regional inequality. It is therefore a good case through which to illuminate the multi-dimensional challenges of air pollution control.

In the interests of space, and because different readers will have different backgrounds and concerns, this document provides a summary of our analysis, with references out to longer treatments of specific issues by members of the working group and other researchers. Where possible, we have drawn on review papers and readers should consult these for additional sources. For a list of working group members and their role in the project, see Appendix 1.

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1 The Beijing-Tianjin-Hebei Region (known as jingjinji 京津冀 in Chinese), is composed of the two mega cities and the surrounding province of Hebei. It has a land area of approximately 217,000 km$^2$ (2.2% of the national total), and a population of more than 100 million people (7% of the national population).
2. THE SCIENTIFIC CHALLENGE

2.1 Air Pollution

We often speak of 'air pollution' as if it describes a single environmental hazard, but it is more accurate to understand it as a combination of distinct, if often coinciding, hazards that share a common medium of transmission: the air.

The science of air pollution is far from complete. The sources of pollution are numerous and environmental and atmospheric scientists are continually trying to improve their understanding of the relationship between emissions and air quality in the context of highly complex and changing economies and natural systems. Many challenges remain in disentangling the intersection of the chemical, physical, and biological processes involved. Meanwhile, health scientists still have much to learn about specific chemical and physiological mechanisms of air pollution's effects on health, as well as the dominant pathways of human exposure.

Critically, moreover, clean air is a moving target. Air quality problems and associated public health risks not only evolve year-to-year, but also vary with the seasons and even day-to-day, as the many factors that influence them also change: the size and structure of the economy, the energy mix, technologies of both combustion and control, settlement patterns, lifestyle choices, and much more. This year-to-year evolution is particularly pertinent to China, where over the last four decades more than a billion people have experienced the fastest developmental transformation in history: the collection of air pollution hazards that China faces in 2018 is substantially different from those it faced in 2007, or even in 2012.

The scientific complexity of air pollution has profound implications for policy. Variation in the sources of air pollution and its evolution over time means that solutions that may be effective in one place cannot be simply transferred to another location with the same result. Ensuring clean air in any region should be understood as a puzzle that must be solved through an analysis of very specific local characteristics. These include myriad human factors relating to the structure of the economy and consumption patterns, but also critical natural ones, such as topography, meteorology and the local ecology. Each local air quality puzzle typically has links to adjoining puzzles upwind, and sometimes to puzzles even thousands of kilometers away.

All these interlinked dimensions come into play as China not only responds to its severe air

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2 This section of the report was adapted from Nielsen and Ho (2013)
pollution challenges on a national basis, but also grapples with their diverse causes and unequal effects across the many regions of the country. This section of the report seeks to provide non-expert readers with a basic understanding of the most important scientific challenges in atmospheric chemistry and environmental epidemiology and their implications for pollution prevention and control.

The major pollutants that are currently monitored and regulated (often referred to as ‘criteria pollutants’) are particulate matter of various sizes (PM), sulfur dioxide (SO₂), nitrogen dioxides (NO₂), ground level ozone, carbon monoxide and lead. Section 1 of the full report introduces these pollutants, their major sources, their known health effects and the ways in which they interact with each other to form secondary pollutants. It also includes a brief discussion of the major non-criteria pollutants of concern, including volatile organic compounds (VOCs), and ammonia. Here we focus on PM2.5, which is of particular concern due to its serious health effects.

2.1.1 PM₂.₅

Particulate Matter (PM) refers to particles of solid and/or liquid matter small enough to be suspended in the air. It is usually classified by size: total PM, also termed Total Suspended Particles (TSP), is comprised of all particles; PM₁₀ is all PM under 10 micrometers in diameter; and PM₂.₅ is all PM under 2.5 micrometers. TSP includes all PM₁₀, and PM₁₀ includes all PM₂.₅. It is important to note that PM is different from other air pollutants in that it is defined only by physical characteristics – its size. Other pollutants are defined by their chemistry, as reflected in their molecular notation, such as SO₂. But PM₂.₅ can have any chemical composition at all.

The burgeoning public awareness in China of PM₂.₅ is warranted, as risk assessments indicate that it is exposure to fine particles, of all air pollutants, that causes the greatest health damage. Particles under 10 micrometers in diameter can pass through the nose and throat to enter the lungs, with the smallest ones—PM₂.₅ and even smaller size fractions—penetrating most deeply and even entering the bloodstream. A large body of epidemiological research has firmly linked PM₁₀ and especially PM₂.₅ exposure to severe health impacts, including premature death (particularly in those with heart or lung disease), cardiovascular disease such as heart attacks and irregular heartbeat, respiratory diseases, and lung cancer. However, while epidemiologists have found very strong mortality (death) and morbidity (disease) associations with exposure to PM₂.₅, they have only begun to disentangle which chemical constituents of particles may be causing the greatest harm.

PM₂.₅ can come from thousands of source types, hundreds of which may be important to effective policy. It can occur naturally, for instance, from wildfires or as wind-blown crustal dust.
It can be generated by mechanical human activities, such as earthmoving at construction sites or material grinding at cement plants. And of course it can be emitted directly by combustion, from energy generation, industry, the tailpipes of diesel trucks or the burning of crop wastes in fields.

Crucially, PM$_{2.5}$ is often formed chemically *in the air* from reactions of diverse precursor gases, yielding 'secondary' fine particles. ('Primary' pollutants are emitted directly from emission sources, like those immediately above.) The rates of these chemical reactions are typically influenced by natural meteorological conditions such as relative humidity, temperature, and incidence of solar radiation, which in turn change continuously over time. It is true that the precursor gases are mainly emitted by human activity and are thus potentially subject to control. However, even deciphering, let alone counteracting, the variety of relevant sources of PM$_{2.5}$ in a given location at a given time can be an extraordinarily complex undertaking because so many formation pathways—some not fully understood by science—must be accounted for simultaneously.

### 2.1.2 Emissions and air quality

On a scientific level, the sources of criteria pollutants are well understood. But measuring the contribution of specific emissions sources to concentrations of particular pollutants in the atmosphere in a given place is not a straightforward matter. This is because the sources of pollution vary widely both across different regions of China and within them, often changing even within the same region or city across seasons. For example, residential heating adds a significant additional burden of pollution for northern China in the winter. Because pollutants travel through the atmosphere, it can be difficult to establish clear relationships between emissions in one place and air quality in another; and local governments, who are held responsible for air quality in their cities, may not have jurisdiction over far away sources.

Even in locations with similar pollution profiles and emission levels, air quality is also affected by topographical and meteorological factors, including wind direction and speed, temperature, and humidity. These can cause pollutants to accumulate more rapidly in some places than others and also cause seasonal variation. This has been a major challenge for the Beijing-Tianjin-Hebei region, which has continued to see prolonged periods of very severe pollution despite a drop in annual concentrations, in part due to such factors.

This complexity should not of course be a reason for backing off from stricter enforcement, but it does mean that targeting and controlling pollution effectively is not an easy task and it is crucial that policy draws on the best scientific evidence available in order to achieve maximal results.
2.1.3 Air pollution data: what we know and how

In discussions of air pollution, two types of data are reported: data on emissions (the type and quantity of pollutants released by pollution sources); and data on atmospheric concentrations of pollutants (air quality data). As noted above, the relationship between these two is not straightforward. Air quality data tells us what pollutants are in the air in a certain place, but not where they came from, while emissions data tell us how much of which pollutants is being emitted by various sources, but not where they end up or in what form. This is because pollutants that are emitted in one place can be transported through the air to other locations, and can interact to form new, health-endangering secondary pollutants such as ozone and PM$_{2.5}$.

Because the ultimate goal of pollution control is to improve air quality, and this depends in large part upon understanding the contribution of different sources, a lot of scientific energy is devoted to trying to match up information about emissions and concentrations. Given the enormous distances over which some pollutants travel, this is often possible only over large (sometimes global) scales. It involves a number of different activities: measuring the quantity of different pollutants in the air, which can be done using a number of different techniques that can produce different results; measuring and estimating from information about inputs and production processes the amounts of various pollutants that are emitted from various sources to produce emission inventories; and understanding the ways in which those pollutants are transported through the atmosphere and interact to form new chemicals. Given the number of sources and pollutants involved, and the complexity of transportation patterns and chemical interactions, even the best models are far from perfectly accurate.

In China, capacity to build the source inventories needed to accurately assess pollution emissions from different sources is very varied, as is the capacity to develop regionally specific atmospheric transport models. Only large facilities are equipped with automatic monitoring equipment, and emissions from other, smaller, sources must be estimated, often using imperfect information about energy use and other inputs, as well as the scale of production and technologies in use. This is extremely difficult, especially when market forces and new regulations mean that the location, scale of production and technology of enterprises is in a state of constant flux. At the same time, some enterprises are known to engage in practices designed to disguise their level of emissions, including tampering with monitoring equipment and turning off pollution abatement equipment at night.

There are two main sources of data on emissions and concentrations of pollutants in China, official data and data from independent scientific studies. It may be tempting to assume that these are competing data types, and that we only care which data are 'better.' But this is
simplistic. The two types of data have different strengths and weaknesses and while it is statistically demonstrable that official air pollution data have sometimes been manipulated, few non-experts realize that there are sometimes also more benign technical explanations for differences between official and scientific pollution data. In many cases data measure different characteristics of a phenomenon because they were collected for different reasons: supporting regulatory objectives versus scientific inquiry.

Government data on emissions is incomplete. While crucial for regulatory purposes, official data on concentrations of pollution in the atmosphere are also limited. Data cover the whole country, but are still collected mainly in cities, and often at disadvantageous locations within them (such as close to streets). They also include only a limited number of pollutants. This can make them unrepresentative for understanding the composition of pollution over larger spatial scales and disentangling source processes. Furthermore, the data are inaccessible in raw form, usually reported in aggregate forms such as hourly means, urban averages, or multi-pollutant indices. These factors undermine the value of official data for research on the critical regional dimensions of many of China's most difficult air quality problems.

Scientific studies compile much more detailed source inventories and develop more accurate models for understanding the movement and interaction of chemicals under different atmospheric conditions. But the high levels of research capacity and funding that are required to do this means that such models are more limited. While scientific studies are more detailed and accurate, they often do not cover the whole country and are more complete for the mega cities and their surrounding regions. Different monitoring technologies will also produce different results. For example, on the ground monitoring stations will most effectively assess concentrations of pollution to which people in a given city are exposed, but the results will vary according to where they are placed. Satellite monitoring now provides some of the best data on concentrations currently available, but it is limited to fairly large spatial units and is inaccurate at night.

As a result of these complexities, many cities are not yet in a position to develop air pollution control measures that are tailored to their circumstances. Even in BTH, which has the strongest scientific base, models that attempt to predict average annual pollution concentrations using emissions inventories and meteorological models have over or underestimated them by as much as 20% for some cities (CAAC 2016). State-of-the-art models, moreover, are having still greater difficulty simulating the PM2.5 concentrations of red alert haze events in wintertime, suggesting chemical and or meteorological factors that differ from the range of more typical conditions for which the models were originally developed. These factors are simply not yet well understood and are the focus of much active scientific research. In lower tier cities inventory development
and atmospheric modeling are much less advanced and a major challenge.

Analysis is complicated by the different time frames over which various pollutants have been measured and reported. Overall, emissions data from scientific studies largely track the trends of those reported in official statistics, but the independent estimates are higher and in some cases diverge. This is due in part to more complete coverage of sources in the scientific studies, but biases in official reporting protocols likely contribute to the difference. Because PM$_{2.5}$ has only recently been added to official monitoring and reporting, it is not possible to assess long term trends, but Figure 1 below compares official and scientific data for PM, from 1995-2015.

**Figure 1** Scientific and official estimates of emissions of particulates in China in teragrams per year, 1995-2015.

(A) TSP. (B) PM$_{10}$. Note: Zhao Y. et al. (2013, 2011) calculated 95% confidence intervals, shown as error bars. See the full report for references.
To illustrate the variation in concentration data that can result from different measurement techniques and the time and spatial frames over which pollutants are monitored, we include here one example that shows the findings from 35 different scientific studies of PM2.5 concentrations in Beijing from 1998 to 2013.

**Figure 2  PM$_{2.5}$ time-series for Beijing, 1998-2013**

Black dots and vertical lines denote monthly mean and 25th-75th percentile of satellite-derived values. PM$_{2.5}$ values collected from the scientific literature are plotted with each number and color corresponding to 35 different scientific sources. Horizontal lines correspond to the measurement duration. Specific colors and sources are referenced in van Donkelaar et al. (2015) Supplemental Material, reproduced with permission ...

### 2.1.4 Trends in emissions and concentrations of pollutants

While recognizing the limitations discussed above, because of its more comprehensive coverage and comparability over time and space, we refer mostly to official data in the remainder of this report. This data shows that, overall, China has been quite successful in reducing emissions of some major pollutants, including SO$_2$, NO$_X$, and PM$_{10}$. From 2006 to 2014, total sulfur dioxide emissions fell from 25.9 million tons to 19.7 million tons, largely as the result of policies requiring the installation of desulfurization equipment in electric power plants. Total emissions of nitrogen oxides have also fallen, from 24 million tons in 2011 to 20.8 million in 2014. However, these overall improvements have not resulted in uniform improvements in concentrations of
pollutants across China.

In many cities, average annual concentrations of PM2.5 have also fallen or stabilized. For example, average levels in Beijing have fallen to 58 micrograms per cubic meter in 2017, down 34.8% from 2013. However, although it has declined in most parts of the country over the last three years, PM2.5 has shown an increase in several cities in the west of China. PM2.5, NO2 and ozone are also still far above safe levels in the majority of monitored cities (Nielsen and Ho, 2017). This regional variation is discussed in more detail below.

### 2.1.5 Implications

The purpose of explaining some of the complexity in understanding air pollution is not to suggest that available evidence is insufficient to guide action. It is indisputable that despite progress in recent years, the levels of air pollution seen in China, especially of PM2.5, are still unacceptably high and there is no responsible choice but to take action to try to reduce it. Science can provide some essential guidance for those actions. But it is in everyone’s interest to pursue an air quality strategy rooted in the most objective understanding of the challenges possible, or risk misallocating resources for control in a way that will fail to achieve the best possible results and minimize the possibility of unintended negative outcomes. Uneven progress in pollution control cannot be blamed on failed policy implementation alone, which is unfortunately the impression often given by the media. This is a misunderstanding of the fundamental nature of the problems and a recipe for less progress than current scientific knowledge can support.

### 2.2 Health Impacts

#### 2.2.1 Methods and scientific challenges

It is growing awareness of the serious impacts of pollution on health that has motivated action to prevent and control air pollution. Health scientists have identified many associations of air pollution and health outcomes, including mortality and morbidity from cardiovascular and respiratory diseases and strokes, as well as impacts on child development and cognition (see the GBD MAPS Working Group 2016 for a summary of recent studies). However, the science behind these associations is, unfortunately, more uncertain than most people are aware. Although it is indisputable that air pollution is bad for health in a general sense, it is not at all straightforward to quantify the health impacts of particular pollutant levels. When a newspaper headline asserts flatly that 1.2 million Chinese citizens die prematurely each year from air pollution, readers
should be aware that this is a rough estimate that does not reflect the uncertainties and more nuanced results of scientific research. Studies applying different assumptions and methods, and using different data, may produce quite different estimates, with scientists themselves often debating which results are more authoritative.

In assessing health effects, it is important to distinguish between estimates from toxicological studies, which seek to understand the effects of chemicals associated with air pollution on health by exposing animals to them under laboratory conditions, and epidemiological studies that observe changes in health outcomes in human populations over time and seek to relate them to levels of pollution. While toxicology is useful for providing evidence of cancer risks, it is less helpful in evaluating other pollution related health risks such as cardiovascular or respiratory disease. It is also difficult to extrapolate from the large doses administered in laboratories to long term but lower levels of exposure in the population. However, epidemiological studies entail different kinds of uncertainty because, outside the laboratory, the influence of confounding factors is hard to control. For example, in China, population mobility over the last 30 years means that many people are no longer spending their whole life or even the whole of any individual year in the same atmospheric environment.

