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# THOUGHT LEADERSHIP BRIEF

# Straw Burning, $PM_{2.5}$ and Death: Evidence from China

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Photo by Satoshi Kaya / Flickr.

## KEY POINTS

- Agricultural straw burning significantly increases air pollution and cardiorespiratory mortality.
- A 10 μg/m³ increase in $PM_{2.5}$ increases monthly mortality by 3.25%.
- Middle-aged and old people are particularly vulnerable to straw burning pollution.
- Subsidizing straw recycling can bring about significant health benefits.

## ISSUE

Farmers often burn agricultural straw residues from crops such as wheat, rice, maize, and cotton in *situ* after harvest. Straw burning is particularly prevalent in developing countries that rely heavily on agricultural production and is a major cause of seasonal air pollution. However, effective regulations on straw burning are rare and the lack of scientific evidence on how straw burning affects people's health can make the government reluctant to design and enforce strict regulations.

China is the largest producer of crops and straw in the world. A large proportion of the population live near the farmland, and are exposed to severe air pollution from seasonal straw burning in summer and autumn. Despite strict command-and-control regulations banning straw burning since the late 1990s, the number of straw fires has been continuously increasing over the past two decades. As such, estimating the impact of agricultural fires and identifying effective ways to control straw burning are of great policy relevance and urgency. In this study, we estimate the impacts of straw burning on air pollution and mortality using data from China and try to quantify the potential benefits of China's recent efforts in straw recycling.

## ASSESSMENT

Our analysis is based on a novel panel dataset that assembles detailed information on straw burning, air pollution, and mortality in China (Figure 1). High-resolution satellite image data are used to identify the exact locations of straw burning in China from 2013 to 2015. Straw burning data are then linked to local air quality data collected from 1,650 ground-level monitors. Death records from a quarter of the Chinese population are obtained from the Disease Surveillance Point system (DSPS) of China's Center for Disease Control and Prevention, which contains information on gender, age group, and cause of death at the county level for the same period. With these data matched at the county level, we then estimate how straw burning affects air pollution and mortality.

Our baseline results show that 10 additional straw fires within 50 km of a county center will lead to a 4.79 μg/m$^3$ (or 7.62%) increase in monthly fine particulate matter ($PM_{2.5}$, diameter < 2.5μm) and a 1.56% increase in all-cause mortality in Chinese counties (Table 1). Using straw burning as an instrumental variable, we further estimate that a 10 μg/m$^3$ increase in monthly $PM_{2.5}$ can lead to a 3.25% increase in mortality. Heterogeneity analyses reveal that straw burning pollution primarily increases cardiorespiratory mortality, and has a strong impact on people over 40 in rural and poor areas, but has no statistically significant impact on younger people.

The key concern of our baseline results is that straw burning may affect human health through channels other than air pollution. For example, local governments may implement straw burning regulations that are endogenous to local population health. It is also possible that straw burning can create temporary income shocks to farmers, as the activity is associated with harvesting. To address these issues, we adopt two augmented instrumental variable strategies, which together lend additional credibility to our baseline finding. In our first augmented strategy, we use non-local straw burning to instrument local air pollution (conditional on local straw burning). Non-local straw burning is an appealing instrument for air pollution because the burning behaviors of non-local farmers are typically not subject to the local government's control. In the second strategy, we explore different wind patterns for identification. We separate straw burning from upwind and downwind areas and use the difference in the coefficients between upwind and downwind fires to isolate the pollution effect from the potential income effect. The identification relies on the fact that upwind and downwind straw fires have asymmetric impacts on air pollution, but have symmetric impacts on local people's income. In both exercises, we obtain estimates that are quantitatively similar IV to the baseline model (3.27% and 4.47%, respectively), suggesting the endogeneity of straw burning is not a big concern in our research context.

**Figure 1. Satellite Detected Straw Burning and $PM_{2.5}$ in Summer During 2013-2015**

Note: Colored polygons represent DSP (Disease Surveillance Point) cities used in the paper. Gray and white areas denote non-DSP cities. DSP counties are too small to see on the maps and thus are not plotted.

