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Air pollution lowers high skill public sector worker productivity in China

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Abstract

China’s urbanites continue to be exposed to high levels of air pollution. Such pollution exposure raises mortality risk, lowers the day-to-day sentiment of the population and lowers outdoor worker productivity. Using a unique set of data for Chinese judges, we document that local air pollution also lowers the productivity of high skilled government officials who work indoors. Our new evidence on the effects of air pollution highlights both the challenge that pollution poses for quality of life and workforce productivity and indicates that the Chinese urban elites gain co-benefits when their cities burn less fossil fuel.

1. Introduction

China’s urbanites are exposed to high levels of air pollution. Such pollution exposure raises mortality risk and nudges some people to migrate to cleaner places (Qin and Zhu 2018, Cui et al 2019). Recent research has documented that private sector agricultural workers, indoor low-skilled workers and outdoor highly-skilled professionals perform worse when it is more polluted and hotter outside (Graff Zivin and Neidell 2012, Zander et al 2015, Chang et al 2016, 2019, Archsmith et al 2018, Somanathan et al 2018, Adhvaryu et al 2019, Almås et al 2019, He et al 2019). Empirical studies have documented that the day to day sentiment of the population and cognitive performance declines during times of high air pollution in urban China (Lavy et al 2014, Zhang et al 2018, Gilnaire 2019, Zheng et al 2019).

Using a unique set of data for Chinese judges, we document that local air pollution also lowers the productivity of high skilled government officials who work indoors. Judges are highly educated and well compensated. We examine the effects of pollution and heat on public sector worker productivity in China by measuring the decision time for a judge to rule on a given case. A longer deliberation period creates delays for the overall judicial system. Thus, the decision time is a useful metric of worker productivity. We observe the decisions made by 157 378 judges in 13 million criminal and civil cases adjudicated during the years 2014–2017. These judges work in 337 different prefectures. We find that judges are affected by pollution exposure. We find little evidence that outdoor heat lowers worker productivity. This fact is explained by adaptation through widespread air conditioning access.

China is slowly reducing its reliance on coal for generating power and winter heating (Zhang et al 2019). In 2017, 64.7% of power in China was generated by coal. Despite the decline in the share of power generated using coal, coal combustion still contributed to 63% of primary PM$_{2.5}$ emissions and around 56% of the pollutants serving as chemical precursors for secondary PM$_{2.5}$ in different regions (Natural Resource Defense Council 2016). Among the major coal-burning sectors, industrial coal burning is the dominant contributors, followed by coal combustion in power plants (Ma et al 2017). In addition to industrial combustion, residential sector and mobile sources are responsible for around 35% and 4% of PM$_{2.5}$ respectively (Liu et al 2016, Li et al 2017, Qi et al 2017).

Environmental scholars have emphasized the co-benefits of reduced PM ambient levels associated with burning less coal (West et al 2013, Shaw et al 2014). Given the local social costs associated with elevated levels of air pollution, burning less coal reduces China’s PM$_{2.5}$ levels and reduces the nation’s carbon footprint. We document that PM$_{2.5}$ affects the nation’s elite through reducing their productivity...
and quality of life. This provides the leadership with an incentive to pursue new measures to reduce the nation’s reliance on fossil fuels.

2. Background information on the daily routine of a judge in China

In China, the civil service is a very popular employment sector for young people who value its job security and non-monetary benefits. These workers receive government housing and low stress. Judges work shorter hours than comparable private sector workers (see table A1). A judge’s annual evaluation depends on a broad set of performance scores during within-court competitions between colleagues for promotion to vacancies within the courts. In order to motivate judges to work harder, many courts publish the unvarnished quantitative rankings of each judge within a court. This creates a tournament where judges are competing against each other (Lazear and Rosen 1981). In 2011, the China Supreme Court (hereafter SPC) issued an official document to guide the assessment of judges’ court performance. The key promotion criteria used are the total number of cases completed or handled, the appeal rate and the remand rate for retrial.

The workload for judges has been increasing. For instance, in 2004, the average daily burden of incoming civil and criminal cases assigned per judge serving anywhere in the nation was 0.079 matters. The number of average daily incoming matters per judge jumped to 0.515 in 2017, mostly due to the substantial increase in filings and reduction in headcount of judges. The basic-level court judges handle far more cases than upper level court judges do. This explains why the court system leaders must manage their time wisely.

Longer case durations will lead to fewer cases being handled or completed within a given year. Below, we will test how outdoor dirty air affects a judge’s deliberation time. The average judge in our sample is exposed to high levels of air pollution on 88.9% of the days he/she works. The marginal effect of such disamenities on productivity is large enough to affect promotion rates. Judges should have strong career concerns to reduce their exposure to pollution.

