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Abstract

Each year air pollution in China claims hundreds of thousands of lives. The root cause is an economy dependent on coal and heavy industry in combination with continued emissions from inefficient household stoves in hundreds of millions of homes and from open burning of crop waste in the field. The dependency on coal is also the reason why China emits far more CO_2 than any other nation. The Chinese central government is aware of the problems and has set reasonably ambitious targets for air quality. There is significant progress in terms of introducing abatement technologies. The progress in reducing coal dependency is less obvious and moreover, the government hesitates to use effective policies.

[1] Chapter prepared for Palgrave Handbook of Sustainability. See author affiliation at the end.

Background: Basic facts about air pollution in China

The interested public is well aware that China has a huge air pollution problem. It is frequently reported in social media and the international press. Visitors to Chinese cities see it with their own eyes. The Chinese government is open about it. There even exist a number of apps that translate monitored data of air quality in Chinese cities into real-time readings of environmental risk, sending off green, yellow or red signals as the case may be.

Yet basic facts of the problem are often left out of mass-media coverage. This chapter mainly deals with responses to the problem of air pollution and greenhouse gas emissions in China. We outline trends in air pollution and greenhouse gas emissions, we review policy goals and targets, and we discuss policy instruments to meet those targets. But first it is necessary, by way of background to outline basic facts of the air pollution and greenhouse gas problems.[2]

There are many types of air pollutants. Particulate matter (PM) less than 2.5 μm in diameter, called $PM_{2.5}$, is currently the most common indicator of dangerous pollution. $PM_{10,}$ which includes coarser particles up to 10 μm in diameter, is an older indicator. $PM_{2.5}$ has a diameter of approximately one-thirtieth the width of a human hair. We cannot see the individual particle with our eyes, but we may notice a haze when the particles are abundant. $PM_{2.5}$ can stay in the air for six months or more, and it can travel for hundreds, sometimes thousands of kilometers. Hence $PM_{2.5}$ is a dangerous, individually invisible pollutant whose cause (emission) and effect (exposure, inhalation and damage) are separated in time and space.

The weak connection between cause and effect is further complicated by the fact that $PM_{2.5}$ is not always emitted as $PM_{2.5}$. PM that is directly emitted is called *primary* PM. PM that is formed in the atmosphere from gaseous pollutants is called *secondary* PM. Usually, primary particles from combus-

[2] Greenhouse gas emissions are not strictly air pollution. Greenhouse gases affect the global climate, but by air pollution we mean dirty air that potentially damages health and ecosystems. Hence we distinguish between air pollution and greenhouse gas emissions.

tion processes, and secondary particles, are the smallest and more of them belong in the $PM_{2.5}$ category. Primary particles from industrial processes and road and soil dust are coarser and more of them belong in the PM_{10} category. In China an increasing share of the particulate air pollution is secondary particles, as primary PM is being abated to a larger extent than PM precursors (Zhao, Wang, Dong, et al. 2013, Zhang and Cao 2015). In order to comprehensively reduce PM in the air one must address the sources of secondary PM. The main sources of secondary PM are sulfur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOCs), and ammonia (NH_3). All of these and of course, primary PM as well, must be taken down in a wide area for PM control to stand a chance.

The most important environmental consequence of $PM_{2.5}$ is arguably that it increases mortality risk. Because of the small size of $PM_{2.5}$ it can be inhaled deep into the lungs where it impairs respiratory function. It can also enter the bloodstream, where it causes cardiovascular complications. $PM_{2.5}$ is associated with increased mortality rates for cardiovascular diseases, cancers, strokes and other common causes of death. A huge number of studies in different climates, living conditions etc., including many Chinese studies, have confirmed that both short term exposure to elevated $PM_{2.5}$ episodes and long term exposure to chronically elevated $PM_{2.5}$ increase the frequency of mortality from these diseases as well as the frequency of people living with the diseases (WHO 2006). In fact, the number of links between $PM_{2.5}$ and health conditions keeps growing all the time. Recent links include diabetes, neurodevelopment, cognitive impairment, see WHO (2013) or Calderon-Garciduenas et al. (2014).