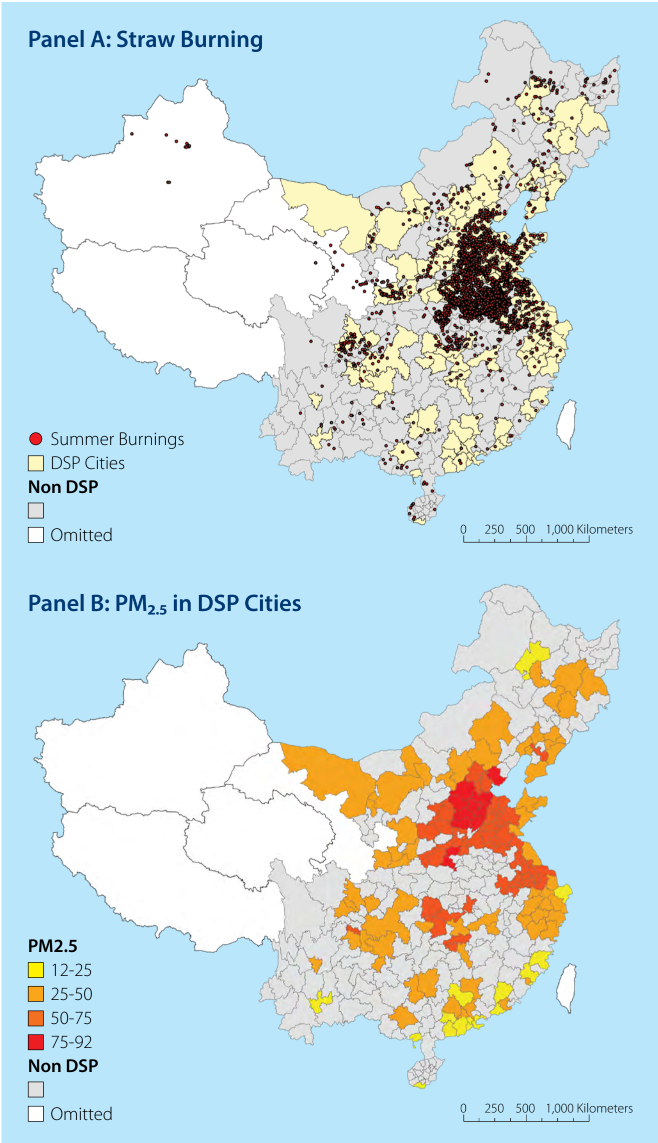


**Table 1. Effects of Straw Burning and Pollution on Log # of Death**

Note: Each column represents a separate regression. The reduced-form estimates, IV estimates, and OLS estimates are reported in Panels A, B, and C, respectively. Columns (1) – (2) examine the effects of pollution on percentage change in monthly all-cause mortality. Columns (3) – (4) and Columns (5) – (6) examine the effects on cardiorespiratory and non-cardiorespiratory mortality, respectively. Weather variables include wind speed, wind direction, precipitation, temperature, and relative humidity. Standard errors in parentheses are two-way clustered at county and month level. *** p<0.01, ** p<0.05, * p<0.1.

| | All-Cause | | Cardiorespiratory | | Non-Cardiorespiratory | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| **Panel A. The Impact of Straw Burning (Reduced-Form Estimates)** | | | | | | |
| Straw Burning | 1.79** | 1.56** | 2.11** | 1.82** | -0.72 | -0.58 |
| *(per 10 points)* | (0.92) | (0.80) | (0.98) | (0.81) | (0.86) | (0.96) |
| **Panel B. $PM_{2.5}$ and Deaths (IV Estimates)** | | | | | | |
| $PM_{2.5}$ | 3.56*** | 3.25** | 4.19*** | 3.80*** | -1.43 | -1.21 |
| *(per 10 μg/m³)* | (1.38) | (1.43) | (1.45) | (1.48) | (1.78) | (2.10) |
| **Panel C. $PM_{2.5}$ and Deaths (OLS Estimates)** | | | | | | |
| $PM_{2.5}$ | 0.13 | 0.32 | 0.29 | 0.47 | -0.46 | -0.25 |
| *(per 10 μg/m³)* | (0.26) | (0.23) | (0.43) | (0.38) | (0.35) | (0.47) |
| Observations | 1,595 | 1,538 | 1,595 | 1,538 | 1,595 | 1,538 |
| # Counties | 215 | 209 | 215 | 209 | 215 | 209 |
| Fixed Effects | Y | Y | Y | Y | Y | Y |
| Weather | | Y | | Y | | Y |