3. Methodology

We seek to test for the association between outdoor air pollution levels and the length of time of a court case. In our linear regressions, the dependent variable is the log of the length of time taken in a given trial. Our main empirical specification is presented in the following equation:

\[
Y_{ijCT} = \beta_0 + \beta_1 P_{ijCT} + \beta_2 W_{ijCT} + \beta_3 M_{ijCT} + \beta_4 X_{ij} + \theta_i + \delta_j + \varphi_m + \mu_t + \epsilon_{ij} \tag{1}
\]

where \(Y_{ijCT}\) is the log of the case duration (between the date when a case was assigned to a judge and the date when the right case was adjudicated by that judge) of case \(i\), belonging to crime type \(s\), assigned to the judge \(j\) sitting in a court of prefecture \(C\) on sentencing day \(t\) of month \(m\) in year \(y\), \(P_{ijCT}\) (or \(W_{ijCT}\)) is the average air pollution (or weather conditions) across stations located within prefecture \(C\) where judge \(j\) worked on case \(i\) during a trial that lasted \(T\) days. By observing the judicial decisions across many locations allows us to capture the effects of acute exposure to air pollution on case duration (see table A2).

To the best of our knowledge, there was no air filtration system installed in China’s courtrooms before 2019. People are more likely to invest in self-protection when they anticipate high levels of ambient pollution (Moretti and Neidell 2011, Zhang and Mu. 2018, Jia et al. 2019, Ito and Zhang 2020). To address this issue, in equation (1) we add \(M_{ijCT}\) which is measured the daily Baidu search index on ‘mask’ of prefecture \(C\) where judge \(j\) worked on case \(i\) over time interval \(T\). The value of \(M\) is positively correlated with people’s search volume for the key word ‘mask’ in a prefecture on a given day. Thus, it captures the contemporaneous aggregate interests on mask purchase in a prefecture. This mask variable is not at the individual level of a judge. Instead, it is a geographic aggregate variable that captures the prefecture’s overall awareness and interest in the pollution challenge at a point in time.

The criminal sentencing data are used in our baseline regressions primarily because there are many cases and the outcomes are easy to classify. The documents typically include several paragraphs that sketch the arguments made by the litigants and the ruling of the judges. For each criminal case that is adjudicated, a record is made of key case details
including the defendant’s characteristics (e.g. juvenile defendants), case traits (e.g. crime type), severity of crimes, outcomes (e.g. sentence length), the court in which sentencing occurs, name of the judge, and so on.

In estimating equation (1), there are likely to be other case-level factors that influence the timing of the case settlement. To address this issue, $X_{ijt}$ is included as a vector of covariates including both legal factors (e.g. offense severity and prior record) and extra-legal factors (e.g. victims’ unwillingness to press charges) that might predict the criminal case duration (see table 2 for the variables we use as controls).

To mitigate omitted variables concerns, a set of fixed effects are also added in our regressions. Since judges may have different sentencing policies for different crimes, crime type fixed effects $\theta_i$ are included as additional controls. The vector $\delta_y$ includes year fixed effects. $\varphi_{ym}$ is a vector of a province by month fixed effects, which allows for different seasonal patterns by province (e.g. the seasonal variation of wind direction). The vector $\mu_i$ contains the judge-specific fixed effects to control for the idiosyncratic tendencies of each judge. $\varepsilon_{it}$ is an error term. To control for heteroscedasticity and serial correlation, we cluster the standard errors at the judge level.

In studying the relationship between judicial performance and pollution and heat, China’s justice system’s features allow us to avoid several identification challenges. First, within the same court, each defendant’s case is in principle randomly assigned to a judge who presides over the trial, plea bargaining, and the sentencing process. The judge is also unaware of the details of the upcoming cases. Second, the case duration can be several days between the filing of the claim to case resolution. Despite adjudications being made indoors, the judge in charge might conduct on-site investigations to determine the real reasons for the litigation. They might be exposed to heat and pollution both indoors and outdoors before they make the final decisions. Third, individual judges have a high degree of personal discretion and independence in the way in which they evaluate files.

Finally, given the extremely heavy caseload on the judge’s docket, judges only sit in one courthouse. Trial court decisions are generally final because appeals are only available on limited bases, occur infrequently, and seldom lead to reversal in China.

4. Data

Our main data source is online transcripts of judicial decisions. These documents first became available online in late 2013 in a handful of courts, and coverage widened over time. We collect over 13 million criminal and civil cases adjudicated between 2014 and 2017 by 157,378 judges across China. The final dataset used in this paper consists of approximately 56% of all criminal first instance cases and 27% of civil first instance cases adjudicated in basic courts over the years 2014 to 2017 (see table 1 for more information).