There are several attempts at estimating the number of people who die prematurely from $PM_{2.5}$ exposure each year in China, see e.g. Cao et al. (2011) and Rohde and Muller (2015). The Global Burden of Disease project provides comparable estimates of deaths attributable to a range of risk factors across the globe, including air pollution (Lim et al. 2012)[3]. The most recent update from this study

[3] See also the web pages of the World Health Organization (WHO) http://www.who.int/healthinfo/global_burden_disease/about/en/ and the Institute of Health Metrics and Evaluation http://vizhub.healthdata.org/gbd-compare/

finds that 1.75 million people in China died in 2013 as a result of air pollution, see table 8.1. This death toll manifests itself through higher incidence of common causes of death. Hence it is difficult to spot on the ground and must be deducted from statistical analysis. The 1.75 million number includes about 800 000 who died from indoor air pollution related to smoke from burning wood and coal for cooking and heating, in addition to 900 000 who died from ambient air pollution. In addition, around 65 000 are estimated to die from ozone pollution. Ozone pollution is a consequence of emissions of NOx and VOC (in the presence of sunlight), i.e. two of the compounds that make secondary PM, and gives a double reason for controlling these.

Table 8.1 Premature deaths from air pollution in China 2013

Cause	Annual deaths per 100,000 people	Total
Ambient (outdoor) $PM_{2.5}$ pollution	65.8	900,000
Household (indoor) air pollution from solid fuels	57.9	790,000
Ambient ozone pollution	4.8	65,000
Total	128.6	1,750,000

Source: IHME (2015). There were 1.36 billion people in China in 2013

Although it is difficult to draw the connection in time and space between PM exposure and its sources, the compounds that together form $PM_{2.5}$ can in many regions be attributed to a common main source: Coal.[4] Combustion of coal, whether in tiny household stoves, small industrial boilers, big industrial facilities or huge power plants leads to emissions of primary PM and most of the compounds that form secondary PM. There are several abatement technologies available to reduce emissions, and one of the environmental successes of China in recent years is that more and more chimneys are equipped with abatement technologies, while several small sources including coal burning

[4] Some may protest that traffic is a main source of one of the compounds, NOx. But that seems so far not to be the case in China, see e.g., Zhao et al. (2013).

in household stoves have been prohibited in some areas. We will discuss that in more detail below. But coal remains a major cause of PM pollution in China, which now consumes more than half of all the coal in the world (51% according to BP (2016)). This huge amount of coal consumption also explains why China is by far the world's largest source of greenhouse gas emissions.

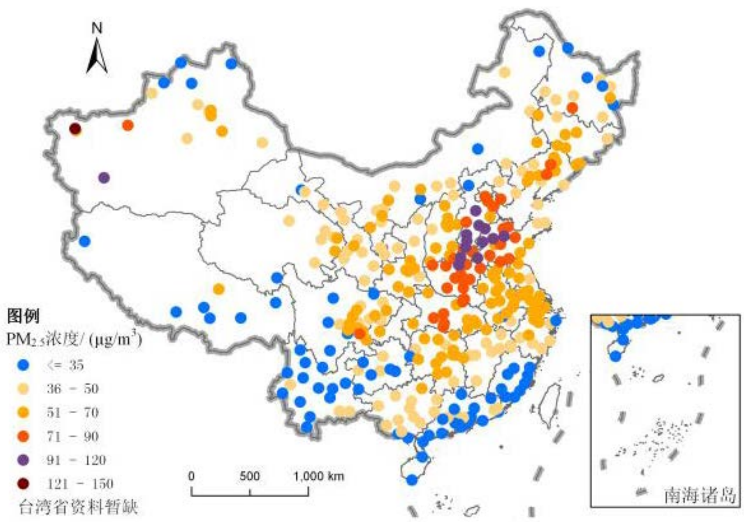
In summary, some basic background facts about air pollution in China are: Small particles measured as $PM_{2.5}$ is the main indicator of air pollution to worry about in context of health damage. It comes in two varieties: Primary PM is emitted as PM. Secondary PM is formed from emission of SO_2, NO_x and other compounds. $PM_{2.5}$ increases mortality and morbidity risks for a range of common diseases. About 1.75 million people are estimated to die prematurely from air pollution in China every year. The main source of PM pollution in ambient air in China is coal combustion. Burning of biomass and coal in simple household stoves also constitutes an important health risk, primarily in rural and peri-urban areas. Coal combustion is the reason why China is the country in the world that emits the most greenhouse gases.