Then there is the challenge of assessing both the short and the long-term health effects of air pollution. Time series studies can measure the short-term impact of fluctuations in pollution, for example as the result of pollution spikes or the impact of measures taken to control pollution during the 2008 Olympics. They are relatively easy to conduct and inexpensive, but they do not capture the effects of long term cumulative exposure. Cohort studies, which follow individual subjects for decades, collecting data not only on health outcomes but also possible confounding risks, are more able to capture long term effects but they require the maintenance of large, stable and representative samples, which is difficult and expensive. Scientists are also continuing to investigate the multiple effects of air pollution on such health outcomes as premature births, birthweight and child development, as well as on psychological health and wellbeing and on cognition. (for example, Chen, Deng, Zhang 2016; and Chen, Zhang, Zhang 2017).

A further complexity relates to exposure levels and pathways. Assessing the health effects of pollution requires not only information about concentrations of pollutants in the atmosphere, but also information about the number of people who are exposed to these pollutants and for how long. This involves mapping the distribution of population in relation to atmospheric concentrations of pollutants and, because people with different occupations, living conditions and modes of transport will have different levels of exposure, understanding these in different national and regional contexts and for people of different age and gender cohorts. For example, a traffic policeman working on a busy highway in central Beijing will have a very different level of
exposure to pollution than a person who spends most of the day at home or in an office, especially if it is equipped with an effective air filter.

In the absence of good cohort data for China, the health effects of air pollution were for some time estimated using exposure-response relationships derived from international studies, mostly in the United States. However, pollution concentrations in China are significantly higher than in the US, and the exposure-response curve for exposure to air pollution is not linear: it tails off at higher levels, so straight-line extrapolation is inaccurate. Furthermore, the lifestyles of many people in China are quite different from those in developed countries. Recent studies have sought to take this into account and develop exposure parameters and exposure-response relationships for China (Ministry of Environmental Protection 2013). But current estimations of health effects still based on models that inevitably have quite high levels of uncertainty in addition to those already associated with the measurement of pollutant concentrations discussed above (GBD MAPs Working Group 2016).

2.2.2 Estimates of health effects

A recent Health Effects Institute (2016) study provides reviews of the methods and findings of previous studies of the health effects of pollutants in China. Analyzing data from the Global Burden of Disease study, Yang et al. (2013) estimated 1.2 million premature deaths from ambient PM2.5 in 2010, making it the 4th leading mortality risk. Of this total, 49% were attributed to cerebrovascular disease, 23% to ischemic heart disease, 16% to chronic obstructive pulmonary disease (COPD), 11% for cancers of the trachea, bronchus, and lungs, and 1% for lower respiratory infections. The more recent Health Effects Institute study produced a slightly lower estimate of 916,000 deaths in 2013 attributable to PM2.5 and 5.4% of all Disability Adjusted Life Years, up from 3.8% in 1990 (GBD MAPs Working Group 2016). That two respected research institutions can produce estimates that differ by 25% indicates the challenges in developing accurate estimates of health effects of PM2.5, which require multiple levels of assumptions about both underlying concentrations of pollutants, and about exposure-response relationships for various populations.

Many health effects of PM2.5 are also still imperfectly understood, including the implications of the different composition of PM2.5 in different places, and the interaction between long term and short term exposures. For example, a frail, elderly person’s death may be hastened by poor air quality during an acute pollution episode, regardless of whether it is the main cause of their underlying ill-health, while in other cases air pollution may be a long term contributing factor to ill-health but not the immediate cause of death. The ways in which ‘premature’ death is measured also varies across studies with different goals and measures and there are also
different ways of measuring morbidity and reduced wellbeing.

It is also important to note that the ageing of the population is likely to lead to growing health impacts of air pollution even if it remains at the same level or declines, because elderly people are more sensitive to pollution. This can disguise the positive effects of policy to control pollution to date. For example, although the total numbers of deaths from diseases caused by exposure to PM$_{2.5}$ increased from 1990 to 2013, *age-standardized death rates* show a slight decrease over the same period, from 80 deaths per 100,000 to 71 per 100,000, and an annual decline of about 0.5%. There has also been a decrease in Disability Adjusted Life Years attributable to PM$_{2.5}$ due to reduction in the incidence of Lower Respiratory Infections. (GBD MAPS Working Group 2016).

### 2.2.3 Implications

The range of results from different assessments of health effects can be understandably confusing to non-expert readers. The goal here is not to suggest that exposure to current high levels of pollution does not have serious health effects, but rather to stress the scientific challenge of assessing these with accuracy. Journalistic biases often creep into popular media coverage: sources critical of Chinese environmental performance tend to cite higher estimates from the literature, while those seeking to credit pollution control efforts cite lower ones. In both cases, key assumptions helping to explain the disparities of results are seldom acknowledged.

Although efforts to assess total numbers of deaths have been crucial in drawing attention to the need to control air pollution, at this point what is more urgently needed from a policy perspective is a better understanding of the health effects of exposure to specific pollutants, individually and in combination, among different populations to guide the prioritization of pollution control and public health information. The 2016 Health Effects Institute study begins to do this by using pollution source apportionment as a way to attribute health impacts to individual sectors (GBD MAPS Working Group 2016). These studies will help to inform policy, but given the uncertainty inherent in the models, the conclusions they draw regarding the benefits of different policy interventions should be regarded as broad estimates. Moreover, their implications for policy will not always be straightforward, as we discuss further in the context of regional and seasonal variation in pollutant levels below.

While the health effects of air pollution have rightly become a focus of public and government concern, these also to need to be considered in the broader context of other policies that support health, including other types of environmental protection but also public health policy more broadly. Because their goal is often to draw attention to what was previously a neglected
issue, but also because of their scientific focus, few studies examine air pollution in the context of the broader landscape of public health. For example, the Global Burden of Disease Study found that ambient air pollution was the 4th most important risk factor for ill health in China. However, at 8%, it is far behind the first two: dietary risks, at 16.5% and high blood pressure, at 12%, and also behind smoking at 9.5% (Yang et al 2013). As we welcome efforts to grapple with air pollution, these risk factors should not be neglected in setting priorities for investment in public health and weighing the benefits and costs of different policy measures.

2.3 Geographical Variation in Pollutant Concentrations, Sources and Health Effects

One of the major challenges for policy is that both the emission and the concentration of air pollutants vary widely across the country. This geographical variation is due in part to differences in the natural environment – especially topography, climate and meteorological conditions – but also to the nature and number of pollution sources, which are in turn related to industrial structure, energy use and patterns of consumption. Even where the nature of the sources is similar, emission levels will often be different due to the scale of industrial and energy production or the number of vehicles; the types of inputs (for example energy sources and fuel type and quality); and technological factors, including whether or not pollution mitigation equipment is used. All these factors, which are shown in Box 1 below, are affected by both market forces and policy measures and the effectiveness of enforcement.

Box 1 Factors affecting the level of emissions

- **Scale**: expansion or reduction of production without changes in other factors (efficiency of resource use, type of inputs, technology and structure)
- **Structure**: the balance in a given economy of industries with different pollution intensities (for example heavy as opposed to light manufacturing)
- **Inputs**: different production inputs (for example use of different grades of coal or raw materials for cement will have different implications for the type and intensity of emissions)
- **Technology**: changes in production processes that affect the level of pollution per unit of output by increasing overall efficiency (reducing the level of polluting inputs) or through cleaner production processes (reducing emissions with the same level of inputs and outputs)
- **Trade and industry transfer**: changes in the location of industry that affects the regional distribution of emissions

Source: adapted from Stern 2003.
2.3.1 Changing Regional Patterns in Concentrations and Composition of PM$_{2.5}$

Figure 3 shows the change in PM$_{2.5}$ from 2013-2017 for the 31 provincial capitals. Acknowledging the problems discussed above, we use government monitoring data in the remainder of this report because of its comprehensive coverage and greater comparability over time.

In most cities there has been a steady decline in PM$_{2.5}$ over this period, but not in the north western cities of Xian, Lanzhou, Xining, Yinchuan and Urumqi. Despite the strong policies to combat PM$_{2.5}$ in the BTH region, it also shows an uptick in Shijiazhuang in 2016, after a sharp decline in the preceding years. However, as Figure 4 shows, levels of various monitored pollutants are also quite different across cities, even within the same broad region.

**Figure 3** Concentrations of PM$_{2.5}$ in Provincial Capitals, 2013-17

![Concentrations of PM$_{2.5}$ in Provincial Capitals, 2013-17](image)

**Figure 4** Levels of monitored pollutants in provincial capitals, 2017

![Levels of monitored pollutants in provincial capitals, 2017](image)

Source of Figure 3 and 4: Compiled from National Environmental Monitoring Station data
PM2.5 also shows considerable variation in its composition and its sources across different cities. Figure 5 compiles its chemical composition for different cities in different years from a number of studies. It indicates that neither geographical location, nor scale of the emissions, nor the city’s level of economic development alone can explain the composition of PM2.5. The mega cities of Beijing, Shanghai and Guangzhou have different PM2.5 profiles, and so do the three Southern Chinese cities of Guangzhou, Shenzhen and Hong Kong. These differences reflect the structure of industry in these areas as well as differences in topography, meteorology, and climate. The pollutants of concern, and thus importantly the most effective control responses, therefore differ.

**Figure 5  Composition of PM2.5 in different cities**

| Source: Atmospheric Particular Matter and Regional Complex Air Pollution, He Kebin et. al., Science Press, 2011. Reproduced from CCICED 2012. (Note: this figure uses data compiled from different studies and results may not be comparable. It is used for illustrative purposes only.)


The maps below show the regional distribution of some of the key industries (steel, cement and power) that are major sources of air pollutants. Other sources, including transportation and agriculture also show significant regional variation (see the full report for details).
Maps 1 and 2 Distribution of the power and cement, and steel, coking and glass industries

Source: Wang and Li 2015

To further complicate matters, the distribution of pollution sources is constantly changing. Policies to promote the development of western China, along with market forces including the cost of land and labour, and, more recently, environmental protection policies, have led to significant redistribution of industry, mostly from the east coast toward the centre and west and from urban cores to peripheries. Figure 6 below presents the added value from industry by province and its growth rate from 2000 to 2015. It shows the declining importance of industry in some provinces where it was formerly important (Liaoning, Shandong, Guangdong and Zhejiang), while provinces in the Southwest and Northwest of China are seeing a rapid growth in industry on a low base. This obviously raises concerns that emissions will see a similar shift, and we see from Fig 3 above that these northwestern cities are the ones in which PM$_{2.5}$ has in fact increased over the last few years.

**Figure 6  Change in Industrial Added Value by Province 2000-2015**

2.3.2 Within Region Variation: Beijing-Tianjin-Hebei

Differences in the distribution of pollution sources, as well as topographical factors, mean that even within regions, despite the mixing effects of atmospheric transport, the concentrations and composition of pollution can vary considerably by location. Here we discuss the case of the Beijing-Tianjin-Hebei region.

The BTH region has 8% of China's total population and accounts for 10% of GDP. It also suffers much of the worst pollution in China: seven of the cities with the worst average air quality in China are in the BTH region (China National Environmental Monitoring Centre, 2016). The area suffers from severe regional air pollution due in substantial part to the concentration of heavy industry; for example, Hebei accounts for a quarter of China's steel production. The region's high population density also causes high levels of emissions from cars and power generation. In winter, residential heating adds an additional burden (Wang Yuesi 2015). However, as figure 7 below shows, even within the province of Hebei, there is considerable variation in the concentration of different pollutants.

Figure 7 Rates of attainment of daily average air pollutant standards across cities in Hebei Province, 2017

This situation reflects the distribution of various sources across the province. The BTH region also has a topography and seasonal meteorological patterns that lead concentrations to build up. It is bounded by mountains to the north, which means that if winds are from the south, pollution is trapped. Northwesterly winds can be effective in dispersing pollution rapidly, bringing clear air in their wake. But wind speeds have dropped in recent years, making the problem worse, particularly in winter. Even within the region itself, local conditions mean that some cities see a heavy build-up of pollution before others, and because of wind patterns, regional pollution
makes a significant contribution to overall concentrations of pollution in Beijing, sometimes accounting for as much as 36% (Zhang Hefeng et al 2016). Another meteorological factor is the occurrence of temperature inversions, or flows of warm air that can prevent normal convection and trap polluted air close to the ground (see Wang Yuesi 2015 for details).

There is also considerable seasonal variation in the contribution of different sectors to PM2.5 concentrations in BTH. One recent source apportionment study found that on average, industry (44%) and residential (30%) sources dominate, followed by power plants (8%) agriculture (8%) and transportation (7%). But in January, the dominant source is residential (48%) with industry accounting for only 33% because of emissions from residential heating, while in summer, industry and transportation are larger contributors. The source contributions of natural sources show some seasonality. Outdoor biomass burning and mineral dust tend to peak in summer and spring, respectively (Li et al 2015).

**Figure 8** Source apportionment of urban PM2.5 in BTH for 2013: annual average and for January and July 2013

Source: adapted from Li et al 2015

2.3.3 Geographic variation in health effects

The Health Effects Institute has modeled the distribution of total deaths and DALYs attributable to PM2.5 in 2013, which shows a pattern that could be broadly predicted from the distribution of and trends in emissions sources described above. While health impacts are more severe in the north, pockets of high effects are also evident in the southwest (the Sichuan basin). The same study has attempted to distinguish the contribution of different sectors to ambient air pollution and PM2.5. It estimates that pollution from coal consumption caused an estimated 366,000 excess deaths in China in 2013. Domestic burning of coal and biomass were the next most important
contributors, responsible for 177,000 premature deaths in 2013, followed by transportation, at 137,000 deaths. As noted above, however, these estimates are based on elaborate models that contain significant uncertainties. (GDB MAPS Working Group 2016:20-27).

Maps 3 and 4 Regional distribution of DALYs and deaths attributable to PM2.5 Exposure, by Province, for 2013 (age standardized)


2.3.4 Implications

To be effective, pollution control policies have to grapple with the diversity and regional variation in the distribution of emissions sources described above. They also have to consider topography, meteorology, and chemical interactions between pollutants because emissions standards that might keep air quality at acceptable levels under some conditions will not achieve the same result consistently in others.

This raises some difficult but critical questions for pollution control and prevention. The very different patterns of pollution sources in different parts of the country suggest that it will be difficult to achieve even rates of improvement in air pollution control and health effects across the country, because the challenges involved are very different. Regions which are more dependent on coal for heating and on polluting industries will obviously find it harder to achieve compliance. This raises complex challenges for governance, because it implies that different standards may be necessary in different places and that these will need to be adjusted over time in response to changing industry structure and consumption patterns. This makes it difficult to stipulate hard, enforceable national targets backed up by law and it partly explains the development of a patchwork of local targets and related governance challenges discussed below.
Seasonal variation and changes in meteorological conditions are also a challenge for policy. For example, should pollution control policies be set at a level that can ensure air quality in Beijing meets national standards even under the most unfavorable meteorological conditions? Or are a certain number of ‘bad’ days acceptable; and if so, how many and at what cost? These questions are complicated by our limited knowledge of the different effects of long and short term exposure to pollution discussed in Section 1. For example, the health benefits of a long term but reliable decrease in pollution due to consistent policies implemented over the long term may be greater than the benefits of reducing serious pollution for a few days a year, especially if measures can be taken by individuals to reduce exposure on those days. But this kind of incremental progress is less immediately evident to the public. At the same time, emergency policies to address extreme pollution events raise difficult legal issues, especially if the ‘emergency’ becomes longstanding. As discussed further below, the costs associated with different measures over different time frames – for example the administrative burden and the impact on production and transport – also have to be considered.

2.4 Health, Environment and Economy

2.4.1 Economic costs of pollution’s effects on health

Growing awareness of the negative impacts of air pollution on public health – and associated economic costs – has been a strong motivating factor in the introduction of tougher air pollution measures in China. There is now a strong consensus that not only GDP but also public health needs to be taken seriously as an indicator of development. While this argument can be made on humanitarian grounds alone, starting in the 1990s, a number of studies have attempted to assess the economic cost of the health effects of air pollution, to support the argument that air pollution is a significant drag on China’s economic development, measured in terms of GDP growth.