Air pollution data are published daily by the China’s Ministry of Environmental Protection (MEP). The data for 2013 to 2017 cover 1497 nation-level monitoring stations across all 337 prefectures. Weather data are collected from China Meteorological Data Sharing Service System (http://cdc.cma.gov.cn/). Those data contains daily readings from 820 weather stations in China during the 2013 to 2017 period. The pollution and meteorological variables are aggregated to the prefecture level by averaging the daily readings of all the monitoring stations within a prefecture. Less than 10% of the observations were dropped due to missing meteorological and pollution information.

The Baidu Index used in this paper is a data product analogous to Google Trends. It measures the search frequencies of the selected terms. We collect daily Baidu Index data on the Chinese keyword ‘kouzhao’ (mask) in the 337 matched prefectures with the judicial data in 2014–2017. This variable measures the city wide dynamic interest in investing in self-protection against pollution.

Table 2 provides the summary statistics for all of the variables we use. The average case lasts for 37 d from the filing of the claim to the resolution of the case. Figure A1 presents the density distribution of the criminal case duration, the primary outcome of our interest. The distribution is positively skewed because many criminal court cases are settled relatively early on, within 60 d.

9The Chinese document can be found at www.court.gov.cn/zixun-xiangqing-13520.html.

10China’s legal system is a civil law system, as opposed to a common law system, with only statutory law. Judges’ decisions are usually not accompanied by written legal opinions explaining their reasoning. Moreover, judicial decisions do not have any legally binding precedential effect on other cases. Thus, the interpretations by the SPC are important guides for judges. However, many interpretations are replete with vague passages that provide neither predictability nor transparency. Therefore, judges have a great deal of flexibility in implementation.

11In late 2013, the SPC promulgated Regulations on Publishing Verdicts of Peoples’ Courts Online. According to this document, verdicts of peoples’ courts at various levels should be published online except for those (1) involving state secrets or individual privacy; (2) involving juveniles; (3) resolved through mediation; and (4) other ‘improper’ situations. See http://wenshu.court.gov.cn/ for the data source.

12The MEP directly operates 1497 State-level monitoring stations nationwide, which ensures that the data collected are independent of local government oversight, thus preventing interference and guaranteeing accuracy and authenticity.

13According to China’s Criminal Procedure Law, sentencing should normally take place within two months of the trial, and at most three months. That period may be extended a further three months for various reasons with the permission of the court above the one that conducted the trial. Any further extension requires the sentencing court to apply to and receive specific permission from the SPC.
Table 1. Sample size and share of the total population.

| Year | Case type | Population size (millions) | Initial sample | Final sample |
|------|-----------|---------------------------|----------------|--------------|
|      |           | Size (millions) | Share of population (%) | Size (millions) | Share of population (%) |
| 2014 | Criminal  | 1.0            | 0.8            | 77.3         | 0.7            | 64.4         |
|      | Civil     | 8.0            | 3.6            | 44.9         | 1.9            | 23.6         |
| 2015 | Criminal  | 1.1            | 0.8            | 69.2         | 0.7            | 62.1         |
|      | Civil     | 9.6            | 3.5            | 36.9         | 2.6            | 26.6         |
| 2016 | Criminal  | 1.1            | 0.9            | 80.2         | 0.7            | 59.0         |
|      | Civil     | 10.8           | 6.2            | 57.2         | 3.1            | 29.1         |
| 2017 | Criminal  | 1.3            | 0.7            | 51.3         | 0.5            | 42.0         |
|      | Civil     | 11.7           | 8.8            | 75.5         | 3.2            | 27.7         |
|      | Sum       | 4.5            | 3.1            | 68.6         | 2.5            | 56.1         |
|      | Civil     | 40.0           | 22.1           | 55.2         | 10.8           | 27.0         |

Notes: The table reports our sample size and share of the total population of criminal and civil cases of the first instance handled in China's basic courts. Data on population size are from the China Law Yearbook in various years. All our results in this paper are estimated on the final sample and thus our results should be interpreted with this sample in mind. The initial data processing removes: (1) cases without judges’ names; (2) cases without the exact date when they were assigned to judges; (3) cases with erroneous dates (i.e. too far in the past or in the future); (4) cases handled in prefectures where meteorological or pollution information are missing; (5) cases handled in special courts (e.g. military, maritime, railway and forestry courts); (6) cases with decision time over 361 d; (7) criminal cases with more than one count of conviction and single events with more than one-person offense; (8) written orders and notices of entry judgment.

5. Pollution and heat effects on the duration of cases

We report linear regression estimates to study how local pollution and heat affect a trial’s duration. The main results are summarized in Table 3. Column 1 presents results based on including a set of fixed effects and weather controls. The results show that air pollution is associated with longer criminal case’s duration. In columns 2–4, we add additional controls. This significantly increases the explanatory power of the regressions. The impact of air pollution on the case handling time is robust to the inclusion of the additional variables. In column 3, we present our preferred specification with the Baidu Mask Index as an additional control. We find that a 1% increase in PM2.5 leads to 0.182% increase in the case handling time.