Distribution of air pollution across China

Estimates of consequences of air pollution rely on modelling and measurement of exposure to polluted air. A standard metric is population-weighted concentration. The nation-wide, population-weighted mean annual concentration of $PM_{2.5}$ in ambient (outdoor) air in China is currently estimated at about 55-60 micrograms per cubic meter ($\mu g/m^3$) (Zhang and Cao 2015, Brauer et al. 2016). By comparison, the corresponding figure in Western Europe and North America is below 15 $\mu g/m^3$ (EEA 2015). The WHO air quality guideline, which is set to reduce health risks to a minimum for all, including sensitive individuals, is 10 $\mu g/m^3$, although laxer, intermediate targets are suggested for developing countries.

The annual average indicates the magnitude of the air pollution problem in China. The average however hides large spatial and seasonal variations. In fact, the provinces in the east and north, which contain main centers of population and industry, fare much worse than the provinces in the south (figure 8.1).

Figure 8.1. Annual average $PM_{2.5}$ concentrations in China in 2015.[5]



In the worst hit regions, which include the capital Beijing and neighboring provinces, including Hebei province, the annual $PM_{2.5}$ concentration exceeds 90 $\mu g/m^3$ in large areas. Regarding soot particles (or black carbon, a PM2.5 component formed by incomplete combustion and suspected to be more toxic than the average PM particle), it is estimated that the average population-weighted exposure in the North China plain and the Sichuan basin is about *ten times* higher than in Europe and North America (Wang et al. 2014).

Trends in air pollution

When assessing the situation, a question of interest is whether air pollution has become worse over time. Unfortunately, $PM_{2.5}$ was not regularly and broadly monitored in China before 2013 and it is difficult to compare current air pollution to that of previous years. It is still only monitored in urban areas. PM_{10}, which we recall consists of $PM_{2.5}$ and coarser particles, has been monitored for a longer

[5] Annual average values based on hourly data downloaded from China National Environment Monitoring Center http://106.37.208.233:20035/ Accessed 27 April 2016.

time. The data indicates that urban levels of PM_{10} have in fact decreased substantially in the period from around 2000 to 2012 in the North, while there is a small increase in the South. This suggests that the situation has improved. On the other hand, secondary PM has increased over time in China, and is particularly high during high pollution episodes (Huang et al. 2014). This modifies the conclusion from the PM_{10} data. A study of $PM_{2.5}$ hot spots indicated a small increase in $PM_{2.5}$ over the period 2004-2013 (Ma et al. 2016). All in all, it is premature to conclude that dangerous $PM_{2.5}$ ambient air pollution levels are coming down in China, but they do not seem to increase either. The geographical variation is large.

So far we have described trends in ambient air pollution. But as mentioned above the Global Burden of Disease study and WHO find that household air pollution (which permeates the air not only indoors but also locally in the village or neighborhood) is an almost as important cause of premature mortality in China as outdoor air pollution. Moreover, household air pollution occurs disproportionally in rural areas, in the poorer segments of the population. In fact, emissions from household stoves is also an important contributor to ambient air pollution in many regions (Liu et al. 2016, Chafe et al. 2014).