These estimates are usually made by calculating the number of work years lost due to premature mortality and/or DALYs and in some cases also the cost of damage to agriculture and forestry productivity and to infrastructure from pollution caused by various sources. A recent World Bank report estimates that ambient air pollution contributed to 1,625,164 deaths in China, with a total economic loss equivalent to 10.9 percent of GDP in 2013 (World Bank and Institute of Health Metrics and Evaluation 2016).

In a context in which, for many years, the government was emphasizing economic growth over environmental protection, it has been important to demonstrate that failing to control pollution
also has high economic costs. Clearly, it has. However, it seems questionable that these costs have entirely canceled out China's economic growth as these studies suggest. This is probably because the complex models used to estimate them involve multiple levels of uncertainty regarding emissions, concentrations of pollutants, exposure-response relationships and health effects. By the time the final phase of assessing costs is reached, there is already a very wide possible margin of error. Economic costs must then also be estimated. This is done using one or a combination of approaches that seek to measure lost income over the lifetime or people's Willingness to Pay to avoid premature mortality or illness. As data for these are lacking in China, they are currently modeled using baseline data from the US and other developed countries (for an explanation of one such model and the difficult methodological choices that have to be made, see World Bank and IHME 2016). This inevitably introduces yet more uncertainty into the analysis. Refining such models is therefore an ongoing scientific challenge.

2.4.2 Economic development and health

At the same time, while such studies rightly point to the huge potential economic benefits of pollution control, it is also important not to neglect the relationship between economic development and health. We therefore include some discussion of this here and return to this question of economic costs and benefits in the case study of BTH below.

There is no simple linear relationship between increases in GDP and health outcomes, and relative as well as absolute wealth has an effect on health. However, for poor countries, economic growth, usually pursued through increases in productivity from industrialization and the intensification of agriculture, can bring important benefits for health through increased incomes, better nutrition, improved living conditions and more funding for health and other public services (Biggs et al 2010). It can also provide more resources for environmental protection. Urbanization is also usually associated with improvements in public health because it facilitates the development of infrastructure and the provision of health and other services (Brady et al. 2007).

These patterns are clear in China. The map of China's regional GDP and the map of life expectancy show a strong correlation. Although there are exceptions, the east coast and industrialized parts of the hinterland generally are both wealthier and have longer life expectancy than the western and central provinces. Recent analysis of the Global Burden of Disease Data for China shows that from 1990 to 2013, life expectancy for the whole country increased by 8.5 years to 76 years. The gap in life expectancy between the places with the highest (Shanghai) and lowest (Tibet) life expectancy also narrowed from 19 years to 11.9 years. This is probably due mostly to reductions in child and perinatal mortality, and differences in health expenditures also need to
be factored in. However, it nonetheless suggests that rapid economic growth has not led to greater inequality in health outcomes, at least on the broad measure of life-expectancy and the inter-provincial level, although this may not hold for other outcomes or other axes of inequality (for example rural-urban or gender) (Zhou et al 2016).

At the same time the differences in life expectancy that remain are equivalent to those between countries of very different levels of development, with the richest areas of Shanghai, Tianjin and Beijing having higher life expectancy than the US and South Korea, while the poorest provinces, mostly in Western China are more similar to poor South Asian countries (Zhou et al 2016). The Economist (2015) groups China’s provinces into five clusters in terms of their life expectancy, largely on a regional basis, but in fact one can also see major differences within regions that also reflect patterns of economic inequality. Hebei, for example, has much lower life expectancy than Beijing: according to the Economist’s map, Beijing would be similar to the wealthy island of Malta (84 years for women and 78 for men), while Hebei would be like the poor eastern European nation of Bulgaria (79 years for women and 72 for men).

**Map 5. Average life expectancy by province, 2013**

2.4.3 Implications

Although wealthier parts of China have reached an income threshold where pollution control is likely to have greater benefits for public health than additional increases in income, inter-and intra-regional inequality means that in poorer parts of the country, improvements in public health are still also likely to be strongly linked for some time to economic status. It will be important in those places to ensure that the costs of achieving better air quality do not undermine other factors that support health, whether these may be stable employment or public investment in health services. In this context, it is important to note that in China the majority of expenditures for healthcare are borne by local government and the level of investment varies significantly. If stronger environmental protection comes into competition with other public services for investment, inter-regional transfers may be necessary to offset these losses. Beyond healthcare services, consideration of other factors that affect health and wellbeing, such as employment, will be more complex but also call for analysis and responsive policies.
3. GOVERNANCE CHALLENGES

3.1 National Laws and Plans

Over the last five years the government has rolled out a dizzying array of new laws, policies, plans and administrative measures designed to attack pollution in what has been described a war similar to the one it previously waged on poverty (Li Keqiang 2014). These laws and policies have addressed all the factors that contribute to emissions, requiring cleaner production processes and inputs and more effective pollution mitigation technologies, and reducing the scale of production and its density. The sheer number of measures being introduced by different government agencies at different levels makes it difficult to provide a full account here; and because targets and implementation measures are constantly being ratcheted up, any account will inevitably be out of date very quickly. To reduce the discussion to a manageable scope we first discuss the national picture and then narrow down to policies to address PM2.5 in the BTH region. For finer grained detail we use examples mostly from Beijing, Hebei Province and Tangshan City.

Air pollution prevention and control has been conducted through a web of legislation, plans and policies issued by both national and local government. The 2014 revision of the Environmental Protection Law brought some important changes. It stipulated that pollution prevention should be conducted through cross-administrative district management, introduced new requirements for information disclosure, replaced one time violation fees with daily penalties, removed the ceiling on fees for emissions violations, and strengthened public oversight (Feng and Liao 2016). It also includes, for the first time, an article specifically related to environment and health, which stipulates that,

the nation will set up a comprehensive system for environment and health, and a system for monitoring and assessing risks; it will encourage and organize research into the effects of environmental quality on health, and take measures to prevent and control diseases associated with environmental pollution (Environmental Protection Law 2014: article 39).

The Law on the Prevention and Control of Atmospheric Pollution (hereafter, the Air Pollution Prevention and Control Law), which was passed in 2000 and revised in 2007, was revised again in 2015 and took effect in January 2016. Unlike previous versions, the new law mentions "safeguarding public health" as a goal of air pollution control and covers VOCs and greenhouse gases. Specific articles address the promotion of cleaner coal and clean energy; and emissions
from the steel and mining sectors; residential heating; agriculture, freight transportation and shipping; and construction, as well as smaller sources including catering, dry cleaning, fireworks, and even crematoria. Local municipalities are made responsible for achieving air quality targets within their jurisdictions and regional coordination mechanisms for air pollution control are to be established. Enterprises that fail to install required pollution mitigation equipment, use or sell coal or fuel that does not meet required standards, emit atmospheric pollutants without a legal permit, exceed the emission limit or evade supervision and inspection can be fined between RMB100,000-1,000,000. Lower fines (RMB 20,000-200,000) are set for failing to install or tampering with required monitoring devices or faking data; and fines of up to three times the value for the sale or re-sale of equipment and vehicles that do not meet technical requirements.

Several provisions relate to public information transparency regarding standards, air quality and emissions, and the law requires local government to establish hotlines to report violators and follow up on complaints. It stipulates that alert systems should be set up to give warnings on weather conditions that worsen smog and provides that governments may in such circumstances "command relevant enterprises stop or limit their production, limit the usage of certain vehicles, prohibit fireworks, suspend earthworks engineering, demolition of buildings, outdoor grill and outdoor activities of kindergartens and schools and undertake weather modification and other contingency measures." (Air Pollution Prevention and Control Law 2015: article 96). The Law did not, however, include some proposed amendments for a cap on coal consumption and specific air quality standards, which have been left to the plans discussed below.

Several other types of law are relevant to air pollution control. Several overarching laws (in the sense that they apply beyond the area of environmental protection), including the Budget Law, and the Property Law, are important because they relate to due process and the authority and rights of various government and private entities, for example to levy and assign funds or to administer punishments that involve the use of private property such as vehicles or industrial plants. Other relevant laws include the Cleaner Production Promotion Law which focuses on cleaner production and energy efficiency in industry; the Environmental Impact Assessment Law which requires impact assessment of plans and construction projects; and the Energy Conservation Law which calls for economic structural adjustment and energy-efficiency improvement to lower carbon dioxide intensity of the economy.

In addition to the Constitution and national laws, local governments (usually provinces and self-governing cities) can also issue local regulations and rules, which must be consistent with national law but may be stricter. Provinces and major cities have now issued specific regulations or rules for implementing the Air Pollution Prevention and Control Law within their jurisdictions.
Laws are relatively stable and legally binding but in China they are often quite general, with specific provisions set out in administrative regulations (tiaoli 条例) issued by the State Council and rules (guiding 规定) which can be issued by a range of ministries and commissions under the State Council. Plans, which include the overarching Five Year Plans for National Economic and Social Development as well as narrower problem or sector specific plans, set out major government or ministry objectives and broad strategies for achieving them. They often include targets for progress which, while not legally binding, drive the formation and implementation of specific policies by different levels of government.

The first comprehensive Action Plan for the Prevention and Control of Air Pollution was issued by the State Council in 2013.³ The plan designated three 'key regions' (Beijing-Tianjin-Hebei region, and the Yangtze and Pearl River Delta regions) and six 'city clusters' (central Liaoning, the Shandong Peninsula, Wuhan and its surrounding area, the Changsha-Zhuzhou-Xiangtan region, the Chengdu-Chongqing region, and the western coast of the Taiwan Straits) for prevention and control of regional air pollution. It also identified the key pollutants (SO2, NOx, PM and VOCs) to be controlled in order to reduce acid rain, haze and photochemical smog pollution. Measures were to include optimizing the structure and distribution of industry; increasing the use of clean energy and stepping up control of vehicle pollution. Binding targets were set for ambient air quality improvement by 2017, stipulating decreasing annual average concentrations of PM10, SO2 and NO2, as well as control of ozone and acid rain. PM10 concentrations were to be reduced by at least 10% compared to 2012 levels in urban areas, and PM2.5 concentrations by 25%, 20% and 15% in Beijing-Tianjin-Hebei, the Yangtze River Delta and the Pearl River Delta, respectively. Annual average PM2.5 concentrations in Beijing were to be controlled within 60mg/m3. Other areas were to adopt PM2.5 as a target for the near future (State Council 2013a).

³ Because the plan contained 10 points, as did later plans for preventing and controlling water and air pollution, it is also known as the 10 Points for Air (qishitiao 气十条).
17 kinds of environmental information to be made available to the public through real time online platforms as well as government reports (State Council 2013a).

The Action Plan has two sets of indicators, which relate to outcomes (the reductions in concentrations of pollutants discussed above) and processes of implementation or tasks that are seen as essential to ensure achieving the targets. These tasks can be divided into four broad categories: industry specific measures targeting energy, transportation, industrial production and construction; general technical measures targeting power and industrial processes; overall industrial structure adjustment; and construction of early warning and rapid responses systems. These measures broadly target all the factors that contribute to increased emissions: scale, density, inputs and technology. They are listed in Table 1.

Table 1       Measures in the Action Plan for the Prevention and Control of Air Pollution

| Industrial structure          | Reduction of excess production capacity Elimination of outdated production capacity Relocation of highly polluting |
| Energy structure              | Control of total coal consumption Optimization of coal consumption structure Improvement of coal quality Improvement of energy efficiency |
| Dust pollution                | Control of dust pollution in construction sites Control of dust pollution on roads |
| Motor vehicles                | Elimination of yellow-label (high-polluting) vehicles Improvement of fuel quality (diesel and petrol) Strict standards for emissions of new motor vehicles Vehicle population and use restrictions Promoting new energy vehicles |
| Industrial atmospheric pollution | Elimination of small and inefficient coal-fired boilers Desulfurization, nitrogen oxides controls, and particulate controls |
| Heavy pollution warning       | Real-time warning system Emergency response plan system |

Source: Adapted from China Council for International Cooperation on Environment and Development (CCICED) 2014.
3.2 Implementation

Because it is not possible here to detail all the measures that are being taken, we look in the next section in more depth about what we know about the implementation of the Action Plan in Hebei Province, which has the worst pollution of the three administrative jurisdictions and faces some of the toughest challenges. First, however, some background on what we know from previous research about the challenges of implementing air pollution control policies in China.

It has long been acknowledged that China’s environmental protection policy suffers from what is often referred to as an "implementation gap." Research has identified a number of reasons for this. They include problems relating to the structure of authority in which environmental protection agencies are answerable ‘horizontally’ to local government rather than ‘vertically’ through the ministerial chain of command; and under which local governments lack authority over central level State-Owned Enterprises which may be serious polluters. Another set of obstacles relates to capacity, with a large body of research showing that local Environmental Protection Bureaus often lack the funds, staff and equipment to fully enforce regulations. The third major set of obstacles is often referred to broadly as "local protectionism," and relates to the unwillingness of local government to implement policies against industries that are important to the local economy (see Van Rooij et al. 2017 and Kostka 2017, 2014 for summaries).

The extent to which these factors are hard constraints that are genuinely difficult for local government to overcome, at least without assistance from higher levels, probably varies considerably across jurisdictions. But the success of the current air pollution control measures will clearly depend in large part on whether these previously rather intractable problems can be addressed. BTH is a particularly interesting case through which to explore this question. On the one hand, the national government is playing an extremely active role in pushing forward air pollution prevention and control in BTH. At the same time, the region is composed of two very rich cities surrounded by a much poorer province that is heavily dependent on industry, presenting a strong conflict of interest between central and local government. It will therefore be an important test case of whether strong central policy can overcome local interests.

3.3 Coordinated Air Pollution Control in BTH

Both the national Air Pollution Law and the Action Plan required that provincial and municipal governments develop their own plans and institutional structures to implement air pollution prevention and control. We will discuss these mostly in the context of the BTH region. The region has some of the worse air pollution in the country and has also been a target for
aggressive intervention: it therefore offers a good case for understanding how policies are being implemented, their effectiveness and the challenges involved. However, the recent nature of many initiatives makes it difficult to evaluate their effectiveness and there have been few formal evaluations to date (or few that are in the public domain). We can therefore often only make tentative inferences from a body of information that has yet to be systematically analyzed.

On 17 September 2013, the MEP issued the Implementation Rules of the Action Plan on Prevention and Control of Air Pollution in Beijing-Tianjin-Hebei Region and Surrounding Area (MEP 2013). The Rules set the target that by 2017, PM2.5 concentrations will be reduced by 25%, 20%, and 10% compared to 2012 levels in BTH, and the neighboring Shanxi-Shandong Region, and Inner Mongolia Autonomous Region, and that annual average PM2.5 concentrations in Beijing should be kept within 60 mg/m$^3$. Furthermore, all cities should strive to reach the national standard (annual average PM2.5 concentration equals 35μg/m$^3$) by 2030 (MEP 2013).

The key tasks of the Implementation Rules are in line with those of the National Action Plan and included: 1) implementing integrated control and intensifying the reduction of emissions of multi-pollutants; 2) urban traffic management and controlling vehicle pollution; 3) adjusting industrial structure and optimizing regional economic layout; 4) controlling total coal consumption and promoting efficient and clean use of conventional energy; 5) strengthening basic monitoring, warning, and emergency response systems; 6) intensifying organization and leadership (MEP 2013). The Beijing–Tianjin–Hebei and Surrounding Regions Air Pollution Prevention and Control Coordination Group was set up to coordinate, and supervise air pollution control in BTH. The group is supervised by a vice-premier and participating government agencies include the Ministry of Finance, the National Development and Reform Commission, and MEP, as well as the seven provincial governments. An office under the direction of the vice mayor of Beijing and the vice minister of MEP manages its daily work (Asian Development Bank (ADB) 2015).

