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**The Effects of Air Pollution on Education and Human Capital:  
Evidence from Prefecture-Level Cities in China**

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# The Effects of Air Pollution on Education and Human Capital: Evidence from Prefecture-Level Cities in China

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## Abstract

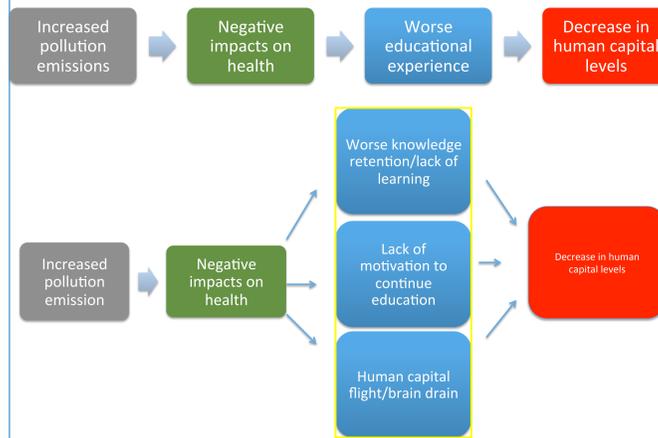
This analysis investigates the impact of pollution on human capital stocks in Chinese cities. Using panel data, from multiple data sources, on 283 prefecture-level Chinese cities for the years 2004-2013, we conduct an econometric analysis on the effects of pollution on human capital stocks. Our findings show evidence that pollution has negative effects on the human capital stocks of these cities. These negative effects are mostly found in terms of average wages and the number of college graduates in cities that are more heavily polluted. We find that a 1000-ton increase in SO<sub>2</sub> emissions predicts a decrease in college graduates by about 7, while a 1000-ton increase in SO<sub>2</sub> emissions predicts a decrease in annual average wages by 4 Yuan.



## Introduction

- 9.9% annual average growth rate (GDP)
- Largest polluter in the world
- Costs of air pollution estimated to be 6.5% of GDP
- Estimated total returns to human capital in China is between 30% and 40%
- Industrial/Agricultural sectors very energy inefficient
- Transportation pollutants increasing
- China 2030 (2012): World Bank 6 strategies to improve Chinese economy:
  - Further market-oriented reforms
  - Increase innovation
  - Incentivize "green" development
  - Expand social security
  - Reform financial system
  - Strengthen international trade opportunities

## Framework



Our basic economic model is as follows:

$$HumanCapital_{it} = F(Pollution_{it}, X_{it}, \dots)$$

And our basic econometric model is:

$$HumanCapital_t = \beta_0 + \beta_1 pollution_{it} + \beta_2 X_{it} + \dots + e_{it}$$

## Data

In order to conduct our analysis, we have to compile data on variables that measure human capital stocks as well as variables that measure emissions of pollution in Chinese cities. Furthermore, we need to collect data on variables, such as socio-economic factors and weather, which also affect human capital.

For this analysis we use data in the "China Statistical Yearbooks" from 2003-2013 for 31 cities, the "China City Statistical Yearbooks" from 2004-2013 for 283 cities and the "China Data Center," a database that compiles data from multiple different sources, mostly from similar statistical yearbooks, from 1995-2013 for 274 cities. The weather data are taken from the National Oceanic and Atmospheric Association (NOAA) database.