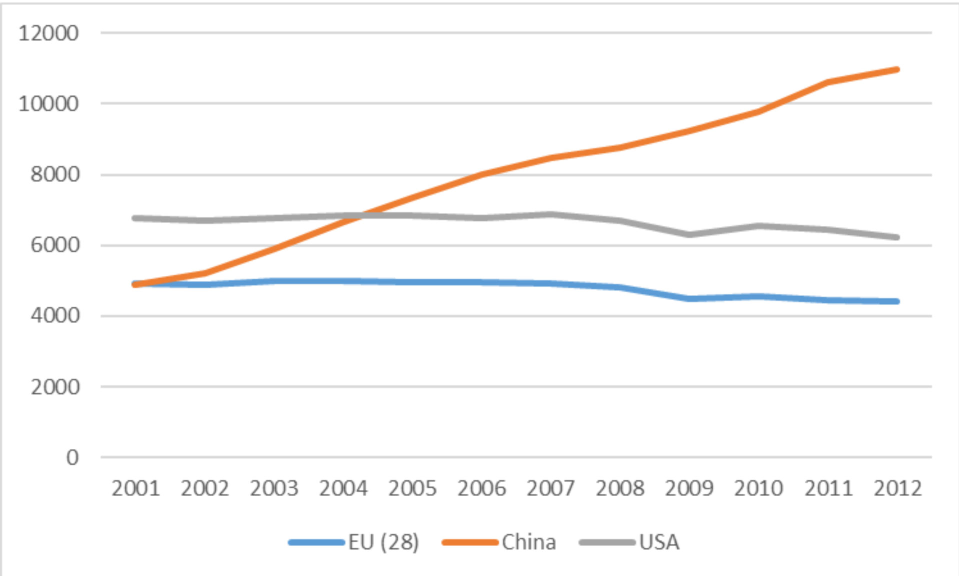
At the time of the most recent population census in 2010, 600 million Chinese relied on solid fuels (wood, crop residues and/or coal) for heating and cooking. Burning wood, crop residues and coal in simple household stoves means that combustion is incomplete and some of the fuel carbon is converted to particles, carbon monoxide and a range of toxic organic components (Naeher et al. 2007). The particle exposure that results is uncertain, but available data indicate an annual $PM_{2.5}$ average among those who rely on solid fuels of 140-500 $\mu g/m^3$. This may be compared to the ambient average in China is about 55-60 and that WHO considers anything above 10 to be a health risk. Thus, for populations that rely on solid fuels, exposure to indoor air pollution is a much more serious problem than ambient air pollution. If a household that relies on solid fuels is situated in an urban area, it may suffer a double burden of heavy indoor and outdoor pollution.

Fortunately, household air pollution is a decreasing problem in China. Census data show that over the ten years 2000-2010 altogether 250 million Chinese switched from coal and firewood to electricity and gas. Both general economic developments including urbanization, and, to a more limited extent, specific public policies such as a fairly successful subsidy program for biogas digesters in rural areas and banning of the use of coal stoves in urban areas have contributed to this decrease.

Greenhouse gas emissons

We also describe greenhouse gas emissions. Figure 8.2 shows that China's greenhouse gas emission more than doubled from 2001 to 2012, the most recent year of these records.

Figure 8.2 Greenhouse gas emissions in China, USA and EU (28) from 2001 to 2012



Source: WRI CAIT Database (WRI 2016). Total GHG emissions excluding land use change and forestry (MtCO2e).

By 2005 EU and US emissions were surpassed. By 2012 China's greenhouse gas emissions were larger than those of the EU and the USA combined. In per capita terms Chinese greenhouse gas emissions are still lower than those of the USA, but they are about equal to emissions in the EU. Moreover, EU and US emissions have a stable to declining trend.

Ambitions and goals

Ambitions and goals for air pollution control in China are articulated in the State Council (2013) Air Pollution Prevention and Control Plan and the NPC (2016) 13th Five Year Plan.[6] First, the State Council (2013) plan. It is a plan for reducing emissions of all the main air pollutants that directly or indirectly contribute to exposure to $PM_{2.5}$. The plan points out that controlling air pollution is "a herculean task", but "the whole society should work together for fresh air and strive for economic development in the course of environmental protection, and environmental protection in the course of economic development." Concretely the plan requires "inhalable particulate matter" to decline by 10 per cent by 2017 compared with 2012. The annual concentration of "fine particulate matter" in Beijing-Tianjin-Hebei Provinces, the Yangtze River Delta and the Pearl River Delta should decline 25 per cent, 20 per cent and 15 per cent respectively. The annual concentration of fine particulate matter in Beijing should be below 60 $\mu g/m^3$.

These are ambitious goals, at least when comparing with the first year of regular measurement, 2013. Recall that there are no official measurements from 2012, which gives authorities some freedom in assessing results. The target for Beijing, which is formulated in $\mu g/m^3$ as opposed to percentage improvement, may be the most ambitious of all. The $PM_{2.5}$ level of Beijing was 80-90 $\mu g/m^3$ in the period 2013-2015 and $PM_{2.5}$ concentrations in the capital will thus need to go down up to 50 per cent by 2017. Currently it is not clear how that is to be achieved. The 25 per cent reduction that is the goal for the Beijing-Tianjin-Hebei region may not be sufficient. Beijing-Tianjin-Hebei is the region of brown and purple dots in the east of China in figure 8.1.