Reliance of the BTH regional economy on polluting heavy industry is one of the major challenges in addressing pollution. Industrial restructuring will therefore be crucial to achieving the targets in the regional air pollution plan for 2017 and for 2030 (CAAC 2016). The Action Plan for the Prevention and Control of Air Pollution is therefore backed up by the Program Outline for Coordinated Development of the BTH Region, which was approved by the Politburo of the Central Committee of the CCP on 30 April 2015. The program focuses on the transfer of industries and public service facilities out of Beijing to neighboring areas, including some energy-intensive industries, wholesale markets, public service entities, and state-owned enterprises and administrative institutions. It sets for targets for 2017 for integrating transportation integration, environmental protection, and industrial upgrading and controlling
the population of Beijing at 23 million by 2020. There is also an emphasis on reducing the gap in social development in the region through the equalization of public services and eliminating the poverty belt that circles Beijing: 80% of the BTH region’s 3.1 million people who live in poverty are in Hebei (ADB 2015).

Planning was then taken down to the next level with local governments releasing their own implementation plans: the Beijing Clean Air Action Plan (2013-2017), the Tianjin Clean Air Action; and the Implementation Scheme for the Action Plan of Air Pollution Prevention and Control for Hebei. The plan for Hebei is discussed in further detail below, but the BTH plan already lays out quite specific targets designed to meet the air quality standards for 2017. These are shown in Table 2, sorted into those that target technology and inputs and measures that tackle scale through structural adjustment of industry and energy.

Table 2 Measures and Targets in the BTH Air Pollution Prevention and Control Plan

<table>
<thead>
<tr>
<th>Type of measure</th>
<th>Measures</th>
<th>Specific target for 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industrial structure</strong></td>
<td>Controlling construction of new and expansion of existing capacity in high energy and polluting industries Eliminating excess production Eliminating production facilities with outdated technology or low capacity/efficiency</td>
<td></td>
</tr>
<tr>
<td><strong>Energy structure</strong></td>
<td>Reducing coal consumption</td>
<td>Reduction of 63 million tons (Beijing 13; Tianjin 10 and Hebei 40, equivalent to reducing production by 61%, 20% and 10%)</td>
</tr>
<tr>
<td></td>
<td>Clean energy substitution</td>
<td>Natural gas consumption to increase by 50 billion cubic meters (13, 12 and 25 billion m3 respectively)</td>
</tr>
<tr>
<td><strong>Transportation structure</strong></td>
<td>Reduce vehicles to reduce diesel and petrol consumption</td>
<td>Focus on Beijing but no target</td>
</tr>
<tr>
<td><strong>Transportation pollution mitigation</strong></td>
<td>Raise technical standards for new vehicles</td>
<td>Implement Euro5 vehicle standards in 2015 for the whole region and, implement Euro6 vehicle</td>
</tr>
<tr>
<td><strong>Industrial Pollution mitigation</strong></td>
<td>Phase out vehicles not meeting standards</td>
<td>Phase out 2 million yellow label vehicles in the region before 2017 and all diesel and other vehicles that do not meet Euro3 standards</td>
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<tr>
<td></td>
<td>Install Stage I and Stage II vapor recycle systems in oil stations</td>
<td></td>
</tr>
<tr>
<td><strong>Phase out vehicles not meeting standards</strong></td>
<td>Install desulfurization and denitrification equipment in coal-fired power plants</td>
<td>Increase the SO2 removal efficiency from 80% in 2012 to 90% in 2017. Mostly affects Hebei</td>
</tr>
<tr>
<td></td>
<td>Install desulfurization equipment in industrial boilers</td>
<td>Raise the percent installed to 100% in 2017</td>
</tr>
<tr>
<td></td>
<td>Upgrade dust collectors in industrial boilers and phase out low efficiency WET devices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Install denitrification equipment in cement plants</td>
<td>Increase the installed percentage from 16% in 2012</td>
</tr>
<tr>
<td></td>
<td>Install desulfurization equipment in sinter plants and</td>
<td>Raise the installed percentage from 35% in 2012 to 100% in 2017</td>
</tr>
<tr>
<td></td>
<td>Reduce VOCs emissions from key industries by 20%</td>
<td>20% reduction by 2017</td>
</tr>
</tbody>
</table>

Adapted from Clean Air Alliance of China (CAAC) No Date).

### 3.3.1 Predicted health benefits of the BTH plan

The Clean Air Alliance of China estimates that if China fully implements the Action Plan by 2017, 110,600 deaths can be prevented every year, average male life expectancy will be extended by 0.24-1.48 years and average female life expectancy by 0.34-3.48 years. The BTH Region—especially Beijing—is predicted to have the greatest improvements in overall life span out of all regions in China because of the high initial levels of PM2.5, and pollution reduction policies that are stricter than those of surrounding areas. Benefits are estimated to be greatest for those aged 65 and under, with average expected life expectancy increases from 0.37-3.77 years and 0.2-1.19 years, respectively. Hebei is estimated to have the greatest reduction in annual deaths and
incidents of respiratory diseases, with cases of acute bronchitis falling by 2.1 million (CAAC 2015a).

These are impressive claims. However, the methodology for calculating them has not been made public, which makes it hard to evaluate them. The margin for error reported is very large: from less than six months of increased life expectancy to nearly three and a half years, which would be a significant difference when considering how much to invest in different policy options to promote health. As noted before, a more detailed estimate of the health effects of air pollution control is provided by a recent study by the Health Effects Institute (2016) and shows the benefits for health associated with different pollution control scenarios. However, this is not specified at the regional level.

As discussed further below, the benefits of reducing air pollution can ultimately also only be understood in the context of the costs of doing so and the alternative health-promoting ways in which the same funds might be spent. This is not to argue against stronger environmental protection but to emphasize that now the government has made the commitment to act, it is no longer enough to show benefits in the aggregate: choices need to be made between specific policy options in specific circumstances and for this we need better estimates of health effects in relation to costs. This is an ongoing challenge for research.

However, the health system seems as yet not to have been fully included in this process: for example, health agencies are not included in the coordinating groups for pollution control and so far it seems no reports have been published on the actual health effects of the improvements in air quality that have been made to date. This may be because the environmental stream often does not have direct access to health data that are needed to assess the impact of pollution control policies. However, if health is truly to be included in all policies, as the Healthy China 2030 Plan calls for (CPC Central Committee and State Council 2016), the health system needs to be able to participate in designing and assessing health interventions across all policy systems, including environmental protection.

3.4 Provincial Level Policies: Hebei

3.4.1 The Provincial Action Plan

In September 2013, following the BTH Regional Action Plan, the MEP signed responsibility agreements for reducing air pollution with the six provinces of Beijing, Tianjin, Hebei, Shanxi, Shandong, and Inner Mongolia, specifying actions to be taken and targets for the next three
years. Hebei committed to achieving the 25% drop in concentrations of PM2.5 by 2017 and the document reiterated the major tasks allocated to the province in the BTH Regional Plan. The Hebei Government and Party Committee followed up with a 50 Point (wushitiao 五十条) provincial plan and committed to strong implementation of what is often referred to as the '6643 policy' for the reduction of excess capacity in steel production by 60 million tons by 2017, in cement by 60 million tons, in coal by 40 million tons, and in plate glass 36 million cases. This was accompanied by other measures across all areas of the economy, including restricting the burning of coal in urban areas, phasing out small boilers, installing desulfurization and denitrification equipment in all power, steel, cement and chemical factories by the end of 2015, cutting total coal consumption by 40 million tons over the 2012 figure, switching rural heating from coal to natural gas or electricity, moving steel, cement and chemical factories out of urban areas, restricting yellow-label vehicles, etc. (Hebei Province Communist Party Committee and Government 2013).

The Asian Development Bank (2015) has usefully illustrated the enormity of this task. It points out that Hebei’s total coal consumption in 2012 (287 million tons) was 12% of the total amount of coal produced nationally and 45% of the coal production of the United States. The target for reduction (12.4 million tons per year) was equivalent to 40–50% of the total energy demand of countries like New Zealand or Switzerland and 3–5% of the total energy demand of countries such as Canada, Germany or the United Kingdom. The targeted reduction in PM2.5 for Hebei (176,000 tons per year) is approximately twice as much as the total PM2.5 emissions of the United Kingdom in 2013. This was truly an ambitious set of goals.

3.4.2 City Level Plans

The targets were further decentralized to specific cities and counties in Hebei, which proceeded to draw up their own plans. It is not clear what the criteria were for allocating quotas for reduction in emissions but it seems to have partly proximity to Beijing and partly the severity of pollution in the city. The Hebei Implementation Plan states that *“the cities of Shijiazhuang, Tangshan, Baoding, Langfang and Dingzhou would have to achieve reductions of 33% in PM2.5 over 2012, while Yantai should achieve 30% and Qinghuangdao, Cangzhou and Hengshui 25% and Chengde and Zhangjiakou more than 20%. City and county leaders were to be made responsible for reaching the binding targets in the plan, with yearly evaluations at the beginning of each year and interim and final evaluations in 2015 and 2017”* (Hebei Province Communist Party Committee and Government 2013).

Tangshan is a good example for examining how policy has played out at the municipal level because it is one of the most polluted cities in Hebei and also because it was one the cities
asked to make the most drastic reductions of 33% in PM2.5 by 2017. In 2013, the city had only 106 days when the average concentration of PM2.5 reached national standards, or 29%, about 6% less than the provincial average. There were 82 days with heavy pollution or worse. The city has always been among the worst ten of the 74 key monitored cities for air pollution and SO2, NO2, and CO were twice the average for the province (Zhang Youyue 2014).

The city’s pollution is clearly related to its industrial structure. At the end of 2012, the city’s steel production capacity had reached 140 million tons, or half the total for the province. Its cement capacity was a third of the province, and coking, at 48.75 million tons was 54.1%. The city’s total energy consumption was 97.9 million tons standard coal equivalent or 32.5% of the provincial total, and coal consumption at 86.14 million tons accounted for 28.43%. Raw coal accounted for 98% of all energy use in large scale enterprises of which 95% were in steel, power, coal, construction, coking, chemicals and other high energy sectors. Tangshan emitted 318,000 tons and 390,000 tons of SO2 and NO2, accounting for 23.7% and 22.3% of the provincial total and 1.5 times more than Shijiazhuang or Handan (Zhang Youyue 2014).

Tangshan issued its Plan for the Implementation of the Assault Action on Air Pollution Prevention and Control 2013-2017 on October 10, 2013. It contained 65 points. The plan called for several districts and counties to reduce PM2.5 by 40% over the five year-period (the districts of Fengnan, Fengrun, Guye, and Kaiping, as well as Qianan city, Zunhua City and Luan County). To achieve the targets, by the end of 2017 the whole city was to reduce its coal consumption by 25.6 million tons or more than 29.7%, steel production capacity by 28 million tons (20%) and pig iron by 40 million tons, to bring it in line with the targets of the Hebei Province Plan for the Adjustment of the Steel Industry. (河北省钢铁产业结构调整方案). By the end of 2013 the city was to eliminate 3.15 million tons of outdated coking capacity, and by the end of 2014, 34.73 million tons of outdated cement capacity. By the end of 2015, the city was to reduce production capacity in the cement industry by a further 300 000 tons; for a total reduction of 1.32 million tons by the end of 2017. By September 2014, the whole city would implement controls on yellow label vehicles: by the end of 2015, yellow label vehicles registered before 2005 would be eliminated; and all of them would be gone by the end of 2017. By the end of 2014, all 1,222 petrol stations and 10 petrol storage facilities and 165 oil storage tanker vehicles would have their oil collected and treated (Tangshan City 2014).

The city appears to have moved quickly. In a work report on 10 February 2014, the head of the Tangshan Bureau of Environmental Protection, Zhang Youyue, reported that the city had set up a Leading Group under the Mayor and already signed responsibility agreements. A few figures give some indication of the huge effort that has been underway. It states that, in 2013, the city completed 206 pollution reduction projects, and 617 desulfurization, denitrification and dust
removal projects that reduced S02 and NOx emissions by 35,600 and 49,900 tons, respectively; 577 polluting enterprises were regulated, of which 507 were closed; 336 coal boilers were eliminated or upgraded and areas specified in which high polluting fuels would be prohibited. 4,600 yellow-label cars were eliminated and 500 new green public buses put into action; a "Sunday Action to Reduce Excess Production Capacity" closed five production facilities for a total cut in production of 3.62 million tons of iron and 6.20 million tons of steel; and a decrease of 27 million tons of coal use; 157 new monitoring facilities were installed; 1085 small plastics, rubber, sintering, acid washing, electroplating, lime kilns and other polluting industries were closed. (Zhang Youyue 2014).

3.4.3 Implications

Air pollution control efforts have been rolled out at great speed, from the national to provincial and down to the municipal level. The rapidity of this process raises questions about the degree to which these plans and the targets they set for reductions in particular pollutants could possibly be based on a solid scientific basis, given the complexity of sources and atmospheric conditions in the BTH region. It seems that the situation is more one of scientific research and policy proceeding in tandem than one of research, policy design, implementation and feedback. It would therefore not be surprising if there were a significant gap between the targets set in these plans and actual outcomes, as in fact occurred.

At the same time, while it is clear that cities in Hebei have been under immense pressure to take action to reduce pollution sharply within a short time frame, there is no publicly available synthesis or analysis of the measures taken across all the cities in Hebei over the last four years. An inspection by the MEP in winter 2015-16 produced a long list of problems to be rectified (MEP 2016a), yet many questions remain regarding the impact of these measures on emissions from various sources and on air quality.

The sustainability of these measures is also a question, given that many are campaign-style efforts. As earlier work on environmental protection campaigns and compliance has shown, the results of such intensive efforts are sometimes short-lived: once the pressure is off, factories may revert to non-compliance, and even those that are closed may open elsewhere. Campaign-style enforcement also strains administrative capacity and can violate due legal process (see Van Rooij 2017; Kostka 2017, 2014). Careful evaluation of the long-term effectiveness and sustainability of specific regulatory efforts will be needed to understand their contribution to reducing emissions of various pollutants and guide future policy.
3.5 Air Quality Outcomes

Recent data show that, overall, air quality in all three jurisdictions of the region has improved substantially, with average PM2.5 concentrations falling from 2013-2017. The steepest decline was in Hebei, followed by Tianjin and then Beijing, which started at the lowest level. The figures below show the concentrations and the percentage declines.

**Figure 9 Decline in annual average concentrations of PM2.5, 2013-2017**

![Bar chart showing annual average PM2.5 concentrations from 2013 to 2017 for BTH, Beijing, Tianjin, Hebei, and 74 cities.](source)

*Source: National Environmental Monitoring Station Data*

**Figure 10 Percentage decline in annual average PM2.5 concentrations year on year and over four years**

![Bar chart showing percentage decline in annual average PM2.5 concentrations year on year and over four years for BTH, Beijing, Tianjin, Hebei, and 74 cities.](source)

*Source: National Environmental Monitoring Station Data*
The percentage declines over three years, of almost 35% in Beijing and almost 40% for the region as a whole, are very impressive. However, some worrying patterns should be noted. Aside from Beijing, the first two years of the plan saw the biggest percentage drops, with a substantially tailing off in 2016, which made it unlikely that the targets of getting PM2.5 below 60 μg/m³, in Beijing and seeing declines of 25% in Tianjin and Hebei would be reached by 2017. Getting from the 2016 level of 73 μg/m³ to below 60 μg/m³ in 2017 required a historic drop of 15% in one year and the strengthened measures deployed to achieve this are discussed below, but this tailing off suggests that further improvement may be difficult.

Figure 10 also shows very clearly the priority accorded to improving air quality in Beijing. Almost half the reported improvement in air quality over four years took place in 2017, with a massive drop of 20% in that year. Meanwhile, Hebei province saw only an improvement of less than 10% in that year. The reasons for this are not clear, but this imbalance adds weight to the questions of health equity raised earlier.

Another problem is that although, overall, the number of days with excellent or good air quality has increased over the last four years, improvements in average annual concentrations and the total number of good air quality days have not been reflected in even levels of PM$_{2.5}$ throughout the year. For example, from January to October 2016, the percentage of good days in the 13 cities of BTH was 59%, up 4.8% from the preceding year. But in November, the percentage of good days dropped to 36.9%, down 16.3% from 2015, and the average concentration of PM$_{2.5}$ rose to 102, up 8.5%. Beijing’s experience was reflective of the region: from January to October, good days were up to 54.8% and PM$_{2.5}$ was 67, down 9.5%. But in November, the percentage of good days fell to 43.3% and PM$_{2.5}$ was 100, up 15.3% (MEP 2017a). December saw another 8 days of heavy pollution and 6 of very serious pollution. This period, which included three long stretches during which the region was under red alert, brought down the average for the year and also gave the public the impression that pollution control was failing overall.
Figure 11  Change in the number of days of different air quality in Beijing, 2013-17

Excellent = 0-50; good = 51-100; lightly polluted = 101-150; moderately polluted = 151-200; heavily polluted = 201-300; seriously polluted = 301+.