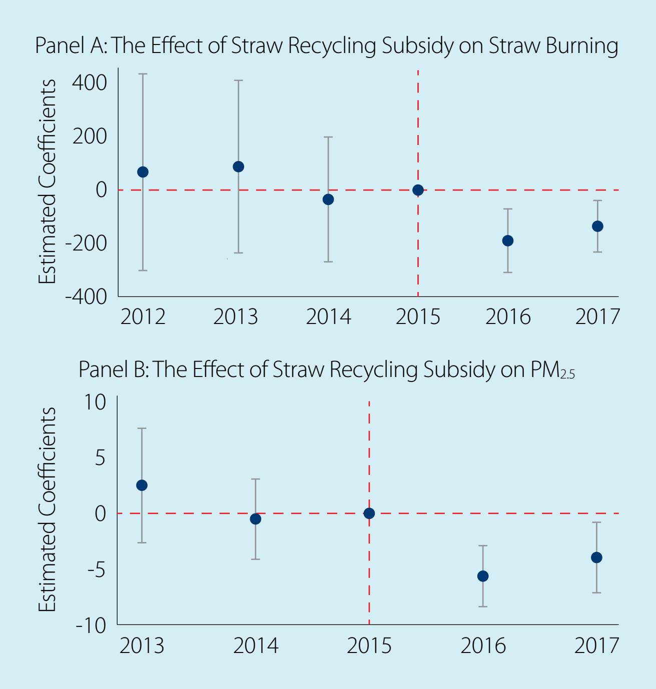
Based on our findings, we evaluate China's recent straw recycling policy. Starting from 2016, ten provinces with the most intensive straw burning activities each received 100 million Chinese yuan (around 14.2 million USD) in 2016 to recycle straw. These provinces are Henan, Anhui, Heilongjiang, Shandong, Jilin, Hebei, Jiangsu, Liaoning, Shanxi and Inner Mongolia. The subsidy's objective is to improve air quality by incentivizing farmers to recycle straw instead of burning it. We find that subsidizing straw recycling effectively reduced straw burning activities and improved air quality (Figure 2). Specifically, the number of straw fires in subsidized provinces dramatically declined after the policy by 153 a year, relative to the non-subsidized provinces, and this change brought down the annual average $PM_{2.5}$ concentrations by 4.33 $\mu g/m^3$. These estimates imply that the straw recycling policy could have averted 18,900 pre-mature deaths annually in China. The health benefit from reduced mortality is estimated to be about 55 billion Chinese yuan (around 7.85 billion USD), which is an order of magnitude larger than the cost. To put these numbers in another way, it costs at most 137,600 Chinese yuan (19,700 USD) to avert a premature death when the government subsidizes straw recycling.

## RECOMMENDATIONS

Our findings have several implications. First, we show that agricultural straw burning primarily kills the middle-aged and the elderly from cardiorespiratory diseases in rural and poor areas in China. Therefore, reducing straw burning will bring about significant health benefits for these people.

**Figure 2. Effects of Straw Recycling Subsidy on Straw Burning and $PM_{2.5}$**

Note: The upper figure in Panel A plots the impacts of straw recycling subsidy on the number of straw fires based on an event-study analysis. The lower figure in Panel B plots the impacts of straw recycling subsidy on $PM_{2.5}$. The year 2015 (one year before the subsidy) is chosen as the reference.



Second, we show that China's straw-recycling subsidy significantly reduced straw burning activities, which provides important insights into designing effective straw burning regulations. Historically, the Chinese government relied on command-and-control regulations to reduce straw burning. Due to the high enforcement costs, however, these policies were not very successful. In contrast, providing subsidies to farmers and recycling companies immediately led to less burning and improvement in air quality. The incentive-based approach seems to outperform the command-and-control approaches in our research context. These findings can be referenced by other agrarian economies with similar agricultural burning issues.

Finally, this study only quantifies the short-term health impacts of straw burning pollution on mortality. Presumably, accumulated exposure to air pollution would cause larger health damages to individuals. That implies, the potential benefits from controlling straw burning would be even greater if the straw recycling can be sustained. Future research is warranted to better understand the welfare implications of these regulations in the long run.

**Guojun He** is an economist working on environmental, development, and governance issues. Currently, he is an assistant professor appointed jointly at Division of Social Science, Division of Environment and Sustainability, and Department of Economics at The Hong Kong University of Science and Technology. He is also a faculty associate of HKUST Institute for Emerging Market Studies and faculty affiliate of Institute for Public Policy. In addition, he holds a concurrent appointment at the University of Chicago's interdisciplinary Energy Policy Institute (EPIC) and serves as the research director of its China center (EPIC-China).

Prof He's research tries to address some of the most challenging problems faced by developing countries and seeks to produce empirically-grounded estimates for optimal policy design. The majority of his work focuses on understanding the benefits and costs of environmental policies, while he also has a broader research interest in development and governance issues.

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Prof Zhou is an experienced epidemiologist and public health researcher in China. His research focuses on chronic non-communicable disease control and prevention, especially mortality trends, burden of diseases, the health effects of risk factors, and intervention strategy development and assessment. His most recent research included the effect of air pollution on health status in China. He is also a leading expert on vital statistics in China. He has received research projects or grants from the main funding sources in China, including the Ministry of Science and Technology, Ministry of Health, and Ministry of Education. He has also received funding from international agencies such as the World Health Organization and has long-term collaborations with the University of Oxford, Harvard University, Stanford University, and Johns Hopkins University in a wide range of research projects on chronic disease control and prevention.

**Reference:**
He, Guojun, Tong Liu, and Maigeng Zhou. "Straw burning, PM2. 5, and death: evidence from China." *Journal of Development Economics.*

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