The recent NPC (2016) 13th Five year Plan restates targets for urban air quality in slightly different terms than State Council (2013). Instead of percentage improvement in annual concentration it says, for instance, that the number of days when $PM_{2.5}$ exceeds allowable limits should be reduced 18 per

[6] http://english.mep.gov.cn/News_service/infocus/201309/t20130924_260707.htm English translation, see: www.cleanairchina.org/file/loadFile/27.html

cent. Besides, it gives targets for *emissions* of SO_2, NO_x, NH_3 and VOC. As noted, these are the main precursors to secondary $PM_{2.5}$. The plan requires SO_2 and NO_x emissions to decline by 15 per cent and NH_3 and VOC to decline by 10 per cent over the five-year period 2016-2020. The 13th five-year plan also contains a cap on total energy consumption in 2020 (5 billion tons coal equivalents (or TCE)). Current energy consumption is a good deal less (4.3 billion TCE). Still the "coal cap" represents a new way of thinking in addressing the main source of SO_2, NO_x and PM emissions. The cap on total energy consumption is also going to be important for China's greenhouse gas emissions, where the voluntary commitment by China to the UN Framework Convention is to peak carbon emissions by 2030 and also make its "best efforts" to peak earlier.

Prior to the State Council (2013) plan and the new 13th Five-year plan the Chinese government had less focus on air quality and greenhouse gas emissions. The focus was on reducing emissions of some air pollutants through the policy of total emissions control. The list of pollutants to control has changed over time, and it never contained $PM_{2.5}$. The one pollutant that has consistently been targeted is sulfur dioxide (SO_2) and in all likelihood SO_2 emissions in China peaked a few years ago.[7] Scrubbers and other abatement technologies to limit SO_2 are available and by and large they are applied in power plants and large industrial sources. Direct emissions of particulate matter in the form of "smoke and dust" were subject to total emission control up to 2005 and abatement technologies such as electrostatic precipitators (ESP) have by now been implemented on most power plants and large industrial sources[8]. The period 2011-2015 introduced emission targets for NO_x and ammonia nitrogen, with the result that de-NO_x abatement technologies are being installed on large point sources and NO_x emissions are leveling off. In fact, State Council (2016) reports NO_x emissions to

[7] The measurement of national emissions is surprisingly difficult. It requires quality monitoring of actual emissions from thousands, if not millions of stacks as well as accounting precisely for the chemical content of energy sources, e.g., how much sulfur in coal. In the case of NO_x it requires information on the properties of combustion (e.g., the furnace heat) as well. NH_3 is emitted from the fields in agriculture and depends on fertilizer use, and from the decomposition of livestock manure, both of which are difficult to quantify precisely. VOC is fugitive, it slips away from gasoline pumps and is not easily measured, etc. In practice any estimate of emissions of air pollutants is uncertain. The change in emissions may be somewhat more certain as one may assume that some sources of uncertainty cancel.

[8] A different and even more effective technology called fabric filter seems to be used less.

have gone down 19 per cent over the five-year period 2011-2015, a good deal more than the target of 8 per cent reduction. The same source says that SO_2 has gone down 18 per cent and NH_3 13 per cent over five years, both exceeding ambitions (Seligsohn, 2016).

We close this section with the following four observations: 1) targets for air quality improvements could be more difficult to reach than targets for emission reductions. The air quality targets that are formulated in terms of concentration levels ($\mu g/m^3$) or number of days without exceedance may be particularly difficult. The Beijing concentration target of less than 60 $\mu g/m^3$, for instance, translates to almost 50 per cent improvement compared to the level today. Even if emission reductions in the range of 20 per cent are achieved as planned, the air quality target will be far from achieved. 2) targets for $PM_{2.5}$ concentrations are particularly hard to reach. This is both due to the dislocation in time and space between emission source and effect in the air, and to the complicated chemistry that forms secondary PM. The complicated chemistry is shown, e.g., by the fact that NH_3 was acknowledged as an important contributor to secondary $PM_{2.5}$ only a few years ago. Moreover, it is likely that a reduction of NO_x may render SO_2 reduction less efficient in reducing secondary $PM_{2.5}$. 3) even if environmental targets for air pollution in China are met the problem is still of a considerable size and the damage in terms of excess mortality and other consequences will persist for many years to come. 4) The voluntary Chinese commitment for greenhouse gas emissions is significantly higher than current consumption.