Significant reductions in \( \text{PM}_{2.5} \) have therefore been achieved in a short space of time, but the initial measures were not sufficient to reach the targets for air quality for 2017 set out in the plans. It also seems that policies which have been effective in lowering average concentrations have not been able to prevent the occurrence of very seriously polluted days. This situation raises questions for research and policy that we discuss below.

3.6  Barriers to effective pollution control

3.6.1  The scientific knowledge base

As discussed in section 1, air pollution is a complex phenomenon. Designing policies that can effectively reduce it relies heavily on the ability to 1) compile accurate inventories of pollution sources and 2) understand climate patterns and meteorological conditions.

The BTH region has received the close attention of some of the best atmospheric scientists in China, who have worked to strengthen emissions inventories and join them with advanced atmospheric models to simulate the likely impact of various pollution control measures. One such model was tested against actual levels of \( \text{PM}_{2.5} \) for BTH cities in 2013 and the results are reported in the CAAC Report, Can Beijing-Tianjin-Hebei Achieve their \( \text{PM}_{2.5} \) Targets for 2017? (No date:5). While the model was very accurate for 9 out of 13 cities, there was quite a large discrepancy for others. In particular, simulations for Shijizhuang and Xingtai were about 25%
lower than actual emissions, while those for Beijing and Tangshan were higher by more than 10% (CAAC No date).

Figure 12 Simulated and actual levels of PM2.5 for BTH cities in 2013

![Graph showing simulated and actual levels of PM2.5 for BTH cities in 2013.]

Source: reproduced with permission from CAAC No date. Can BTH Achieve its Air Quality Targets by 2017?

One reason behind this is that even in BTH inventories of pollution sources remain incomplete. The response of Hebei to the MEP inspection in the winter of 2015-16 mentions the need to compile more accurate pollutant source inventories and conduct enforcement on the basis of these (shishi qingdan zhi 实施清单制) (Hebei Provincial Communist Party Committee and Government 2016a), The Tangshan and Handan responses to the Inspection also make repeated references to implementing the inventory system (Tangshan City Government 2016a; Handan People’s Government 2016a). Even Beijing itself does not yet have a full inventory. MEP Minister Chen Jining, in explaining to journalists at a press conference on January 6, 2017 why it is that after every serious pollution episode in Beijing, inspections find and shut down new violating industries, noted that pollution sources still exist of which the MEP is not aware.

BTH has 1239 enterprises which are classified as elevated sources because [their chimneys] are 45 meters or more above ground and can transmit pollution in the high atmosphere. From January 2016 they have all been connected to the automatic monitoring system... and the non-compliance rate... has improved from 30% to 3%. The other type of pollution sources are small scattered enterprises. These are much harder to find. They are small scale and mobile... and there are a lot of these scattered small industries in BTH.... They have to be discovered using
remote sensing, big data or drones and we hope the public will report more of these small enterprises. You have to find them before you can regulate them (shouxian yao xian faxian ta, caineng jianguanta 首先要先发现它，才能监管它). (MEP 2017c)

Capacity to assemble accurate emissions inventories in other parts of the country is much more limited. Outside the mega cities, the evidence base for targeted policy is limited. The Hebei Department of Environmental Protection did not set up an Atmospheric Pollution Division until 2013, and the Hebei Research Academy of Environmental Sciences only establish its Atmospheric Pollution Prevention and Control Leading Group in that year (Wang and Sun 2014). Our understanding of capacity in other cities is limited, but the CAAC report on the implementation of air pollution prevention and control in Changzhou, Jiangsu, where the organization has been providing technical support, states that although in 2014, the city established a pollutant emission inventory, and published pollution prevention and treatment actions plans and emergency response plans, it "still lacks adequate research to correlate total pollutant control with overall improvements in air quality, signifying that research efforts are yet to be able to fully support policymaking" (CAAC 2015b) Media interviews with mayors in other parts of China, report similar problems, with local leaders saying that they have put together teams and money to fight the war on pollution but they do not know where to target their efforts. As one put it, "You have to tell me where to aim the gun." (Wang and Sun 2014).

Even with a better grasp of emissions sources, other scientific challenges remain, most particularly in understanding the climate and meteorological factors and complex chemistry of air pollution. This is a particular challenge when it comes to understanding the factors that cause pollution spikes.

### 3.6.2 Inadequate enforcement

The significant decreases in pollution that have been achieved are evidence in themselves that enforcement has been more vigorous than in the past. Reports from municipal environmental protection agencies contain long lists of the number of plants of various kinds that have been closed or fined or moved as well as other initiatives in the transportation and heating sectors. The Tangshan report on air pollution prevention and control work for 2013 discussed above shows the level of energy that has been poured into environmental protection work in recent years.

But despite more inspections, tougher punishments and falling emissions, it is clear that there are still enterprises that are "violators" in terms of their pollution emissions. From December 31,
2015 to February 4, 2016, a Central Environmental Protection Inspection Team sent by the MEP conducted an inspection in Hebei Province. They reported 47 problems, which resulted in Hebei committing to 283 specific "rectifications measures" and stipulating "clear responsibility units, the responsible persons, rectification goals, and rectification time limits." The following passages regarding what needs to be rectified indicate that many old problems persist.

...the 13,784 illegal construction projects found by the 2015 environmental protection inspection will be dealt with, according to the classification rules, to ensure that by the end of 2016 all illegal construction projects will have been eliminated....

...strict environmental law enforcement supervision and management will be carried out. Special actions on cutting pollution will be carried out in depth, focusing on combating secret pollution discharge, illegal discharge of toxic and harmful pollutants, illegal disposal of hazardous waste, abnormal use of pollution prevention facilities, environmental monitoring data fraud, and other illegal behaviors. (Hebei Provincial Communist Party Committee and People’s Government 2016a).

Qualitative research in Hebei (Mu 2015; Yang 2015; Van der Kamp 2015) confirms that other familiar obstacles remain: out of concern to protect revenue and employment, the local government is unwilling to regulate ‘pillar’ industries. In some cases, factory boilers may also be supplying heat to communities and alternatives must be put in place before they can be shut down. We return to these larger questions of the costs of pollution control below.

When it comes to centrally owned state enterprises (yangqi 央企), the authority of the local government is limited and it can find it hard to fully implement laws and policy measures (CCICED 2014). Even with intensive enforcement it is also still relatively easy for enterprises that operate overnight or are located in rural areas to evade inspection (Wang Li et al. 2018; Van der Kamp 2015). Fees for violations may also still not be high enough, in which case enterprises may prefer to pay them rather than invest in pollution mitigation equipment (Feng and Liao 2016).

The government is now discussing new measures to deal with these problems, in addition to holding local leadership more tightly accountable. The first is to replace pollution fees with pollution taxes to increase the cost of polluting for enterprises and institutionalize it. However, because the pollution tax would be collected by the Ministry of Finance, it is not clear what the allocation of this tax would mean for the resources of the environmental protection system, which has relied on pollution fees to cover the costs of enforcement (Van der Kamp 2015). Other approaches, such as communication between environmental protection agencies and courts to
secure heavier penalties for polluters, are also being tried in some cities, though as discussed below this raises questions about the independence of the legal system (Yu 2015).

3.6.3 Variation in sources, climate and meteorological conditions

Another significant difficulty for pollution control in BTH is the variation in the sources of emissions and in atmospheric conditions. Winter is the time when the largest number of polluted days occur, partly because residential heating increases the burden of emissions, generating as much as 30% of Beijing's pollution in the winter (MEP 2017c). Many communities still also rely on small coal boilers that are inefficient and polluting. This is partly because the grid is not yet established (to provide electric heat) but it is also a matter of economics: installing desulfurization and denitrification equipment at the current price for electric heat is not viable. The burning of low grade coal in rural areas is another problem. This problem is now being tackled aggressively in the strengthened plans by promoting coal-free zones in urban areas and speeding up the program for switching rural heating to gas or electricity but procuring and installing this equipment takes time (MEP 2017c). It is therefore likely that winter will prove a challenging time for pollution control for some time to come. The problem is exacerbated by the fact that temperature inversions that trap pollution are also more common in the winter and wind speeds have dropped (Wang Yuesi 2015). As a result, this is the time of year when emergency measures are most likely to be deployed, with the attendant problems discussed below.

3.6.4 Implications

Air pollution control continues to face significant scientific, practical and political challenges. As is clear from section 1, for effective pollution control, getting the science right matters, and to do that at the local level is a complex task, requiring as it does an understanding of emissions sources and atmospheric conditions. Just as China is now pursuing a targeted (jingzhun 精准) approach to poverty alleviation, it also increasingly needs a similarly locally tailored approach to environmental protection if resources are to be used to maximum effect, but the scientific capacity to do this is still lacking. Assessing and meeting these technical needs will be an important focus of work for the future. Given that it is unlikely that lower tier cities can quickly replicate the detailed inventories and atmospheric models used in the mega cities, it will probably be important to develop rougher but more easily utilizable models for use in the interim.

At the same time, it seems that many of the previous obstacles to the full implementation of policy remain to some extent, including the evasion of inspections and illegal emitting, and
these will need to be tackled if further reductions in emissions are to be made and sustained through improved compliance. But the knowledge base for doing so is also incomplete. For example, there continues to be little information available about the relationship between the costs of compliance and enterprise behavior that would be needed to fine tune incentives and penalties. We know little about how companies make decisions on how to respond to regulation; why they evade, or undermine inspections and monitoring, and when and why they start to comply. Although there is a lot of anecdotal reference to the problem of selective enforcement, we also do not have any systematic information about which enterprises local governments fail to regulate and why, and what percentage of emissions they are responsible for. Overall, it is unclear how much of the gap between the targets and the actual air quality improvement achieved is due to scientific challenges and how much to enforcement issues. As we stressed in section 1, it is certainly not the case that failure to meet the standards is entirely a failure of implementation. But given the costs involved in implementing stricter measures, which we discuss below, it would seem important to research and address this problem.

3.7 Recent Measures

3.7.1 Calls for deeper industrial and energy restructuring

Despite the uncertainties above, most experts concurred that it would be impossible to achieve the 2017 targets or future more ambitious ones without profound restructuring of the BTH region’s energy and industrial structure. Only if the overall scale of emissions were drastically reduced throughout the year would it be possible to achieve consistently good air quality regardless of changes in seasonal needs for energy and in climate conditions.

In 2016 the CAAC and Tsinghua University published a model showing the improvements in air quality that could be expected under the original plan and showing that the targets could not be reached without stronger measures.
They proposed the following additional actions:

- Increasing the coal washing rate to 100% for industry use and banning the use of high-sulfur coal (sulfur content higher than 0.6%)
- Equipping in-use heavy duty vehicles in the region with a Diesel Particulate Filter (DPF)
- Cutting steel production in Hebei by 60 million tons instead of the original target of 40 million tons in order reduce coal consumption
- Upgrading technology in the steel industry in Hebei and Tianjin
- Installing FAB in cement kilns in Hebei and Tianjin, and install SNCR in cement plants in Hebei
- Upgrading dust collectors in Hebei’s coking industry
- Install denitrification facilities in coal-fired heating plants in Hebei and Tianjin
- Limiting the use of Euro3 diesel vehicles in Hebei and Tianjin to keep diesel consumption below 20% of total consumption
- Reducing VOC emissions from key industries by 30%-40% in Tianjin and Hebei, such as the coking, paint, and pharmaceutical industries
- Increasing the proportion of large scale livestock production to 30%, and promote the use of slow release fertilizers in Tianjin and Hebei (CAAC No date).

A second CAAC study looked at the longer term picture of attempting to achieve levels of PM2.5 of 3.5mg/m3 by 2030, modeling the improvement in air quality that would be associated with different approaches, including predominantly technical measures and energy and industrial restructuring. The report concludes that argues that end-of-pipe (Best Available Technology) solutions would need to be supported by an Enhanced Energy Structure in order to meet the target for 2030 (CAAC 2016).
3.7.2 Strengthened BTH Plans and Policies

In June 2016, the MEP and the city governments of Beijing, Tianjin and Hebei jointly released the Strengthened Measures to Prevent and Control Air Pollution in BTH (MEP 2016b). It emphasized that the targets in the BTH Action Plan are hard political tasks set by the Party Central Committee and the State Council and must reached without "deductions" (buzhebukou 不折不扣). It required Beijing, Tianjin, Hebei Province and the cities of Tangshan, Langfang, Baoding and Cangzhou to come up with plans to meet the 2017 goals, with targets to be set down to the street level and responsible people specified and time limits set. It required the specification of coal-free districts in urban areas and that the National Grid and gas and oil companies cooperate in coming up with a plan to move forward the schedule for moving rural areas from coal to natural gas. The schedule for a number of other actions, including ultra-low emissions standards for power stations and tightened control of VOCs were also to be moved forward. Support from central to local fiscal transfers is promised but no amount was given. Monthly checks were to be instituted to monitor progress.

3.7.3 Strengthened Hebei Plan

Even before the regional plan was announced, the Provincial Governor of Hebei announced on March 8, 2016 that the province would engage in more fundamental restructuring. This would involve closing 240 of 400 (or 60%) of steel factories in the province by 2020 and reducing overall production to below 200 million tons a year. Over the next two years, cement production
would also be cut by two-thirds, or 60 million tons, with cuts also in coal and the glass industry (Yu and Liu 2016). The Hebei Province Strengthened Measures to Prevent and Control Air Pollution in BTH, 2016-17 followed in November 2016 and stipulated six measures to ensure that PM$_{2.5}$ could reach 67 mg/m$^3$ across the whole province by 2017, a 13% drop from 2015. These would include speeding up the transition to coal-free energy in Baoding, Langfang and counties bordering on Beijing; closing enterprises with excess capacity or that were in violation, including cutting iron by 10.39 million tons, steel by 8.2 million tons, cement by 1.5 million tons and plate glass by 6 million tons; stepping up enforcement against small polluting industries; compiling a complete inventory of elevated sources with files for each company, closing those that cannot ensure consistent compliance, and bringing them all under online monitoring; and requiring industrial enterprises to produce off schedule in winter. Detailed air quality targets were also set for all individual cities with a focus again on those surrounding Beijing (Hebei Provincial Party Committee and Government 2016b).

3.7.4 Strengthened Local Plans

In response to the MEP Inspection and the Strengthened Measures at the regional and provincial level, cities drew up a new set of plans. These make even clearer the level of action required to reach the targets as well as some of the gaps in previous enforcement, which are mentioned along the way. For example, the Tangshan City Strengthened Measures for Air Pollution Prevention and Control for this 2016 Winter and Spring, issued in November 2016, has new measures mixed in with requirements to ensure the achievement of previous targets. From November 15 to March 2017, many enterprises were asked to conduct production off schedule; all cement factories other than those that are supplying heat or that were in compliance were to stop production; foundries were to be closed for most of the winter; steel and other plants that had not completed desulfurization and denitrification were to stop or limit production, as were power plants that could not consistently ensure ultra-low emissions as long as the power supply to the grid could be ensured. Longer term targets for 2020 were set that involved bigger cuts in the steel industry to meet the provincial target of reducing to 200 million tons by that date (Tangshan City Government 2016b).