Variable	Definition	Years	Data Source
<b>Pollution Variables</b>			
Industrial wastewater emissions (ten thousand tons)	Refers to total volume of wastewater discharged by all the drainage outlets in industrial factories area to outside of the above factories. These water includes discharged waste water from production, sewage from daily-life use in plant area, discharged directly cooled water, poisonous and harmful mineral and underground water exceeding the discharge standard of mine district, and exclude discharged indirectly cooled water. The directly cooled water and indirectly cooled water in some enterprises those are not discriminated easily can be calculated together.	2004-2013	China City Statistical Yearbook
Industrial sulfur dioxide emissions (tons)	Refers to the total volume of discharged sulfur dioxide into atmosphere from production and fuel-burning procedures of industrial factories.	2004-2013	China City Statistical Yearbook
Industrial Soot Emissions	Refers to the volume of solid soot in the smoke discharged in the process of fuel burning in the area of the factory.	2004-2013	China City Statistical Yearbook
Ceiling Visibility(feet)	Definition: Ceiling is defined here as the height above ground of the base of the lowest layer of clouds that when combined with any layers below it, accounts for more than half of the sky above the point of observation. Visibility is defined as the greatest horizontal distance that can be seen in half or more of the horizon circle. Purpose: This summary shows the percent frequency of occurrence that weather station visibilities are greater than or equal to any of 16 selected visibility thresholds (given in miles) while ceilings are at or below any of 31 selected ceiling threshold values (given in feet). Ceiling values range from 0 to	2004-2013	NOAA
<b>Human Capital Variables</b>			
College Graduates(persons)	Refers to number of graduates from higher education institutions	2004-2013	China Data Center
New Enrollment Junior Secondary (persons)	Refers to the number of newly registered students in secondary schools.	2004-2013	China Data Center
New Enrollment Primary (persons)	Refers to the number of newly registered students in schools.	2004-2013	China Data Center
Pre-School Enrollment(persons)	Refers to the number of registered students in pre-primary educational institutions.	2004-2013	China Data Center
Average Wage(Yuan/Year)	Refers to the average wage in money terms per person during a certain period of time for staff and workers in enterprises, institutions, and government agencies, which reflects the general level of wage income during a certain period of time and is calculated as follows: Average Wage of Staff and Workers = Total Wages of Staff and Workers in Reference Period/Average Number of Staff and Workers in Reference Period.	2004-2013	China Data Center

## Results

The Effects of SO<sub>2</sub> Emissions on Number of College Graduates

	1	2	3	4	5	6
SO2	13.87 (1.80)	11.48 (1.43)	13.71 (-1.51)	-7.836** (-3.17)	-7.455** (-3.14)	-2.164 (-1.77)
Population	48.26*** (10.99)	57.51*** (11.64)	60.09*** (-11.35)	128.4*** (8.51)	119.4*** (-7.44)	120.0*** (-5.10)
GDP per capita	0.335*** (5.44)	0.397*** (5.34)	0.460*** (4.60)	0.179*** (3.72)	0.102 (-1.53)	-0.00237 (-0.14)
F Traffic	0.164 (1.00)	0.135 (0.89)	0.169 (-1.07)	0.0148 (0.35)	-0.00681 (-0.22)	-0.0529 (-1.82)
P Traffic	0.168 (1.36)	0.141 (1.04)	0.0982 (-0.76)	0.0613 (0.97)	0.0814 (-1.74)	0.128* (-2.14)
Constant	-17732.6*** (-8.07)	-17292.0*** (-5.46)	-23344.3*** (-8.29)	-16670.2*** (-7.43)	-88165.6*** (-7.43)	-71477.3*** (-5.09)
Fixed Effects	No	Regional	Regional	No	Regional	City
Time Trend	No	No	Regional	No	Regional	City
N	1959	1887	1814	1951	1814	1951
adj. R-sq	0.308	0.43	0.438	0.907	0.921	0.971

\* p < .05, \*\* p < .01, \*\*\* p < .001  
 "Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons.

The Effects of SO<sub>2</sub> Emissions on Junior Secondary New Enrollment

	1	2	3	4	5	6
SO2	-3.08 (-0.65)	0.614 (0.14)	-9.167 (-1.93)	3.4 (1.01)	0.846 (-0.32)	2.44 (-1.13)
Population	187.5*** (55.29)	191.2*** (55.01)	195.8*** (59.50)	88.86*** (5.68)	117.4*** (-11.13)	135.0*** (-12.50)
GDP per capita	-0.291*** (-10.62)	-0.270*** (-9.28)	-0.0444 (-1.64)	-0.412*** (-12.79)	0.197*** (-3.89)	0.0161 (-0.33)
F Traffic	-0.298*** (-4.13)	-0.219*** (-3.49)	-0.120*** (-3.49)	-0.182*** (-3.18)	-0.0644** (-3.07)	-0.0187 (-0.75)
P Traffic	0.443*** (6.02)	0.294*** (5.08)	0.185*** (-3.54)	0.224*** (4.52)	0.0820** (-2.77)	0.0348 (-0.73)
Constant	13492.5*** (-11.16)	13037.4*** (-6.15)	28603.1*** (-7.22)	101741.8*** (-8.35)	86692.9*** (-11.21)	90495.4*** (-8.6)
Fixed Effects	No	Regional	Regional	City	Regional	City
Time Trend	No	No	Regional	No	Regional	City
N	1856	1786	1723	1849	1723	1849
adj. R-sq	0.814	0.863	0.889	0.935	0.958	0.975