Policy instruments and implementation

So far we have discussed ambitions and goals. We turn to policy instruments and implementation of the stated goals. The State Council (2013) plan contains ten broad policy measures. They range from a rephrased statement of aims (measure no 1 is “enhance the overall treatment and reduce discharges of multiple pollutants”) to general support for improved legal, monitoring and market based frameworks, and support for public participation. The idea, which is common in Chinese policy making, is that such broad statements should inspire and guide local governments and enterprise leaders to make detailed policies of the desired nature.

In fact, in recent years the incentives for local leaders to adhere to national environmental policy goals are much strengthened. The policy starting from 2016 is that local leaders' promotion prospects to some extent depend on whether they deliver local air quality improvements and emission reduction in their jurisdictions. Local leaders in China are evaluated by their superiors using a "balanced score card" and it is this score card that has been extended to air quality. The State Council (2016) has added that those who violate environmental regulations and those who fail to report violations will be "severely punished". In previous years, local leaders were held responsible by way of the score card for indicators of emissions and energy efficiency. In reality they were not much responsible for the environment at all. The targets were not important enough ("hard" in Chinese parlance) and post 2008 economic growth came back as the overriding concern. Research by Zhang et al. (2011) describes how the system worked in one Chinese province. Wu et al. (2014) show that in the years 2001 to 2009 in close to 300 main cities in China both the Party Secretary and the mayor were less likely to be promoted if they spent a larger share of the city's income on environmental improvement. Hence, if the stated emphasis on environmental performance is implemented in practice, it is an important change.

Of course, given the long-range transport of $PM_{2.5}$ far from the site of origin, controlling air quality at the local level is no easy task. As a general rule, emissions from surface-level sources such as transport exhaust, industries with low stacks, and household stoves impact air quality at the local level the most and it is those sources that local leaders have instruments to address. In Beijing, for example, city leaders have responded by prohibiting cars from driving one work-day a week, and by building more public transportation. During periods of bad air quality cars are prohibited from driving every other day. Under special events, such as the World War II 70th-anniversary Military Parade in 2015, the city may require that the surrounding provinces implement temporary emission control at thousands of factories, power plants and construction sites. In general, however, it is a likely short term consequence of the incentive system that local sources of air quality improvements will be emphasized, while regional sources such as power plant emissions from high stack will be emphasized less. Over the long term local leaders may see the value of cooperation to reduce regional sources.

Chinese environmental and energy policy highlights technical regulations, standards and prohibitions, so-called command-and-control policies. For example, the State Council (2013) document mentions that polluting vehicles (so-called yellow label vehicles) and old vehicles should be prohibited and the quality of fuel oil should be upgraded. Cooking fume pollution from the catering services should be controlled (which is unlikely to have a large impact on air quality in the country). In addition, the document emphasizes that the implementation of abatement technologies for SO_2, NO_x and PM should continue. Another policy mentioned in the document is to force inefficient production facilities in heavy industry and power production to close. Like abatement this policy has been going on for some time, and with good results. For instance, the average efficiency of Chinese coal fired power plants is currently higher than that of U.S. power plants (Seligsohn et al., 2009).

While the command and control policy is prevalent, notably absent from the environmental policy mix in China at the local and central level is the use of economic regulation, also called incentive based regulation. For instance, visitors to China who happen to pass a gas station will notice that the prices posted on billboards are close to world market prices of gasoline – they do not include any gasoline taxes. Actually the prices are set by administrative decree, which means they are not guaranteed to even reflect upturns in world market prices. The prices of electricity are also set by administrative decree and do not necessarily reflect upturns in underlying prices of coal, the main fuel. Certainly they do not reflect the environmental cost of electricity production. The low and regulated prices on gasoline and electricity make it harder to attain environmental goals since they remove the possibility of influencing the millions of consumers and firms who on a daily basis decide whether to take the car or use the bus, use air condition in every room etc. Low prices encourage excess gasoline and electricity consumption.