3.7.5 Emergency measures become more common

In addition to the introduction of Strengthened Measures, the use of emergency measures to control pollution for short periods also increased. For example, the goal for Shijiazhuang in 2016

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4 Because their higher population and pollution intensities, Beijing, Tianjin, and four neighboring cities in Hebei Province, i.e., Baoding, Cangzhou, Langfang, and Tangshan, are designated as the key areas within BTH in the 2015 Priorities for BTH Air Pollution Joint Prevention and Control approved by the coordination group (ADB).
was to ensure that pollution did not show an uptick, to meet the provincial standard of a 10% decrease in PM2.5 and ensure that there were no days of "index-breaking" (baobiao 爆表) PM2.5. But from September there were a lot of heavy pollution days and it was clear the city would not make its 10% target. Like other cities it began to implement measures usually used only during emergencies (very high levels of pollution) or for special events like APEC, referred to as “chopping pollution with a sharp sword” (利剑斩污). The Shijiazhuang government announced that from November 17 to the end of the year, or 45 days, only odd or even numbered cars would be permitted on the roads and almost 1000 steel, coking, cement, glass, ceramics, pharmaceutical and chemical factories were told to stop production on three or four hours notice. One cement factory that usually produces 4500 tons a day was completely stopped and the workers sent home (Sina 2016).

The legal and other questions raised by the normalization of extraordinary measures (chaochang cuoshi 超常措施) are discussed below.

### 3.8 Governance Challenges

As mentioned above, a great deal of research has investigated the reasons behind the gap between environmental protection law and policy and its implementation at the local level (for summaries see Kosta 2017, 2014; and van Rooij et al 2017). As air pollution control has intensified, some of these challenges are becoming more salient, as the government attempts to establish coordinated regional pollution control systems that involve multiple levels of government and multiple policy streams; and struggles to meet fixed air quality targets in the face of fluctuating levels of emissions from different sources and changing meteorological and climate conditions.

There is little published research on these processes yet, but at the FORHEAD annual conferences in 2015, 2016 and 2017, several researchers discussed challenges relating to the institutional forms and legal and administrative measures being used to implement pollution control in BTH (Yu 2015; Van der Kamp 2015). This discussion below draws largely on their presentations, as well as some of the interviews with experts reported in Wang Li and colleagues (2018). Although these concerns may also apply to many other sectors, in the interests of space we use examples largely from the industrial and transportation sectors.

#### 3.8.1 The tension between law and administrative measures

As we have detailed above, air pollution prevention and control is being implemented through a complex mix of laws, plans and policies at the national and local level, but the relationship
between these, the extent to which standards and targets are binding, and the authority of
different entities to issue standards and targets is in many cases unclear. Some plans are public
and have undergone formal approval processes, such as the BTH Coordinated Development Plan,
which was approved by the Central Party Central Government Politburo. Others are
administrative documents and so while government actors may be obliged to act upon them,
they are not legally binding on enterprises. These include the Coordinated Development
Ecological Protection Plan, the BTH and Surrounding Areas Medium to Longterm Air Pollution
Prevention Plan, the BTH Severe Pollution Early Warning and Coordinated Action Plan, and the
BTH and Surrounding Areas Automobile Emissions Pollution Control Coordinated Work
Implementation Plan. Many of these plans and policies contain targets and implementing
measures that are not incorporated into laws.

The unclear legal status of these objectives can make it hard to enforce them, but at the same
time, targets which are binding on local officials through performance assessment systems may
still be aggressively pursued and impose significant costs on enterprises, governments and the
public (Yu 2015; Feng and Liao 2016), for example when production is suddenly cut, or vehicle use
restricted. There is also a problem of transparency because many of these plans have not been
published but shared only with officials of a certain level and experts (Yu 2015). As a result, there
has been no public discussion, and it is impossible for enterprises to plan ahead in order to
ensure compliance. An exception is the List of Industries to be Restricted or Prohibited from
Increasing Production in Beijing, which is published every year and thus serves as a guide to
industry, reducing the problem of sudden closures or cuts in production.

3.8.2 New institutions: their mandates and authority

The implementation of regionally coordinated air pollution control is requiring the establishment
of many new institutional structures at the national, regional and local level, and new questions
are emerging about the status, authority and responsibilities of these, as well as their
interactions. In BTH, the most important institution is the Small Working Group for Cooperation
on Prevention of Air Pollution in BTH. This working group was set up in 2013, and involves seven
provinces and eight ministries. According to the Administrative Organization Law this working
group would be classed as a coordinating body (议事协调机构): it has an official seal, can issue
government documents, and is relatively stable and formal. In other cases, the legitimacy,
authority and stability of new institutions is a question. For example, the status of the Air Quality
Early Monitoring Platform and the Office for Vehicle Emission Control in BTH, which were

5 At the regional level, there are seven provinces/autonomous cities participating: Beijing, Tianjin, Hebei, Shandong, Neimeng,
and the newly added Henan. Within these are six core cities: Beijing, Tianjin, Tangshan, Langfang, Cangzhou and Baoding.
reportedly set up in June 2015, is unclear: it is not known whether they are intended to be temporary or permanent bodies and what their legal and administrative powers are. This matters because their actions can have important consequences. The aggressive plan for reducing power plant emissions in Hebei is another example: it required that by the end of the year all power stations must reach very low emissions requirements or they would be closed. Although it was later formalized, the initial notice was issued by the Hebei Atmospheric Pollution Prevention and Control Working Group Office. It is not at all clear that this is a stable institution with the right to issue formal policy documents, despite the fact that these measures will have a significant impact on the local economy (Yu 2015).

3.8.3 Emission-reduction policies and property rights

In the case of both industry and transportation, reducing emissions levels often requires tackling the problem of the scale and/or number of emissions sources, because technical upgrading alone cannot produce the necessary reductions. But this raises complex legal issues. In addition to the issue of institutional legal standing above, questions are also arising about the legal implications of some of the methods being employed. The first regards temporary stops in production and the use of vehicles, which are authorized by the Air Pollution Control Law and which occur quite frequently in response to heavy pollution events or important political meetings. For example, during the APEC meeting, Beijing used the odd and even license plate measure to restrict cars; and 300 enterprises had to stop or limit production.

While these measures may be acceptable on a short-term basis to protect public health during severe pollution events, Beijing Deputy Mayor Zhang Li Tuxiang has discussed making the car policy a permanent one as a regular pollution control measure. Furthermore, while some of the factories that have been ordered to stop or limit production are in violation of emissions standards or operating illegally, it appears that at least some have valid business licenses and are in compliance with environmental standards. An order to close them or force them to reduce production would usually be classed as an administrative penalty (xingzheng chufa 行政处罚) and according to the rules of the Administrative Penalties Law this can only be done following a hearing. Yet there have been no reports that these procedures are being followed. If not construed as an administrative penalty, temporarily prohibiting an individual from exercising their right to drive a car or an enterprise from producing goods in a facility that is operating legally could also be considered regulatory expropriation. But both the Constitution and the Property Rights Law require that if citizen’s property is expropriated there must be compensation (Yu 2015). Emergency pollution control measures therefore entail questions about legality and about the distribution of the costs involved. There is also the question of what constitutes an ‘emergency’ when these measures are taken to ensure better air quality not only
when pollution is very severe, but also for international meetings and other important political events (Yu 2015).

The legal standing of the many new environmental standards being issued is also unclear. Article 15 of the January 2015 Environmental Protection Law indicates that provinces can set their own standards that are stricter than national ones, requiring only that provinces must give an explanation for these standards and not discussing their legal status. For example, some researchers are of the opinion that requiring all power stations to meet very low emissions is just a local measure without legal force, but it has nonetheless been aggressively enforced. There is also the question of how long enterprises and vehicle owners should be given to come into compliance with new such requirements – only six months was given in the case of the power station emissions plan. Lastly, there is also the issue of the how the costs of implementation will be borne. The plan is to cover the higher costs of energy resulting from the ultra-low power station emissions standards by subsidizing electricity prices by 0.08 yuan per unit. This will be an enormous outgoing, but it does not appear to have been approved as a fiscal expenditure by the People's Congress and if it has not been, then it does not confirm with the rules of the Budgetary Law (Yu 2015).

3.8.4 Balance of authority and responsibilities between government agencies

In some cases, the implementation of air pollution control measures is not in accordance with the arrangements stipulated in the most recent plans. For example, Feng and Liao point out that according to Section 2 of Article 15 of the APPCL, local governments have the authority to verify the total amounts of air pollutants emitted by enterprises and issue air pollutant emission permits. However, in fact these tasks are carried out by the EPB and this seems the more sensible division of labor given that the necessary expertise and professional capacity lies with the EPB. Meanwhile, Article 3 of the Air Pollution Law makes local governments responsible for air quality within their jurisdictions. However, it does not indicate how this responsibility will be evaluated or what will happen if air quality targets are not reached. Articles 4 and 11 of the Air Pollution Law established a target responsibility system and require any municipal government not meeting national Ambient Air Quality Standards to prepare an air quality attainment plan and achieve air quality objectives within a time limit. However, the exact nature of government responsibility for air quality remains sketchy and is not yet backed up by concrete provisions in administrative regulations or departmental rules (Feng and Liao 2016).

Another cross-ministry issue relates to interactions between the environment protection agencies and the legal system. There have been reports that many localities are referencing a practice initiated in Zibo Municipality in Shandong. The city has set up a new system of Joint
Conferences (lianxihuiyi, 联系会议), in which the environmental protection agency meets with prosecutors and judges to discuss how to conduct the legal punishment of criminals in cases of environmental pollution incidents, for example by giving prison sentences, or higher fines. While this might seem an effective way of ensuring a deterrent effect, it goes against the Constitution, which stipulates that People’s Courts must make independent judgments, and be free from interference by administrative organs, social groups or individuals. Strictly speaking, such meetings are not legal (Yu 2015).

3.8.5 Implications

Although the issues above are not yet well understood, the urgency with which stricter pollution control is being implemented is leading to a proliferation of new types of measures, institutions and methods which raise important questions regarding the legal status and authority of the issuing agencies, the rights of the individuals and enterprises they affect and the distribution of the costs involved. These will need to be addressed if policy is to be implemented in a way that is both effective and fair. Understanding the reasons for the continued ‘implementation gap’ even in the face of such intense pressure from the central government will continue to be an important focus of research. At the same time, if environmental protection policies are to be consistent with efforts to strengthen the rule of law in China, attention also needs to be paid to the tensions between effective regulation and legal due process.

3.9 Economic and Social Costs, and Distributional Effects

Regardless of whether they tackle air pollution from the perspective of scale, density/location, inputs or technology, most air pollution control policies will involve costs, including administrative costs associated with monitoring pollution, processing pollution permits and enforcing laws and standards; the costs of technical upgrading, pollution mitigation equipment or cleaner inputs; and the broader costs of industrial restructuring that will affect not only enterprises but also government revenues and employment. Like air pollution itself, the costs of control are both complex and potentially quite mobile. They need to be understood not only in terms of total amounts, but also their breakdown across sectors and regions: the differential impacts they will have on the fiscal resources of various levels of government, and on consumers and workers in different parts of the country (for a discussion of the various costs that are potentially associated with environmental regulation, see Fullerton 2011; Fullerton and Muehlegger 2017; OECD 2001).

While the principle of the ‘polluter pays’ suggests that producers should bear the cost of pollution control, as regulation tightens and increasingly effective and expensive technologies
are deployed, or industries restructured, producers may pass costs on to consumers in the form of higher prices for energy, steel, vehicles and other goods and services. This is a good thing in the sense that formerly externalized environmental costs are factored into prices, but it may sometimes also have regressive distributional consequences (Fullerton 2011). If the government considers costs to be unsupportable by industry or consumers, it may decide to spread them more broadly by using public funds to subsidize the cost of installing pollution mitigation facilities or moving factories, or the price of electricity, or the costs of resettling or providing social insurance for workers. However, in doing so it must still draw on revenue from taxes drawn from enterprises and working citizens and new questions arise regarding the balance of central and local government contributions.

Unpacking the array of different costs that may be associated with a particular form of environmental regulation, and the distribution of these costs across different actors (which is referred to as the incidence of environmental regulation) is an immensely complex analytical task and, probably for this reason, it is an under-developed area of research (Fullerton 2011). Yet, the question of who should pay for which costs is also not only a practical - and as we saw above, a legal - problem, but also a complex ethical one. While we cannot possibly cover this large territory adequately in this short report, below we discuss a few of what seem to be the most important issues that will need to be investigated further in the coming years.

3.9.1 What do we know about the cost of air pollution control?

A report by the Clean Air Alliance of China (2015a) estimated that China would need a total of RMB 1.84 trillion to execute the original Action Plan, of which the BTH region would require RMB 249.03 billion. This would include RMB 63.65 billion to improve energy structure, RMB 76.91 billion to control pollution from mobile sources and RMB 108.46 billion to treat pollution from industrial sources.

The same report estimates that implementing the Action Plan would have positive effects on national GDP. It states that new environmental industries will raise national GDP by RMB 2.8 trillion, while eliminating outdated industries will reduce GDP growth by only RMB 776.2 billion, for a net GDP increase of RMB 2 trillion. The BTH region is expected to see a net increase in GDP of RMB 3.6 billion, proving that investing in cleaner air "can ultimately support sustained economic growth and increase employment on a relatively short timeline" (CAAC 2015a).

It is to be hoped that these optimistic predictions are accurate. However, there are reasons to be cautious. The first is that it does not appear that the money that it is said is needed to produce these outcomes is yet being invested. The central government provided only RMB 5 billion and RMB 10 billion during 2013 and 2014 for air quality improvement measures, leaving a large
deficit in relation to the amount said to be needed (CAAC 2015a). Potentially, this leaves the majority of the funding to be found by local governments or passed on in some way to enterprises and consumers. It is not yet clear where the rest of this funding will come from or to what extent the gap in funding is partly responsible for the failure to meet targets. Certainly, some local governments report that they do not have sufficient funds to implement policy (see below).

The Strengthened Measures mean that the cost has now increased, but no price tag has been made public, nor has the division of fiscal responsibility across jurisdictions. Only a few indications can be gleaned from media reports. For example, from reports on the Beijing People’s Congress budget review in January 2017, we learn that the city’s estimated budget for 2017 is RMB 541.16 billion up 6.5% from 2016 figure of RMB 508.13 billion. Of this, the city apparently spent RMB 13.4 billion on pollution control in 2015, and RMB 16.56 billion in 2016. The planned expenditure for 2017 is RMB 18.2 billion for an average annual increase of 10%. This means that Beijing is now spending just over 3% of its budget (The Beijing News 2017) which meets the target that is recommended.

At the moment, there is no (publicly available) itemized account of government expenditures on air pollution control. However, whereas most expert reports until recently focused on suggesting measures that might achieve the air quality targets without discussing the cost, a recent report from Renmin University has raised the question of whether the targets should be revised in light of the impact on regional GDP of implementing the Air 10 Plan. It estimates at 8.45% of GDP by 2017 and 16.05% by 2020. As the methodology for this analysis is not available it is not possible to assess the accuracy of these estimates, but on the basis of this conclusion that the costs of pollution control will escalate, the report recommends setting an annual average concentration of 70 mg/m³ as the transitional target, with 60 mg/m³ as a medium-term target, and shifting the focus of policy to controlling the number of serious pollution days, especially in winter (Zhang Nan 2017).

3.9.2 Costs borne by enterprises

Many enterprises, especially in the iron and steel, cement, glass and power sectors, have been subject to an increasingly strict set of technical requirements over the last few years. We currently know very little about the impact of these measures on the financial circumstances and behavior of enterprises. Unpacking their effects in the context of a slowing economy and falling demand in some key sectors such as steel is challenging, but in their discussion of barriers to economic restructuring in Hebei, Mu (2015) and colleagues mention that companies are struggling to keep up with repeated requirements to upgrade equipment, that subsidies are insufficient and loans hard to come by because of strict lending requirements.
Some enterprises will be forced out of business and in some sectors this is the goal, especially in the context of over production, but it is not clear how generalized the problem is or where the tipping point lies in terms of enterprises’ capacity to finance technological upgrades. These costs are also likely to be passed on to a certain extent to consumers, and so it will be important to understand the impact on the cost of goods and services, especially vital ones such as energy and transportation. To avoid pressure on poor consumers, the government is in some cases already picking up some of these costs, for example by subsidizing the increased cost of electricity due to tighter emissions standards for power plants in Hebei. But it seems these investments have not been factored into local government budgets (Yu 2015). This means that if central government transfer funds are not forthcoming, local governments will have to draw down on funds originally allocated to some other purpose, with potential negative impacts on public services. Figuring out how which costs can and should be borne by enterprises and which need to be subsidized by government at different levels will be an important issue for research and policy. Until these questions are better understood, it seems it might be wiser to focus on improving compliance with existing policies and avoid introducing new standards until financial mechanisms are in place to support their implementation.