\* p < .05, \*\* p < .01, \*\*\* p < .001  
 "Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons.

The Effects of SO<sub>2</sub> Emissions on Primary School New Enrollment

	1	2	3	4	5	6
SO2	-6.837 (-0.52)	-12.25 (-0.91)	-17.87 (-1.20)	4.279 (0.82)	2.994 (0.60)	4.676 (1.03)
Population	158.8*** (12.29)	149.9*** (12.17)	152.5*** (-11.51)	66.23*** (3.36)	97.96*** (-5.77)	120.7*** (-4.81)
GDP per capita	-0.102** (-2.68)	-0.0136 (-0.46)	0.0535 (-1.53)	-0.00615 (-0.25)	0.116*** (-3.42)	0.0225 (-1.29)
F Traffic	-0.321** (-2.88)	-0.262** (-2.88)	-0.233** (-2.87)	-0.125* (-2.02)	-0.0856* (-1.98)	-0.044 (-0.89)
P Traffic	0.368*** (3.33)	0.325*** (3.49)	0.340*** (-3.49)	0.0907 (1.26)	0.103 (-1.32)	-0.0245 (-0.25)
Constant	(-4333.20) (-1.33)	-10153.1** (-2.86)	-17666.1*** (-3.68)	(443.90) (-0.18)	62235.3*** (-4.7)	(1144.40) (-0.07)
Fixed Effects	No	Regional	Regional	City	Regional	City
Time Trend	No	No	Regional	No	Regional	City
N	2059	1984	1911	2051	1911	2051
adj. R-sq	0.307	0.406	0.406	0.426	0.42	0.37

\* p < .05, \*\* p < .01, \*\*\* p < .001  
 "Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons.

The Effects of SO<sub>2</sub> Emissions on Pre-School Enrollment

	1	2	3	4	5	6
SO2	1.288 (0.11)	20.71* (2.27)	26.11** (2.88)	8.709 (0.63)	2.778 (-0.21)	5.139 (0.37)
Population	160.4*** (24.64)	167.6*** (23.73)	155.7*** (-23.51)	168.0*** (5.55)	100.9** (-3.17)	110.7* (-2.52)
GDP per capita	0.368*** (4.07)	0.457*** (4.51)	0.165 (-1.47)	0.548** (3.11)	-0.139 (-0.87)	-0.297* (-2.07)
F Traffic	-0.297 (-1.29)	-0.0618 (-0.25)	-0.3 (-1.55)	0.126 (0.16)	-0.214 (-1.42)	-0.614** (-2.81)
P Traffic	1.058*** (5.53)	0.643*** (2.94)	0.924*** (-5.41)	0.13 (0.46)	0.474** (-3.11)	0.881** (-3.29)
Constant	(3900.30) (-1)	-14068.9** (-2.76)	(13971.40) (-1.8)	-17884.3*** (-4.96)	(32737.00) (-1.15)	(-31564.70) (-1.08)
Fixed Effects	No	Regional	Regional	City	Regional	City
Time Trend	No	No	Regional	No	Regional	City
N	2055	1982	1910	2047	1910	2047
adj. R-sq	0.455	0.546	0.571	0.597	0.633	0.682

\* p < .05, \*\* p < .01, \*\*\* p < .001  
 "Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons.