Indeed, in China in the past few years the low price of electricity and the priority given to economic growth are major drivers behind the enormous growth in coal consumption that has propelled China's greenhouse gas emissions far past those of the USA. We will now try to explain the economic mechanisms that have driven the growth in coal consumption (Vennemo, Aunan, Lindhjem, et al. 2009). The point of departure is again to note that local leaders have been rewarded for economic growth in their jurisdiction. The surest way to guarantee growth has been to set up a heavy industry factory, producing things like iron and steel, cement or petrochemicals. The factories have been financed by accumulated earnings of previous factories and by household savings. Households seldom invest directly, but banks and informal lending institutions channel their savings to investment. Both corporate savings (retained earnings) and household savings are much higher in China than in Western countries, giving space for this investment.

Part of the production from the new factories has gone into infrastructure in China, such as roads, airports, railways. Another part has been used for construction of housing. Yet other parts have been used for building yet more new factories, whether to produce consumption goods for the world market or a new round of heavy industry. Prices of outputs have been high and the market has accommodated growth in production. At the same time the price of electricity has been low by regulation and a huge consumption of electricity has not increased cost to the same degree.

All this made the new heavy industry factories profitable, confirming the initial presumption of local leaders that they would generate new income, i.e. economic growth. For years, economic growth in China was like a golden circle: The output of new factories was used to build the next generation of factories and to build the infrastructure that could transport the goods that were produced.

But lately the growth model of previous years has come under pressure, to the benefit of the environment. The logic of exponential growth is such that a constant percentage growth rate requires more and more or larger and larger new factories over time. If one factory is sufficient the first year, a local leader who requires ten per cent growth per year will have to invest in 1.1 factory the next year (or a ten per cent larger factory). Unless prices are growing or a new and more productive technology is found, investment and saving will have to grow ten per cent as well. As people who receive the income will be ten per cent richer next year they must save a constant share of income in order to save ten per cent more.

Three things have happened recently to put pressure on this model: First, the Chinese government wants to increase the rate of consumption at the expense of saving and investment. This shift from investment to consumption is the core of the “new normal”, a term coined by Chinese policy makers in 2014 to indicate a shift towards consumption, and a lower rate of growth. The new normal is by general agreement a good thing since the rate of saving in China is unnecessary high. Saving and investment is in reality a transfer from the present generation that saves, to future generations that consume the results of saving, but future generations in China are likely to be more affluent anyway. A somewhat lower rate of saving alleviates this problem, but it leaves less investment resources with which to maintain the former rate of growth.

Second the Chinese government has stated a dedication to let prices of key inputs such as electricity and gasoline be determined by market forces. It is unclear how sincere this dedication is. In the best case it will mean that carbon prices from an emission trading system, of which there are pilots running in China, will translate into higher prices of electricity, fuel and other carbon intensive goods. This will make heavy industry a less profitable investment asset.

Third, the golden circle of higher production, higher demand and higher prices has been broken. This circle was shaken in 2008 by the global financial crisis. The Chinese government responded with a huge stimulus package to increase demand, but eventually capacity in heavy industry has just become too big when the lack of foreign demand also is taken into consideration. With less need for steel and cement to build new factories, demand has fallen even more, and prices have not held up. The result is that as of 2016 there is significant overcapacity in industries like steel and power. The central government has told 15 provinces (out of 31 in total) to stop building new power plants, and several provinces led by Hebei Province bordering Beijing have been told to reduce steel production capacity. Recall that Hebei is in the center of the region with the worst air quality, see figure 8.1.

This three-fold pressure on the growth model has slowed down economic growth, and coal consumption has levelled out. Some draw from this the conclusion that coal consumption has in fact peaked 15 years prior to the date promised to the UN (e.g., Qi et al., 2016), but that could be a premature conclusion. From the available data on underutilization of capacity it is likely that the Chinese economy at present is operating at less than full capacity while it tries to shift to a new growth model that relies less on investment and more on consumption. When capacity utilization increases, coal consumption may increase again. It will require an active use of the price mechanism, along with continued command-and-control policy, to stem the demand impulse from a growing economy. Meanwhile the global climate (CO_2) and Chinese citizens ($PM_{2.5}$) will get some breathing space.

