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Air Pollution and Firm-Level Human Capital, Knowledge and Innovation

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This paper investigates the long-run effects of prolonged air pollution on firm-level human capital, knowledge, and innovation composition. Given the importance of human capital as an engine for economic growth, it is surprising how little evidence there is on how the environment affects human capital accumulation, and its subsequent impacts on knowledge and innovation.

We use a novel firm-level Chinese database, Surveys of Science and Technology Activities of Industrial Firms (SSTA). This dataset covers almost all industrial firms that are engaged in science and technology activities in China, reporting comprehensive information on firm-level human capital (e.g. educational levels, profession titles, and gender), knowledge, and innovation (e.g. publication, invention, and trademark). It records detailed information on employees who work on knowledge-producing activities in an independent research and development (R&D) department, such as experimental bases, laboratories, or pilot workshops. The SSTA covers firms that represent more than 90 percent of industrial knowledge and innovation across 46 two-digit industries in China, and are distributed nearly across the whole country. We combine this dataset with information on environmental pollution (PM2.5) and thermal inversion, which are obtained from the Earth Observing System of National Aeronautics and Space Administration (NASA).

In order to uncover the causal effect of air pollution on firm-level R&D human capital, our empirical strategy uses a spatial regression discontinuity (RD) design, which exploits the spatial discontinuity in air pollution created by China's Huai River heating policy. In the 1950s, due to resource constraints the central Chinese government decided to

provide coal-based heating service only for cities in the north of the Huai River. The division was chosen mainly because cities in the north have no less than 90 days when the annual average temperature is below or equal to 5°C. It was not determined by any other political or economic reasons. Until today, heating in the north primarily relies on coal-based co-generators and boilers, whereas heating in the south primarily relies on electric power. After several decades, the difference in air quality between the north and the south is substantial. Since this pollution gap has been accumulated for more than 50 years, it enables us to explore how the pollution stock affects firm-level human capital over a long period. While the north and the south of China differ from each other in many fundamental ways, in our research design, we compare firms in the south and in the north which are immediately adjacent to the Huai River, where the social, economic, and geographic conditions are statistically continuous, and the only existing significant discontinuity is in air pollution. We provide several tests which give support to the validity of our RD exercise.

Our estimates show that environmental pollution substantially diminishes both the quantity and the quality of firm-level human capital who work exclusively on R&D activities. More specifically, prolonged air pollution significantly affects firm-level human capital composition, reducing the share of employees with a PhD degree and master's degree, but instead increasing the share of employees with bachelor's degrees. Moreover, the difference in the composition of human capital materially change the knowledge and innovation structure of the firms: **with our estimates showing that environmental pollution decrease innovations that demand a high level of creativity (such as publications and inventions) while increasing innovations with a relatively low level of creativity (such as design patents).**

While it is relevant to disentangle the extensive margin effects from the intensive margin effects, data and the Huai River setting limit us to do so. In order to shed some light on the importance of the intensive margin, we investigate the impacts of environmental pollution on human capital productivity (innovations per R&D employee) over the short run, exploiting the two-stage least square (2SLS) approach with thermal inversion as an instrument. As a meteorological phenomenon, thermal inversion is correlated with air quality (PM2.5) but uncorrelated with firm-level short-run R&D workers' productivity in its neighborhood unless through the air quality channel. In this setting, we are able to investigate the short-run effects of air pollution, controlling for firm fixed effects and any firm-level characteristics formed before the sample period (2011-2013), and considering only within-firm variations.

We find that one μg/m^3 increase in the annual average PM2.5 concentration leads to a 0.188 loss in human capital productivity (number of innovations per R&D employee). Our analysis shows that air pollution heterogeneously dampens human capital productivity varying across the creativity intensiveness. The results indicate that R&D employees engaged

in highly knowledge-intensive activities are more prone to productivity losses. Last, the unconditional quantile regression shows that the effects of air pollution exhibit various patterns on quantiles with different levels of human capital productivity. The distributional patterns suggest that the marginal losses of human capital productivity are more sizable and salient in the upper quantiles, implying that top talents suffer more losses at work in response to poor environmental quality. **In sum, the findings indicate that air pollution diminishes human capital formation on the intensive margin by reducing human capital's creativity.**

With economic development understandably high on the agenda for emerging and developing countries, they may choose to introduce policies that might sacrifice environmental quality in exchange for economic prosperity. The hope is that pollution can be mitigated after economic development reaches a certain level. We show that this may not be well founded when considering the negative effects of air pollution on firm-level innovation. **Overall, our results highlight the importance of environmental quality as a significant factor for productivity and welfare.**

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