To test if our results are robust to the choice of estimation strategies, we also employ the complementary log-log model (cloglog) to study the effects of pollution and heat on case survival probabilities. The cloglog model accounts for the fact that the data contains not only information on a case adjudicated at day $t$ but also additional information on the case in jurisdiction until the $t$-1 period. Our OLS results are consistent with cloglog results. The cloglog model results are available on request.

In Table A3, we further examine to what extent the results generalize to other judicial settings. Our results indicate that a judge’s exposure to pollution is associated with the judge taking more time to finalize the judicial decision.

To gauge the economic significance of our estimates, we re-estimate equation (1) with both the decision time variable and PM2.5 variable measured using their actual values. We find that a one unit ($\mu g \ m^{-3}$) increase in PM2.5 will increase case duration by 0.063 d, on average, all else equal. As reported in Table 1, there are around 1.1 million criminal cases annually adjudicated over 2014–2017. Our estimates suggest that a one unit ($\mu g \ m^{-3}$) decrease in PM2.5 is associated with a decrease in total annual criminal case duration of 69 300 d.

The adverse impact of PM2.5 was not widely known to the Chinese populace before 2013 (Jia et al 2019). Before 2013, the Baidu Index on ‘PM2.5’ was close to zero indicating that the Chinese population was generally unaware of this pollutant (Chew et al 2018). Beginning in 2013, the Chinese prefectures started to monitor and publish daily levels of PM2.5. By the end of 2014, all prefectures were posting real-time disclosures of daily PM2.5 levels. To warn residents about extreme pollution levels on any given day, the most polluted cities were required to launch a four-color Smog Alert system by the end of 2014 when more cities announced their first-ever red alert for heavy smog. In column 4 of Table 3, we add an interaction term between log (PM2.5) and a post-2014 dummy. The statistical significance of the interaction terms indicates that the judges have gotten better at adapting to PM2.5 over time now that they are aware of the threat starting in 2015. However, the size of this estimated coefficient is small.

The yellow alert takes effect, the government will warn locals to reduce outdoor activities and take precautions via various media. The yellow alert takes on the values red indicating the highest level, followed by orange, yellow and blue. When a blue alert was not widely known to the Chinese populace before 2013 (Jia et al 2019). Before 2013, the Baidu Index on ‘PM2.5’ was close to zero indicating that the Chinese population was generally unaware of this pollutant (Chew et al 2018). Beginning in 2013, the Chinese prefectures started to monitor and publish daily levels of PM2.5. By the end of 2014, all prefectures were posting real-time disclosures of daily PM2.5 levels. To warn residents about extreme pollution levels on any given day, the most polluted cities were required to launch a four-color Smog Alert system by the end of 2014 when more cities announced their first-ever red alert for heavy smog. In column 4 of Table 3, we add an interaction term between log (PM2.5) and a post-2014 dummy. The statistical significance of the interaction terms indicates that the judges have gotten better at adapting to PM2.5 over time now that they are aware of the threat starting in 2015. However, the size of this estimated coefficient is small.
To further test whether judges adapt to high PM$_{2.5}$ levels, we code each Smog Alert day in 62 prefectures in 2016 and 2017. In column 5, we include a new variable measured by the percentage of smog alert days during the case’s time period. If judges respond to the information that a smog alert has been issued, then they should take costly actions at this time to reduce their exposure. The adaptation hypothesis predicts that the smog alert variable (controlling for outdoor the PM$_{2.5}$ level) should have a negative effect. As shown in column 5, we find a negative and statistically significant effect. Specifically, a 1% increase in smog alert days leads to 0.3% decrease in the case handling time. Column 6 reports the pollution results condition on forecasts (so the identifying variation in PM$_{2.5}$ comes only from surprise events). The negative coefficient of forecasts indicate judges can better adapt to the air pollution if they know it will be polluted.

To capture potential nonlinear effects of pollution on case duration, in column 7, we include specifications with a series of PM2.5 indicator variables.

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Note: All the environmental variables are measured at prefecture level.
Table 3. Testing for the effects of heat and pollution on productivity.

|                          | Log(Decision_Time) |
|--------------------------|--------------------|
|                           | (1)               |
| Log(PM$_{2.5}$)          | 0.260***          |
|                          | (0.004)           |
| Baidu_Mask_Index/100     | −0.136***         |
|                          | (0.005)           |
| Log(PM$_{2.5}$) × Post2014| −0.017***       |
|                          | (0.005)           |
| Smog_Alert_Share         | −0.003***         |
|                          | (0.000)           |
| Forecast_Max_AQI/10      | −0.062***         |
|                          | (0.002)           |
| PM$_{2.5}$ 25 µg m$^{-3}$–35 µg m$^{-3}$ | 0.130*** |
|                          | (0.003)           |
| PM$_{2.5}$ 35 µg m$^{-3}$–75 µg m$^{-3}$ | 0.214*** |
|                          | (0.004)           |
| PM$_{2.5}$ 75 µg m$^{-3}$–150 µg m$^{-3}$ | 0.236*** |
|                          | (0.005)           |
| PM$_{2.5}$ ≥150 µg m$^{-3}$ | 0.125*** |
|                          | (0.009)           |
| Heat                     | −0.162***         |
|                          | (0.003)           |