## Results (cont'd)

The Effects of SO<sub>2</sub> Emissions on Average Wage

	1	2	3	4	5	6
SO2	-4.19 (-1.73)	-4.757* (-2.14)	2.188 (-1.24)	-1.139 (-0.79)	-1.719** (-3.06)	-2.035** (-3.30)
Population	2.05 (1.50)	6.279*** (4.60)	0.986 (-1.11)	53.42** (2.97)	10.29* (-2.45)	12.06 (-1.49)
GDP per capita	0.313*** (13.44)	0.348*** (12.08)	0.149*** (-8.89)	0.446*** (6.47)	0.0647** (-3.19)	0.0504* (-2.25)
F Traffic	0.111* (2.06)	0.113* (2.33)	0.0029 (-0.14)	0.135* (2.28)	0.00441 (-0.45)	0.0207 (-0.61)
P Traffic	-0.0511 (-1.14)	-0.1 (-1.78)	0.0259 (-1.27)	-0.157 (-1.74)	-0.013 (-0.54)	-0.0451 (-0.58)
Constant	17113.8*** (-8.07)	18783.6*** (-5.46)	6020.8*** (-8.29)	(-3863.50) (-7.43)	(1411.30) (-5.09)	(-1266.60) (-3.07)
Fixed Effects	No	Regional	Regional	No	Regional	City
Time Trend	No	No	Regional	No	Regional	City
N	2066	1991	1919	2058	1919	2058
adj. R-sq	0.387	0.429	0.704	0.502	0.748	0.753

\* p < .05, \*\* p < .01, \*\*\* p < .001  
 "Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons.

The Effects of Visibility on Average Wage

	1	2	3	4	5	6
Visibility	0.0529 (0.01)	4.231** (2.28)	-7.289* (-2.35)	1.577* (2.35)	-0.492 (-0.79)	0.117 (-0.36)
Population	41.39*** (5.07)	64.23*** (9.14)	63.52*** (-10.58)	152.3*** (3.99)	171.1** (2.80)	95.79 (-1.91)
GDP per capita	0.223** (5.19)	0.367*** (8.82)	0.800*** (3.97)	0.095* (4.43)	0.0294 (9.65)	-0.0607* (-2.17)
F Traffic	-0.268 (-1.54)	-0.466* (-2.52)	0.331 (0.69)	-0.107 (-1.03)	-0.169* (-2.07)	-0.098 (-0.80)
P Traffic	0.954*** (-5.87)	1.095*** (-7.48)	1.042*** (-8.54)	0.629*** (-5.94)	0.25** (3.09)	0.226* (-2.40)
Temperature	-84.45 (-0.91)	-150.6 (-1.37)	-170.4 (-1.93)	344.2** (2.93)	309.9*** (4.03)	144.3* (-2.11)
Precipitation	-151.2*** (-4.80)	-85.81* (-2.47)	-43.77 (-1.33)	53.94* (2.48)	28.56 (3.64)	-4.475 (-0.38)
Constant	-3809.1 (-0.69)	-30842.9** (-2.98)	-20240.9* (-2.27)	-104926.5*** (-4.04)	-112669.4*** (-2.95)	-61903.4* (-2.03)
Fixed Effects	No	Regional	Regional	City	Regional	City
Time Trend	No	No	Regional	No	Regional	City
N	317	317	317	317	317	317
adj. R-sq	0.452	0.738	0.789	0.959	0.969	0.987

\* p < .05, \*\* p < .01, \*\*\* p < .001  
 "Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons. "Temperature" refers to average annual temperature, measured in degrees and "Precipitation" refers to total amount of annual precipitation, measured in inches.

## Conclusion

Our estimated results, from all of our data sources, show that there are negative effects of air pollution on some of our human capital variables. Specifically, we find that there are significant effects of air pollution on annual average wages and the number of college graduates. Our results using junior secondary, primary and pre-school enrollment numbers as our dependent variables found few significant results. Overall, however, our results do appear to provide evidence that worse air pollution in Chinese cities can lead to lower human capital stocks. We find that a 1000-ton increase in SO<sub>2</sub> emissions predicts a decrease in college graduates by about 7, while a 1000-ton increase in SO<sub>2</sub> emissions predicts a decrease in annual average wages by 4 Yuan.

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