3.9.3 Administrative costs for local government

Stricter air pollution control brings new administrative costs for local governments, which are largely responsible for monitoring emissions, conducting inspections, and issuing permits and fines. There are also costs involved in participating in regional pollution control efforts. Central and provincial governments negotiate a budget together at the beginning of the year to support a set of priority targets for the province (Van der Kamp 2015). Municipal governments are being encouraged to allocate at least 3% of their budget to air pollution control and to prioritize it over other types of environmental protection in the fiscal allocation. However, it seems from the work of the CAAC in prefecture-level cities like Changzhou that lack of financial resources is a problem. The city has not been able to assign the targeted 3% of GDP to environmental protection and says it does not have sufficient resources for research, personnel training and enforcement (CAAC 2015b). It also seems that this prioritizing of air pollution may not necessarily be appropriate for all cities, which may have different constellations of environmental problems.

Details of these municipal budgets in relation to the actual costs of enforcement are not available but it does seem as if local governments are under significant pressure. In her research in Wei County in Handan Municipality, the local EPB told Van der Kamp (2015) that dealing with the flood of enterprises applying for newly required emission permits was a struggle because they did not have the financial resources or personnel to process these permits in a timely fashion. In the same study, the Hebei provincial EPD reported that the budget for environmental regulation was too rigid in terms of the allocation of funds for specific purposes (a problem that has been
reported in many policy spheres where funds are tied to specific programs). Sometimes, the central government added requirements later in the year or pollution incidents occurred that entailed unexpected expenses. For example, if climate conditions result in a sudden build up of pollution, local EPBs will be required to take emergency measures for which funding has not been allocated.

A recent article by Christine Wong and Valerie Karpus (2017) takes a somewhat more optimistic view, pointing out that the expansion of transfer programmes has led to 50% of the total expenditure on energy saving and environmental programs being born by central government. However, they also observe that it is not clear how the various costs of air pollution control will be "divided up between public coffers, industries and households" and that even when funds are sufficient, human resources are often not. If air pollution control policies are going to be consistently enforced, these financial and human resource problems will need to be better understood and addressed.

3.9.4 Impacts of air pollution control on local government revenue

The ability of local governments to absorb the costs discussed above will depend in large part on their revenue streams and on the degree to which revenue is dependent on taxes paid by industries that are targeted for emissions control. The backdrop to this is the underlying economic uneven development across and within China’s regions: the per capita GDP of Gansu in 2015 (26.165) was only about a quarter that of Beijing (RMB 107,497) and that of Hebei (40,255) less than half. In 2005, the richest province had more than 8 times the per capita spending power of the poorest and the richest county 48 times as much as the poorest (Dollar and Hofman 2006). This situation is exacerbated by the fact that sub-national governments bear a heavier burden of fiscal responsibility than in most other countries, being responsible for as much as 70% of expenditures on public services, including health and education, while receiving only 40% of tax revenues. While transfers from central to local governments offset this gap to some extent, they are insufficient and are also often earmarked for specific purposes (Dollar and Hofman 2006).

Additional costs for air pollution control are occurring in the context of an overall slowdown in economic growth, and this drop may be exacerbated in some cities if industries affected by air pollution control measures are substantial contributors to government revenue: at least in the short term, successful enforcement of air pollution control measures is likely to reduce enterprise profit margins and therefore the amount of tax they pay. For example, it is regularly cited that a reduction of 10 million tons of capacity in the iron and steel industry will reduce government revenue by RMB 1.42 billion (Jiao Feng 2016).
This ‘pincer effect,’ where costs rise and revenue falls (Van der Kamp 2015) could have a number of effects. The first is that it could reduce the motivation to enforce regulations, especially if cities are already facing a fiscal deficit. It is difficult to assess the extent to which this is happening directly, but Van der Kamp and a colleague have done so indirectly by investigating the effect of financial deficits on cities' score on the Pollution Information Transparency Index, a measure of their record in environmental information transparency and enforcement performance developed by the Institute for Public Affairs and Environment. They found that cities with a worse than average fiscal deficit had a score on average 18 points lower than those with a better than average fiscal balance (out of a total possible score of 70. This is the equivalent of falling from Beijing’s enforcement performance to that of Lanzhou and it shows that a strong association between local financial resources and environmental regulation performance. (Van der Kamp et al. 2017).

Another question is what the impact of greater investment in environmental protection is for local government expenditure in other areas such as healthcare, education and poverty alleviation for which they are primarily responsible. At the national level, in 2014, government expenditure on health was 5.5% of GDP and 10.10% of total government expenditure. The burden of health expenditure still falls heavily on individuals. In 2014, 44.21% of health expenditures were made by the government, and 31.99% of all health expenditures were paid out of pocket. This is an improvement from 2000, when government expenditures were only 38.26% of all health expenditures, and 58.98% of all health expenditures were out of pocket (WHO 2016). However, it is clear that there is still considerable room for government to ease the burden of health costs on individual households. This must be considered in the context of the fiscal inequalities discussed above which mean that poor areas face the tightest budgetary constraints. China will face hard decisions in the coming years over how best to allocate scarce resources to improve public health.

We do not have a good picture of how this situation is playing out and the situation will inevitably vary greatly across cities depending on how dependent they are for revenue on industries targeted for restructuring and how well situated they are to develop other sectors. But some media reports illuminate the tradeoffs that are facing cities that are heavily dependent on polluting industries. Tangshan again is a good example given its reliance on iron and steel. In 2015, Tangshan city’s total government income fell 20% from the 2014 figure of 56 billion. In terms of expenditures, the amount spent on public security fell from 1 billion in 2014 to 0.8 billion in 2015, while spending on social security and employment insurance (rather worryingly in light of the impact on employment discussed below) also fell from 0.75 billion in 2014 to 0.69 in 2015. The city, which has the biggest economy in Hebei, was dependent in 2015 on central government subsidies for 42% of its revenue (Ma Jihua 2016).
3.9.5 Industrial restructuring and impacts on employment

Industrial restructuring is a key part of the strategy to control air pollution in BTH and especially in Hebei, and for good reason. Industry has dominated Hebei’s economy since the 1970s, hovering at around 50% or more of provincial GDP. Within industry, heavy industry accounted for 80% of the value of output in 2012. The dominant industries are steel, coking, cement, plate glass and paper, all of which are high energy and high polluting and targeted for control. Steel alone accounts for 25% of GDP. Meanwhile, Hebei’s service sector is fairly small, having grown from 20% of GDP to just over 30% in 2012. Within the sector, traditional services, including transportation, hotel and catering and wholesale and retail account for a much larger percentage of GDP than modern services including finance and real estate. However, the latter have been growing at a faster speed from their low base (Mu 2015).

Figure 15. Changes in industrial structure in Hebei, 1978-2014

Figure 16 Change in the composition of the service sector, Hebei, 2005-15

Source of figure 15 and 16: Mu, 2015
This concentration of industry means that, for Hebei, technical upgrading to the best available pollution technology is not going to be enough: the scale of production is simply too large. Restructuring the province’s economy to reduce reliance on polluting industries and its energy structure to reduce reliance on coal will both be necessary. This is why reports like the two recent ones from CAAC, and others by the World Bank, the CICCED and others, all strongly recommend industrial and energy restructuring: nearly all scientific experts are of the opinion that BTH cannot meet its long-term air quality targets without industrial restructuring and many have advised accelerating the process in order to ensure that the 2017 targets can be met. This advice has been taken up and included in the strengthened plans for BTH, for Hebei, and for Tangshan.

However, restructuring will have implications, not only for GDP but also for employment. In most available accounts, the potential employment impacts of industrial restructuring are discussed on an aggregate level, in terms of the total number of positions that may be lost in heavy industry and created in new ones, in particular green energy. Some estimates of the likely impact of restructuring on employment are encouraging. The CAAC report on the costs of implementing the (original) Air Pollution Control Plan estimates that it will have positive effects on employment, with new environmental industries creating 3.8 million jobs, and the elimination of outdated industries resulting in the loss of only 891,800 jobs, for a net growth of 2.9 million positions. The BTH region is expected to see a net increase in a net job growth of 41,000 million positions (CAAC 2015a). The Paulson Institute (2015) cites a 2010 study by the Institute for Urban and Environmental Studies (IUE) and the China Academy of Social Sciences (CASS) which estimates that green growth policies such as investment in renewable energy technology and energy efficiency technologies would directly or indirectly create 30 million jobs, while closure of small coal plants would cost 800,000 jobs; the study further estimated that by 2020 over 1 million jobs would be created in emissions control and higher-efficiency coal combustion plants and suppliers, and over 4 million jobs in renewable energy.

These figures may be accurate, but none of these studies provide a clear account of the methodologies used to produce them, so it is hard to evaluate them. More importantly, even if they are accurate in the aggregate, in considering the impact of industrial restructuring on employment, it is important to consider labor market flexibility across sectors and locations (Fullerton 2011). Many workers have specific skills that are not transferable; high end service industries generally require high levels of education; and even low end jobs in the catering or retail sector often require soft skills that many older industrial workers who will be hardest hit by restructuring lack (Kollmeyer and Pichler 2013). Therefore, while the aggregate effect may be positive on the national or regional level in terms of the total number of jobs created, the employment impacts of restructuring will probably be unevenly distributed and more
concentrated in some cities and among sub-groups of the population.

There have been few empirical studies of the impact on employment of more recent, air pollution-related policies, or at least few that have been published. One study, conducted using data from the Hebei Department of Human Resources and Social Protection, analyzes the impact on employment of the provinces 6643 Plan to reduce excess production and reduce emissions from the steel, coal, cement and glass industries. The HDRSP estimated that by 2017 these policies will cause the loss of a million positions, of which 400,000 will be direct losses and 600,000 indirect. It gives the example of Tangshan, which is a target area for reduction of excess steel capacity, estimating that the reduction of 40 million tons of steel will directly affect 70-100,000 jobs, directly. Given that the ratio of jobs indirectly dependent on the steel industry is 1:5, this means that in Tangshan alone about 400,000 workers will need to be resettled by 2017 (Bian 2015). Tangshan had a population of 7.3 million in 2014 and a working age population (generously understood as those aged 15-55) of 4.78 million, so this already amounts to about 10% of the workforce just for recent restructuring in the steel industry. Not surprisingly, there is concern that if this is not handled well, it will not only affect these workers and their families, but also have knock on effects and increase social instability (Bian 2015).

Another survey of 128,400 workers affected by the culling of 826 outdated enterprises in 2011-2013 found that 52% were resettled by finding other jobs in the same enterprise industry, 14% found other work or set up businesses, and another 11% found work through other means. 23% were migrant workers who returned to the countryside, 90% of whom moved elsewhere for employment. This is encouraging, but it can also be assumed that the more workers are laid off, the harder it will be to absorb them locally; furthermore, there is little information in the study about the nature of the new employment in terms of its security, wage levels and benefits. Despite its optimistic conclusion, the article notes that stronger policies will be needed to deal with worker resettlement, including training, and the creation of new opportunities in new industries and the service sector (Bian 2015).

Another study, by Yang Lichao, suggests that the impact of restructuring will also be very different across sectors and types of enterprise and picks up on the problem of migrant workers mentioned above. Her study in two counties in Hebei, where cement production and rock breaking employed the majority of workers, found that most of those unemployed had not found other work but were still at home, living off savings and trying to figure out what to do. County governments were trying to develop alternative plans for development, including clean industry and tourism, but were a long way from having viable options to for the local resettlement of laid-off cement workers. It seems from this study that workers in smaller, informal industries, who have no unemployment compensation and low skills, will find it harder than workers in
larger, formal enterprises to find work. This suggests that to the extent that pollution control policies affect employment, the result is likely to be regressive, hitting the least resilient workers and their families hardest (Yang 2015).

Most other information on employment impacts comes from the media, but the story is often complicated by the fact that environmental policies are intersecting with other policies to reduce excess production capacity. One article in May 2016 focused on excess capacity in the iron, steel, coal, cement and plate glass industries. It notes that these industries were also labour intensive, and that the government estimates that 10 million employees may eventually need to be resettled (Jiao Feng 2016). Of those who would be laid off by the end of 2017 due to industrial restructuring associated with 6643 in Hebei, 700,000 were formally employed workers with insurance and 358,000 were migrant or temporary workers with no insurance. While it is not clear where the information comes from, the report states that "about 310,000 migrant workers will need new jobs" (Jiao Feng 2016).

3.9.6 Policies to address employment impacts

The government is aware of this problem. Article 5, clause 7 of the State Council document 41 for 2013, "Guiding Opinions on Solving the Contradictions from Serious Overproduction" tasks every level of government with making arrangements for the re-employment or resettlement of laid off workers (State Council 2013b) and a follow up document in 2016 calls for stronger implementation, both of restructuring policies (and strict enforcement of environmental standards as one means to this) and of policies to support the resettlement of workers. But there is no systematic analysis of how these policies are being implemented. Media reports state that the central government allocated RMB 100 billion in 2016 for this work (Jiao Feng 2016) and that four main approaches are being encouraged: transfers to new positions within the same company; assistance with finding work in other subsidiaries of the firm or other companies; early retirement and public service employment.

In 2014, Hebei Province also introduced new policies to use the unemployment insurance fund to fund qualified companies to retrain workers, subsidize certain positions, and supplement social security to minimize layoffs. Apparently, since 2014, enterprises that provide jobs for laid off due to overcapacity cuts will receive a subsidy of RMB 1,000 per job, while firms that hire laid

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6 This report states that in 2012, the steel, cement, aluminium plating, flat glass industries production utilization rate was only 72%, 73.7%, 71.9%, 73.1% and 75%. It is not clear how this translates on a provincial level, but it seems that several of these industries are cutting well beyond the 25-30% mark, at least in specificities.

7 This report states that in 2012, the steel, cement, aluminium plating, flat glass industries production utilization rate was only 72%, 73.7%, 71.9%, 73.1% and 75%. It is not clear how this translates on a provincial level, but it seems that several of these industries are cutting well beyond the 25-30% mark, at least in specificities.
off workers will be given tax and fee exemptions, subsidized loans and other subsidies for three years. Altogether Hebei has granted RMB 16 million in social insurance subsidies for workers and RMB 532,000 to enterprises (Jiao Feng 2016). The same media report states that Xingtai City has altogether offered 34 companies RMB 58.52 million in subsidies, assisting more than 50,000 employees. This piece casts restructuring as challenging but as involving 'temporary obstacles' and ultimately resulting in more fulfilling and better paid work for many employees, even some older ones (Jiao Feng 2016). However, despite the optimistic gloss, the report ends, "As time goes on and corporate financial pressure increases, the employment situation in the province will undoubtedly worsen." (Jiao Feng 2016).

Beijing is trying to kick start the development of light manufacturing, services and high tech industries by moving enterprises out of Beijing to Hebei including car manufacturing companies, pharmaceutical companies, and chemical companies. Yet, Hebei's severe lack of skilled and managerial labour means that the local labour force may not benefit immediately from the arrival of these new industries. Mu (2015) points to the example of Beijing Xianlai, a car company that moved from Beijing to Cangzhou in 2014. The factory was expected to bring a total of 6000 jobs to the local economy. Yet of the first wave of 1000 high-tech, high-skilled and managerial staff hired in 2015, only a small fraction of hires were from Hebei. The others were recruited from all over China, because Hebei lacked the labour pool to meet this company's high standards.

3.9.7 Implications

When asked whether continued improvements in air quality in BTH could be achieved, Chen Jining observed, "It depends how much you want to pay" (MEP 2017c). This it seems, will be one of the major questions for air pollution going forward. Another will be, "Who should pay for what?"