Year dummy Yes Yes Yes Yes Yes Yes Yes Yes Yes
Judge dummy Yes Yes Yes Yes Yes Yes Yes Yes Yes
Crime type dummy Yes Yes Yes Yes Yes Yes Yes Yes Yes
Weather condition controls Yes Yes Yes Yes Yes Yes Yes Yes Yes
Province dummy × Month dummy Yes Yes Yes Yes Yes Yes Yes Yes Yes
Offender demographic controls Yes Yes Yes Yes Yes Yes Yes Yes Yes
Legal factor controls Yes Yes Yes Yes Yes Yes Yes Yes Yes
Case complexity controls Yes Yes Yes Yes Yes Yes Yes Yes Yes
Adjusted R square 0.432 0.662 0.663 0.663 0.658 0.643 0.663 0.664
No. of clusters 24 079 24 079 24 079 24 079 4992 4529 24 079 24 079
No. of observations 2358 565 2358 565 2358 565 2358 565 293 267 302 175 2358 565 2358 565

Notes: In column 3, we restrict the analysis to prefectures with complete smog alerts in 2016 and 2017. In column 6, we restrict the analysis to prefectures with complete daily AQI forecasts in 2016 and 2017. In column 7, daily PM$_{2.5}$ less than 25 micrograms per cubic metre is the omitted reference group. The weather condition controls are the daily temperature, humidity, rainfall, sunshine time and wind speed at prefecture level. In column 8, the weather condition controls are the daily humidity, rainfall, sunshine time and wind speed at prefecture level. Reported in parentheses are robust standard errors clustered by judge. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively.
“The indicator variables include 25–35 $\mu g\ m^{-3}$, 35–75 $\mu g\ m^{-3}$, 75–150 $\mu g\ m^{-3}$, and above 150 $\mu g\ m^{-3}$, with <25 $\mu g\ m^{-3}$ as the reference category. The above four bins are chosen because the WHO recommends a daily maximum PM$_{2.5}$ exposure of 25 $\mu g\ m^{-3}$, while China’s equivalent standard is 75 $\mu g\ m^{-3}$. Second, in China, a daily PM$_{2.5}$ concentration lower than 35 $\mu g\ m^{-3}$ indicates good air quality. Finally, a blue smog alert (the lowest level in the four-color coded alert system) will be triggered when levels of PM$_{2.5}$ above 150 $\mu g\ m^{-3}$ (equivalent to 200 on the AQI) are forecast to last for more than 24 h. As shown in column 7 of table 3, the non-linear estimates of pollution indicate that higher levels of pollution increase the case’s decision time. It is relevant to note the non-monotonic effect such that the highest level of pollution category has a smaller effect than the second category. We posit that judges are engaging in more averted behavior when outdoor pollution is at such high levels.

In column 8, we add a Heat dummy variable, which takes the value of 1 if the average daily maximum temperature over a case duration is hotter than 32 degrees Celsius otherwise takes the value of 0, to specifically test the heat effect on case duration. The coefficient estimates reported in column 7 indicate that judges are adapting to the extreme heat. In our regression, we include a full set of province-month fixed effects. This means that we are comparing a judge’s decision time within province-month intervals. Since it is mainly only over 32 degrees Celsius in July and August, our ‘heat results’ are comparing the length of trials in the same month when it hit versus when it is really hot. Our findings support the claim that China’s government effectively uses air conditioning and heat alerts during times of high outdoor temperature and this indoor cooling is associate with an improvement in a judge’s workplace performance.