Lessons learned

The case study on air pollution and greenhouse gas emissions in China offers some valuable insights into the race between unsustainable economic growth and initiatives to support sustainability:

- *Awareness*: Over time the Chinese government and the Chinese public have become more aware of the dangers of $PM_{2.5}$. This statement has at least two facets. One is that scientific knowledge has penetrated Chinese policy circles, shifting attention to $PM_{2.5}$ from other pollution compounds. Another is the interplay between publication of $PM_{2.5}$ air quality data in several hundred cities, an action that was sanctioned by the government, and the increase in awareness in the public that puts pressure on the government to do more. Meanwhile, with respect to greenhouse gases the Chinese government has over time acknowledged more responsibility than it did before. There is less pressure from below, from the Chinese public, on this matter.
- *Promotion to depend on environmental progress*: In the decentralized Chinese system the incentives of local leaders for promotion are important instruments in policy implementation

(Xu 2011). That is why it was significant that environmental investment did not support promotion prospects in the period 2001-2009 (Wu et al. 2014) and why it is significant that new, environmental criteria are now emphasized. The actual emphasis on these criteria will only be known in a few years' time, however.

- *Abatement technologies are penetrating the country*. China has made significant progress in making use of state of the art abatement technologies for SO_2 and NO_x, which are important precursors to $PM_{2.5}$, and in PM itself. Its coal fired power plants are quite efficient, and so is some of its industry. It is building wind and solar power plants in greater quantities than other countries (although not in relative terms) It is not unlikely that China has turned a corner and ambient $PM_{2.5}$ levels will go down in the years to come. Indoor air pollution will also become a smaller problem as urbanization and modernization continues.

Challenges and barriers

While $PM_{2.5}$ levels may be coming down they are still much too high. Current policies are not sufficient since they do not address coal consumption in an effective manner and also leave gasoline consumption unhindered. The levelling off in coal consumption and CO_2-emissions that is currently seen, could be related to the fact that the Chinese economy is operating at less than full capacity and not to purposeful environmental policy. The following are significant challenges:

- *Prices of key resources are still set by administrative decree.* Since prices are set administratively there is no direct link between, e.g., an increase in the price of coal or oil and domestic prices of electricity and gasoline.
- *Environmental costs are not allowed to influence prices of energy.* In theory China could use its administrative capacity to raise the end user prices of energy. In practice that does not happen. Were a carbon trading system to be comprehensively introduced in China, for example, it is an open question whether prices of carbon intensive energy goods would be allowed to increase in price to the relevant degree.

- *Environmental levies are unpopular.* Environmental levies are rather unpopular in China and/or authorities allow the unpopularity to be voiced. In Beijing for example, few officially complains about the even-odd number plate system despite its rigid nature and obvious costs to convenience, but a proposal to introduce a congestion fee has met significant open protest (Hao 2016).
- *Fuel switching does not occur fast enough.* If environmental levies had been in place that punished coal for its environmental cost, and those levies had been allowed to roll unhindered through the economy, China would in all likelihood experience fuel switch from coal to natural gas. Such a fuel switch is the main reason why Europe and the USA has experienced relative success in reducing $PM_{2.5}$ and levelling off CO_2 emissions. Without a pressure through prices and profitability China is slow to embrace natural gas. A pipeline is currently being built from Russia and will improve matters in the long run.

The synthesis of these challenges to sustainability is that China so far does not use the price mechanism to support stated environmental goals. China is still searching for a solution to its unsustainable air pollution problem.

Further reading

Trends in Chinese air pollution, its consequences and drivers in the 90's and 00's are discussed in Vennemo, Aunan, Lindhjem, et al. (2009). Consequences of current air pollution are described in Kan, Chen, and Tong (2012), and Zhang and Samet (2015). The potential impacts of making use of environmental economic instruments in the form of a price on carbon emissions and levy on fossil energy are discussed and quantified in Aunan et al. (2007), Vennemo, Aunan, He, et al. (2009) and Nielsen and Ho (2013).

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