The implementation of the new air pollution control policies will entail a variety of costs about which we currently know far too little. No firm conclusions can be drawn from the small number of studies available. What these examples suggest, rather, is that we need to know more about the likely impacts of different pollution control policies on enterprises, government revenue and employment. Only with this information will it be possible to factor these costs into cost-benefit analyses of different policy options and allocate costs in a rationale, sustainable and fair way. Given the very different levels and sources of revenue of different local governments, and the fact that they also bear the burden of financing most public services, such analyses will be crucial for understanding needs for fiscal transfers and social policies to support municipalities in implementing air pollution control policies and avoid regressive effects.
The way in which the costs of industrial restructuring are distributed will be of crucial importance. But while these costs are certainly on the minds of government agencies in regions such as Hebei that are being heavily affected, they have not received sufficient attention from analysts. At best, the uneven distribution of such costs is noted in some studies as a "political risk" (ADB 2015) that may impede their implementation. But this is not just a risk; it is also a matter of social justice, and if stronger environmental protection is not going to come into direct conflict with other equally important policy goals such as reducing poverty and inter-regional and rural-urban equality, it needs to be better understood and addressed. This should be an important area of research going forward.

3.9.8 International experience of industrial restructuring

The tension between improving environmental quality and maintaining the benefits for health of economic growth, particularly for countries undergoing intense industrialization and urbanization, is evident in the history of many other countries in the world. Although mobile sources continue to be a problem, most of these countries have now brought industrial sources of air pollution under control. This raises the question of what China might learn from their experience.

The United States and Europe did not attempt to implement strict environmental protection or environmental health measures when they were at China’s current level of development and urbanization. Serious concern with the health impacts of pollution in the US is often dated to the publication of Rachel Carson’s *Silent Spring* in 1962, and it was not until the 1970s that environmental protection got into full swing. By this time, the US was a rich country (per capita GDP in 1970 was $15,030 (Maddison Project 2013) that was already de-industrializing. In 1973 only 24% of the workforce was employed in industry and this fell to by 2007 (Lee and Mather 2008). It was also already a highly urbanized country, with its cities and road system in place and much lower demand for steel and cement for basic infrastructure construction and housing. The costs of addressing pollution (estimated at $523 billion for 1970 to 1990 in 1990 dollars), were therefore relatively low and far outweighed by the benefits: by 42 times according to the US Environmental Protection Agency (United States Environmental Protection Agency (EPA) 1997).8

Nonetheless, the costs of industrial restructuring were significant and they were regionally concentrated. While many international organization reports point Chinese to optimistic examples of cities - Pittsburgh, for example - that have now re-vitalized as centers of high-technology or knowledge industries (Paulson 2015), international experience is by no means

8 This is a mean estimate; taking uncertainty into account gives a significant range of 10.7 to 94.5
universally positive. Many former industrial areas of the United States have wrestled with long term problems of unemployment among industrial workers (Lee and Mather 2008); and some researchers of the economic transition from industry to services in the OECD have argued that it has been associated with the long term rise in unemployment rates since the 1970s (see Kollmeyer and Pichler 2013 for a summary of this literature). Long term and unstable unemployment have severe effects on the health and wellbeing of the individuals without work and on their families, affecting the life chances of future generations. They also have repercussions for social cohesion and stability: it is arguable that the recent Brexit and Trump votes in the UK and the US are to some extent the result of the long term failure to deal with the broader social divide created by de-industrialization.

3.9.9 The Ruhr Valley

An illuminating and unusually well-documented example is that of the Ruhr Valley in Germany. Like Hebei, the region was dominated by heavy industry and industrial restructuring was prompted by a combination of economic competition and environmental concerns: the region faced serious air and water pollution. As the charts below show, in 1961 the industrial sector (production industry), including coal and steel but some other industries as well, employed 1,426,000 workers, accounting for almost 62% of total employment in the Ruhr. By 2011, this sector employed just 496,000 workers. Almost one million production industry jobs had been lost, representing about 40% of all employment. Service sector job growth, however, was robust: almost one million new service industry jobs were added over the same period. As a result, the total number of jobs in 2011 was about the same as in 1961. While production industry jobs fell from 62% of the total to 21%, service industry jobs rose from 38% to 78%.

Figure 17 Change in employment by sector in the Ruhr Valley, 1961 to 2011

Source: Adapted from Institute for Industrial Productivity 2015, which draws on data from the
Restructuring in the Ruhr was therefore successful, in the sense that services have now replaced polluting industry as the core of the economy. However, this was a painful process. The most difficult period was in 1987 and 1988, when the unemployment rate reached 15.1% from the effects of coal mine and steel plant layoffs; and even more than forty years later, in 2013, unemployment remained high, at 12.1% in the Ruhr, compared with 9.1% in the region and 7.4% in Germany as a whole (RVR Databank cited in Institute for Industrial Productivity 2015). During this period, the region also lost 11% of its population.

**Figure 18**  **Total employment in the Ruhr Valley Region 1961-2011 (000s)**

![Graph showing total employment in the Ruhr Valley Region from 1961 to 2011.](image)

Source: Adapted from Institute for Industrial Productivity 2015

The transition out of heavy industry in the Ruhr took place in the context of a well-educated workforce and much more comprehensive provision for unemployment benefits and retraining than exists in China today. The transition was also supported by massive infusions of funds for industry development and education from the national and regional level. Of course, China's situation is different in many ways and environmental protection is not the only factor driving change: the industrial sector is also affected by rising wages, international competition, and, increasingly by technological change, particularly the rapid introduction of robots. The point here is merely to show that there are reasons to believe that economic restructuring will create additional pressures on employment in some parts of the country in the short and medium term.

3.9.10 **Leap frog transitions, employment structure and human capital**

Different parts of China are very differently positioned in terms of their ability to make the transition out of resource intensive, polluting industries. For example, there is a four-fold difference between the per capita GDP of the richest provincial-level city of Tianjin, at 99,607...
RMB, and the poorest province of Guizhou at 22,922 RMB) (National Bureau of Statistics (NBS 2014). Their economic structures and levels of human capital are also very different: in 2013, 65 percent of Guizhou’s population was still employed in agriculture, and in 2011, only 12 percent of the province’s population had a high school education or more (NBS 2014). It will be difficult for poor provinces like Guizhou to transition quickly to high value industry and services, and it is not surprising that the expansion of polluting industries such as steel, cement, chemicals and ferrous metals is strong in western China. Avoiding rising emissions and health effects in those areas will be hard.

Even within BTH, the structure of employment and the uneven human capital base present a major challenge. In 2015, Beijing and Tianjin had per capita GDPs of more than 106,000 RMB, while Hebei’s per capita GDP was just 40,255. Within Hebei, the per capita GDP varies between 24,193 RMB (Xingtai City) and 78,232 RMB (Tangshan City) (Hebei Economic Statistical Yearbook 2015). Beijing, where services already account for 80% of GDP, and high value services are a large part of that, the transition will be relatively easy. But as noted earlier, industry still accounted for 52 percent of Hebei’s economy in 2013 and services for only 35.5% and within services, transport, retail, household and other relatively low value traditional services dominate (Hebei Bureau of Statistics 2014).

Compared with Beijing, the province’s human capital base is also much less ready for a transition to a high value economy: only 15.3 percent of the population has a secondary school education, and 7.4 percent has attended university (HBS 2014). Although younger people have higher levels of education than older ones, even among those aged 20-24 years, most have only a middle school education, meaning that their employment options will be quite limited and vocational training will be extremely important. Currently, more than 30% of the population still works in agriculture. In the past, low-skilled jobs in industry and manufacturing have been the traditional first step for workers leaving agriculture: if that door is now closing, the transfer of the rural population out of agriculture will be a major challenge for the region in the coming decades.

Researchers have raised a number of other challenges for restructuring in the region (see Fan 2015 and Mu 2015). Fan Jie, who was the lead scientific advisor on the Plan for Coordinated Development in BTH, has noted that since the Fifth Plenary Session of the 18th Central Party Committee in 2015, the government has emphasized the need for "innovation driven development." But the problem is that this may in fact exacerbate inequality between rural and urban areas, as well as gaps between central and peripheral regions and between the coast and the hinterland. Analysis conducted by Fan and his colleagues found that the gap in innovative capacity between China’s coastal and hinterland areas and between its core and peripheral areas is already actually a lot bigger than the gap in their levels of economic development: for example,
Beijing has not contributed as much as might be expected to the development of the region’s economy, with most of the innovations incubated in the city being taken up by the distant provinces of Jiangsu, Zhejiang and Guangdong. (Fan Jie 2015). What has tended to happen is that instead of developing new industries, those that Beijing is no longer developing are pushed into Hebei, while more skilled workers seek opportunities in Beijing, creating a brain drain (Fan Jie 2015; Mu 2015). Other researchers have also pointed to the human capital constraints on China’s development (Khor et al., 2016; Li et al. 2017).

Another constraint is that of basic infrastructure. Beijing may be the nation’s major transportation hub, but most of the lines radiate outward, the distribution of transportation networks is very uneven and travel between cities within the region can take a long time. The distribution of public service facilities is even more uneven. Tertiary hospitals are very highly clustered in Beijing, as are universities and research centers, and cultural institutions. This creates practical difficulties for industries that might otherwise relocate and makes it difficult to attract workers (Fan Jie 2015).

3.9.11 Implications

As noted above, there has been little empirical research on these issues, and while some differences between the circumstances of China and former industrial regions of the US and Europe are mentioned in recent analyses of the possible impact of industrial restructuring on employment (for example Paulson Institute 2015 and IIP 2015), the enormous differences in the underlying occupational structure and levels of education and human capital and the challenges these present for restructuring are not. If these challenges of employment, social mobility and equity cannot be addressed effectively, there is a risk either that environmental protection and restructuring policies will face strong resistance at the local level and be impossible to implement, or that the central government will push them through, but their economic and social costs will fall disproportionately on poor areas and populations, increasing inequality and undermining health and wellbeing.

In light of all these factors, greater consideration is needed not only of the impacts of development policies on the environment and on health, but also of the economic and social impacts and distributional effects of environmental policies. This is not an argument against stronger environmental regulation, but an argument for a package of integrated environmental, development and social protection policies to ensure that regulation does not have a regressive impact. Such policy will, in turn, need to be supported by integrated research.
This report has considered what we know about China's air pollution challenges and current policies to address it. The government has committed to improving air quality and set ambitious goals for doing so, investing unprecedented levels of financial and human resources. Impressive progress has been made in quite a short time, with concentrations of most pollutants falling significantly over the last three years in most parts of the country. However, progress has been uneven, with some cities, especially in the west of China seeing a worsening in levels of PM$_{2.5}$ and other pollutants; and in the Beijing-Tianjin-Hebei region, it was possible to meet the 2017 targets only through the implementation of stricter control measures than were originally planned.

We have sought to show that this situation reflects a number of challenges. The information that is available from government and media reports indicates that part of the problem continues to be selective or insufficiently aggressive enforcement. There is evidence that some enterprises continue to violate regulations, and that local governments do not always inspect or punish non-compliant industries. To know the extent to which stricter measures are really needed to reach air quality targets, and increase the likelihood of compliance, we need to know more about the extent of non-compliance and the reasons for it, in terms of both government and enterprise behavior.

However, contrary to the impression given by many media reports, weak implementation is not the only problem. In this report we have sought to show that air pollution presents scientific and governance challenges that will persist even in the presence of a strong government commitment to air pollution control.

The scientific challenge stems from the complex nature of 'air pollution,' which, as we have seen, is in fact a constantly changing bundle of hazards presented by a number of different pollutants, which move through atmosphere and interact in ways that scientists do not yet fully understand. Identifying emissions sources and understanding their relationship to air quality in any given place is a complex puzzle and while ever better monitoring techniques and atmospheric models are being developed, these remain far from perfect. For this reason, it is likely that there will continue to be an imperfect fit between the predictions of these models and actual levels of emissions and atmospheric concentrations of pollutants. The capacity to construct such models varies widely across the country and is quite weak outside the mega cities.
The scientific challenge becomes even greater when researchers seek to estimate the health effects of air pollution and their economic costs. The models they use to do so suffer from the same underlying uncertainties as simulations of emissions and concentrations of pollutants. Efforts to assess health effects introduce another level of uncertainty because the exposure levels of different population groups must also be estimated from incomplete data, and exposure-response estimates generally use parameters that are drawn from contexts outside China which are different in many ways. The costs of air pollution are estimated using similarly uncertain data, often also derived by adjusting findings from other contexts, to measure lost income and public Willingness to Pay.

The purpose of pointing out these scientific challenges is not to argue that we do not have sufficient evidence to act. It is clear that air pollution in China is well above the safe international standards and that the human and economic costs are huge. There is no responsible course of action but to try to bring it under control. However, now that the government is acting, and vigorously, it is no longer enough merely to call for stronger policies. What is needed are smarter policies that incorporate the best scientific evidence available and that are regularly evaluated and adjusted in order to achieve the best effects over the long term. Smarter policy also means policy that is grounded in the actual circumstances of particular cities, which will require significant investment in building more accurate emissions inventories and atmospheric models, as well as monitoring of health effects.

Before the government committed to aggressive measures to control air pollution, it was perhaps necessary to emphasize the higher boundary figures for both health effects and economic costs of air pollution. It is also now time to take seriously not only the costs of inaction, which need to be more accurately estimated using data gathered in China, but also the costs of various different types of air pollution measures and their distribution across different actors including central and local government, enterprises and the public. As we have seen, some of these costs are purely financial – the cost of technical upgrading, for example. Here the question is primarily how to distribute them in a fair way across market and government actors. Other costs are not only economic but also social and these present a thornier problem. In particular, the deep industrial restructuring that is being recommended as the only way to reduce pollution in regions such as BTH could potentially have a big impact on local government revenue and on employment. There is a risk that this will eat into government funds for public services that support health, and undermine the livelihoods, and the health and wellbeing, of large numbers of people, including industrial workers but also rural-urban migrants for whom these industries have offered a stepping stone out of poverty and a route to social mobility.

For these reasons, we have argued that addressing air pollution needs to be seen not just as an
environmental policy problem, but as a problem which, in many regions of China, raises much more profound questions about development strategy and social justice. A core question going forward will be how China can make good on its commitment to sustainable development while ensuring that poorer regions and populations do not get left further behind. This is a significant risk when many of them lack the human capital and other resources to take part in higher value, cleaner economic activities.

Until now, there has understandably been a reluctance among advocates of environmental protection to acknowledge this dilemma, for fear of undermining support for pollution control. But if these problems are not addressed there is a risk either that pollution control will stall, or that these costs will be pushed on to those who are least able to bear them. It is for this reason that social scientists who work on social stratification, social development, health equity, social protection and education also need to be engaged in research on air pollution prevention and control, to assist in devising policies that can offset the possible negative consequences for social justice.

4.1 Limitations and future work

This report covers a great deal of territory and inevitably has many limitations. The disadvantage of an interdisciplinary approach is that it necessarily involves the summarizing, and therefore the simplification, of complex fields of research. Experts in each of the fields we have covered will doubtless find places in this report where we have taken this simplification too far, given insufficient attention to issues they feel are important, or failed to adequately unpack debates among scientists within particular research domains. We nonetheless hope that we have demonstrated the advantages of an interdisciplinary approach in highlighting the complex interactions between air pollution control and other policy streams, including economics, law, and social protection. We hope that our report, despite its shortcomings, will allow all of us who are working on this issue from different perspectives to understand the different contributions that disciplinary experts make, the challenges they face and the implications for developing an integrated, sustainable approach to environmental protection.

We plan to expand and deepen the sections on health effects and economic costs, as well as the sections on many issues relating to governance. A major lacuna in the current report is also the role of the public. Although it is also shaped by a broader shift in development policy to upgrade China’s economy, and the need to combat climate change, public concern about the impact of air pollution on health has been a major driving force behind the government’s decision to prioritize air pollution control; public engagement will also be essential if these policies are to succeed. The next iteration of this report will include a new section on public
opinion, civil society and the media, drawing on a number of studies that FORHEAD has commissioned. We hope that this will enable a more informed and fruitful debate about how the public, the media and social organizations can best contribute to moving air pollution forward in a way that is maximally effective and also fair in terms of the distribution of costs.
The first two sections of this report were drafted by Chris Nielsen. Jennifer Holdaway and Wang Wuyi integrated material from other contributors. Section three was drafted by Jennifer Holdaway drawing on the contributions of social scientists in the team and a review of other research. The draft was revised following review and feedback by members of the working group.

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