The above findings based on data from China are qualitatively similar to the findings of Heyes and Saberian (2019) based on U.S. justices’ decisions in asylum hearings. In contrast to their study, we test for whether air pollution increases the judge’s decision time.

| Table 4. Heterogeneous effects of pollution on productivity by judge age. |
|-----------------------------|-------------------|------------------------|-------------------|------------------------|
|                            | Young Judge       | Old Judge              |
|                            | (1)               | (2)                    |
| Log(PM$_{2.5}$)            | 0.147***          | 0.186**                |
| (0.007)                    | (0.004)           |                        |
| Baidu_Mask_Index/100       | -0.075***         | -0.154***              |
| (0.006)                    | (0.006)           |                        |
| Judge dummy                | Yes               | Yes                    |
| Year dummy                 | Yes               | Yes                    |
| Crime type dummy           | Yes               | Yes                    |
| Weather controls           | Yes               | Yes                    |
| Province dummy × Month dummy | Yes             | Yes                    |
| Offender demographic controls | Yes           | Yes                    |
| Legal factor controls      | Yes               | Yes                    |
| Case complexity controls   | Yes               | Yes                    |
| Adjusted R square          | 0.603             | 0.660                  |
| No. of clusters            | 6291              | 22555                  |
| No. of observations        | 283412            | 2073964                |

Notes: The weather condition controls are the daily temperature, humidity, rainfall, sunshine time and wind speed at prefecture level. Reported in parentheses are robust standard errors clustered by judge. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively.

5.1. The effects of pollution by judge age and case complexity

Ongoing social science research studies the cognitive ability of older people (Rohwedder and Willis 2010, Smith et al 2010). A second literature examines how pollution affects decision making in complex laboratory experiments (Chew et al 2018). Our rich micro data set allows us to blend these two independent literatures. We use our rich micro data to explore how pollution affects decision times for young and older judges and we explore how a case’s complexity affects the marginal effects of pollution. In columns 1–2 of table 4 presents our results stratified by the age of the judge. We find that older judges are more influenced by pollution. This finding is consistent with the existing literature (Teitelbaum 2006, Christensen and Szmer 2012).

In columns 1–2 of table 5, we divide the full sample by our proxy for case complexity. We find that it takes judges more days to make a decision on complex cases when it is more polluted outside. In

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21As required by the high-temperature allowance protocol, employers should pay a high-temperature allowance to outdoor workers and indoor employees if the workplace temperature is above 33 degrees Celsius (33 is included). Therefore, in most of Chinese courtrooms, the outdoor temperature bar for air conditioning in summer is set at 32 degrees Celsius.

22China has a three-tier early warning system for high temperatures: a yellow warning (the lowest one) is issued when high temperatures above 35 degrees Celsius are predicted for three consecutive days.

23In Hayes and Saberian’s study (2019), an immigration judge typically determines multiple cases indoors on a given day. Our sample includes all types of criminal and civil cases. A judge typically takes a few days to make the final decision on a case. While adjudications take place indoors, some judges conduct several on-site investigations to determine the real reasons for the crime.

24A case is assumed to be simple if the verdict word count is below the average of our whole sample.
We find that it takes in columns 3–4 of table 5, we divide the full sample by case procedure simplicity.\textsuperscript{25} We find that it takes judges more days to make a decision on cases featuring lawyers when it is polluted outside.\textsuperscript{26} In columns 5–6 of table 5, we present our heterogeneity results by case sentencing with or without guidelines. The weather condition controls are the daily temperature, humidity, rainfall, sunshine time and wind speed at prefecture level. Reported in parentheses are robust standard errors clustered by judge. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively.

### Notes

\textsuperscript{25}In the data sample used in column 3 of table 5, the plaintiff and the defendant usually represent themselves in the trial, that is, the litigants appear without lawyers. During the trial, which typically lasts only a few minutes, the judge sees the litigants for the first time and hears their arguments. The judge has to issue a ruling in the case within seven days of the trial. Litigants who wish to appeal a ruling need to first request approval from the relevant local courts.

\textsuperscript{26}In China, after criminal cases are transferred to the prosecutor’s office for prosecution, defendants have the right to hire lawyers to handle their defense. A criminal lawyer can perform two different functions in the criminal process: provide legal counsel and defense representation. However, there is ample evidence that lawyers have not been able to fulfill their duties (Michelson 2007, Liu and Haliday 2016). To our best knowledge, there is no type of court cases in which one side of the legal case is aware that judges are affected by pollution.

\textsuperscript{27}To mitigate concerns about inter-judge sentencing variation, on January 1st, 2014, the SPC issued sentencing guidelines, which provide suggested sentencing ranges by category of offense. The guidelines take into account both the seriousness of the crime and the defendant’s criminal record when determining sentencing length of the 15 most frequently committed crimes.

\textsuperscript{28}Testing for the effects of pollution on criminal judicial results.

\begin{table}[h]
\centering
\caption{Heterogeneous effects of pollution on productivity by case complexity.}
\begin{tabular}{lcccccc}
\hline
 & Log(Decision\_Time) \\
 & Simple & Hard & Fast-track & Slow-track & With Guideline & Without Guideline \\
\hline
Log(PM$_{2.5}$) & 0.212*** & 0.296*** & 0.136*** & 0.344*** & 0.164*** & 0.190*** \\
 & (0.005) & (0.006) & (0.004) & (0.007) & (0.004) & (0.004) \\
Baidu\_Mask\_Index/100 & −0.138*** & −0.254*** & −0.097*** & −0.272*** & −0.159*** & −0.105*** \\
 & (0.006) & (0.008) & (0.004) & (0.012) & (0.006) & (0.007) \\
Judge dummy & Yes & Yes & Yes & Yes & Yes & Yes \\
Year dummy & Yes & Yes & Yes & Yes & Yes & Yes \\
Crime type dummy & Yes & Yes & Yes & Yes & Yes & Yes \\
Weather controls & Yes & Yes & Yes & Yes & Yes & Yes \\
Province dummy × Month dummy & Yes & Yes & Yes & Yes & Yes & Yes \\
Offender demographic controls & Yes & Yes & Yes & Yes & Yes & Yes \\
Legal factor controls & Yes & Yes & Yes & Yes & Yes & Yes \\
Case complexity controls & No & Yes & No & Yes & Yes & Yes \\
Adjusted R square & 0.449 & 0.453 & 0.371 & 0.338 & 0.649 & 0.688 \\
No. of clusters & 19 823 & 21 047 & 19 874 & 19 684 & 20 172 & 21 235 \\
No. of observations & 1204,337 & 1151 465 & 1376 334 & 979 789 & 1273 822 & 1082 285 \\
\hline
\end{tabular}
\end{table}

\textsuperscript{28}In the data sample used in column 1–2, a case is assumed to be simple if the verdict word count is below the average of our whole sample. In columns 3–4, a case is assumed to be simple if the verdict mentions that that case was handled via the fast-track procedures. Columns 5–6 presents our heterogeneity results by case sentencing with or without guidelines. The weather condition controls are the daily temperature, humidity, rainfall, sunshine time and wind speed at prefecture level. Reported in parentheses are robust standard errors clustered by judge. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively.

\begin{table}[h]
\centering
\caption{Testing for the effects of pollution on criminal judicial results.}
\begin{tabular}{lcc}
\hline
 & Case\_Appeal & Case\_Reverse \\
\hline
Log(PM$_{2.5}$) & 0.003** & 0.001*** \\
 & (0.001) & (0.000) \\
Baidu\_Mask\_Index/100 & −0.004** & −0.002*** \\
 & (0.002) & (0.001) \\
Dependent variable mean & 0.093 & 0.016 \\
Judge dummy & Yes & Yes \\
Year dummy & Yes & Yes \\
Crime type dummy & Yes & Yes \\
Weather controls & Yes & Yes \\
Province dummy × Month dummy & Yes & Yes \\
Offender demographic controls & Yes & Yes \\
Legal factor controls & Yes & Yes \\
Case complexity controls & Yes & Yes \\
Adjusted R square & 0.150 & 0.051 \\
No. of clusters & 24 079 & 24 079 \\
No. of observations & 2358 565 & 2358 565 \\
\hline
\end{tabular}
\end{table}

Notes: In the data sample used in column 3 of table 5, the plaintiff and the defendant usually represent themselves in the trial, that is, the litigants appear without lawyers. During the trial, which typically lasts only a few minutes, the judge sees the litigants for the first time and hears their arguments. The judge has to issue a ruling in the case within seven days of the trial. Litigants who wish to appeal a ruling need to first request approval from the relevant local courts.

Notes: The weather condition controls are the daily temperature, humidity, rainfall, sunshine time and wind speed at prefecture level. Reported in parentheses are robust standard errors clustered by judge. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively.

In table 6, we report results indicating that pollution affects the probability that a case is appealed by...
the defendants or is remanded by the higher courts. These are indicators that the judge did not perform well in adjudicating the trial. The probability of both outcomes is marginally increased when the judge is exposed to more pollution. This finding is in accord with our case complexity findings. Judges have more trouble making ‘good decisions’ when exposed to more pollution.

6. Conclusion

Air pollution in China lowers the productivity of high skilled judges. We find that a 1% increase in PM$_{2.5}$ leads to a 0.182% increase in the case handling time. Highly educated professionals should have the greatest access to self-protection products and a high quality workplace that minimizes the threat posed by environmental exposure. Our results indicate that on more polluted days, judges have trouble ruling on more complex cases and are more likely to make decisions that are appealed and overruled. We find that judges have greater success adapting to the heat relative to adapting to pollution exposure.

The Chinese leadership has emphasized the need for greater public sector efficiency and increased productivity (e.g. the SPC instructed the courts to settle the backlog of cases within a deadline). Recognition of our findings provides the state with an incentive to further reduce urban air pollution levels.

In international greenhouse gas mitigation treaty negotiations, China has expressed a willingness to reduce its greenhouse gas emissions intensity. This intensity is based on the tons of greenhouse gas emissions produced per dollar of gross national product. International greenhouse gas emissions reduction negotiations face the enforcement challenge. Nations may sign such treaties and then not bother to actually enforce them. The incentive to follow through with public promises hinges on the private benefits and private costs to the nation of keeping its promises (Barrett 2003).

Our findings indicate that there are co-benefits to China from abiding by treaties that reduce its reliance on fossil fuels. As China transitions away from generating power from coal, this will reduce the nation’s carbon intensity and it will reduce the nation’s local air pollution levels. Our estimates of the impact of particulates on urban worker productivity provide additional evidence of the benefits for China’s own productivity and quality of life from pursuing the low carbon agenda.

Data availability statement

Our data and codes that support the findings of our study are available through the following link: www.dropbox.com/s/0ibk1obrl1ib8j7z/Data%26Code%20for%20Replication.rar?dl=0

Appendix

Figure A1. The empirical distribution of criminal case decision time.

Notes: This figure provides the frequency distribution of the criminal case decision time.
Table A1. Average hours per week worked and gender difference in 2010.

| Occupation                     | All working time | Male working time | Gender difference |
|--------------------------------|------------------|-------------------|-------------------|
|                                | Average          | Labor             | Working time      |
| Judge                          | 41.6             | 41.4              | 2.00              | 0.99              |
| Lawyer                         | 42.0             | 42.1              | 2.21              | 1.01              |
| Banking service clerk          | 42.0             | 42.1              | 3.01              | 1.01              |
| Computer system analyst        | 43.2             | 43.3              | 1.02              | 1.01              |
| Insurance sale agent           | 43.6             | 43.9              | 0.74              | 1.01              |
| Accountant                     | 43.9             | 44.1              | 0.37              | 1.01              |
| Doctor                         | 44.6             | 45.3              | 0.74              | 1.01              |
| Machinery mechanics            | 45.1             | 45.3              | 4.75              | 1.02              |
| Electrical engineer            | 44.5             | 44.5              | 2.49              | 0.99              |
| Retail salesperson             | 50.2             | 50.8              | 0.74              | 1.02              |
| Chefs and head cooks           | 50.9             | 51.8              | 1.97              | 1.06              |
| Average for all full-time      | 45.2             | 46.4              | 1.25              | 1.06              |
| workers                        |                  |                   |                   |                   |

Note: Gender difference refers to the ratio of total no. of full-time male workers (or a male worker’s average working hours per week) to total no. of full-time female workers (or a female worker’s average working hours per week).

Data source: China Census 2010.

Table A2. Prefecture-wise percentage of polluted days 2013–2017.

| Polluted days (%) (1) | (2) |
|-----------------------|-----|
| January               | 41.22 | 83.55 |
| February              | 32.56 | 83.70 |
| March                 | 28.91 | 85.66 |
| April                 | 21.45 | 83.24 |
| May                   | 21.09 | 79.54 |
| June                  | 17.10 | 67.17 |
| July                  | 7.39  | 56.49 |
| August                | 5.09  | 57.27 |
| September             | 8.24  | 62.45 |
| October               | 19.28 | 72.74 |
| November              | 29.05 | 81.76 |
| December              | 42.62 | 87.35 |

Notes: In China, a ‘blue-sky day’ is defined as a day with the value of AQI less than 100, that is, the air quality is either excellent or good. In column 1, the percentage of polluted days in a certain month is defined as the percentage of days with daily average AQI over 100 at prefecture level during that month. In column 2, the percentage of polluted days in a certain month is defined as the percentage of days with daily average PM$_{2.5}$ over the World Health Organization safe limit (i.e. 25 micrograms per cubic metre 24-hour mean) at prefecture level during that month. All shares reported in this table are weighted by prefecture total population in the year 2010.

Table A3. Testing for the effects of pollution on productivity (other judicial settings).

|                         | Log(Decision_Time) |
|-------------------------|---------------------|
|                         | Civil Case Handled in Courts of First Instance | Criminal Case Handled in Appellate Courts |
| Log(PM$_{2.5}$) (1)     | 0.273*** (0.003)    | 0.308*** (0.011) |
| Baidu_Mask_Index/100 (2)| −0.168*** (0.005)   | −0.111*** (0.010) |
| Judge dummy             | Yes                 | Yes               |
| Year dummy              | Yes                 | Yes               |
| Crime/case type dummy   | Yes                 | Yes               |
| Weather controls        | Yes                 | Yes               |
| Province dummy ×        | Yes                 | Yes               |
| Month dummy             | Yes                 | Yes               |
| Case complexity controls| Yes                 | Yes               |
| Adjusted R square       | 0.756               | 0.311             |
| No. of clusters         | 105 519             | 4392              |
| No. of observations     | 10 234 498          | 291 316           |

Notes: The weather condition controls are the daily temperature, humidity, rainfall, sunshine time and wind speed at prefecture level. Reported in parentheses are robust standard errors clustered by judge. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively.
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