Political Pressure under Pollution Reduction Mandates: Transboundary Spillovers in China

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Camp Resources XXIII

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Introduction: Pollution and the Theory of Externality

- Economic losses from pollution

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- Pollution Reduction Mandates, “Pollution Reduction Performance”, National Intensive Monitoring System, & MEP

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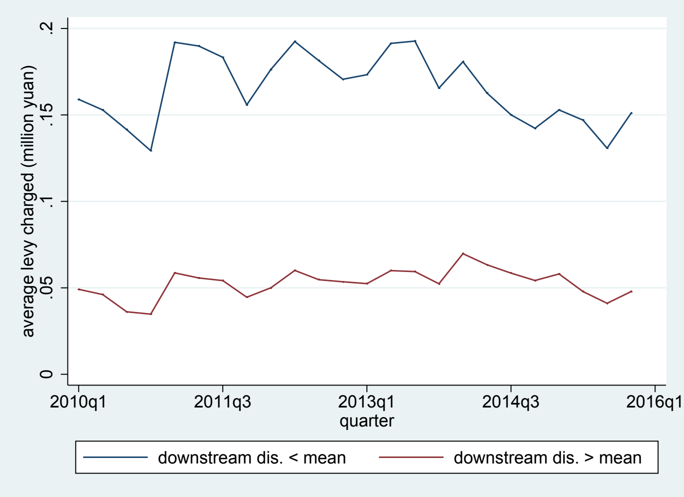
- Political jurisdictions' incentives
- Pollution Externality & "Downstream Effect"

Locational Difference

Difference in Paid Pollution Levies by Downstream Distance



Literature of Environmental Externalities

- Empirical: Sigman (2002, 2005), Helland & Whitford (2003), Lipscomb & Mobarak (2013), Cai et al. (2016) etc.
- Theoretical (inter-jurisdictional spillover): Hochman et al. (1977), Ogawa & Wildasin (2009), Fell and Kaffine (2014), etc.

Motivation

- data
  - stringent measure
  - varying distance
- conceptual
  - health-risk index (varying damage based on location)
  - pollution levy & abatement technology
  - behaviors of firms *and* the government

Research question

Specific relationship between the firm's locational information and its pollution level, both theoretically and empirically.

Conceptual Model

Subgame Perfect Equilibrium: Step 2. Firms

Firm θ chooses the production level $q(\theta)$ and abatement technology investment $a(\theta)$ to maximize its profit:

$$\max_{q(\theta),a(\theta)} pq(\theta) - C(q(\theta), a(\theta)) - (1 - s(\theta))a(\theta) - \tau e(q(\theta), a(\theta)) \tag{1}$$

p, τ: exogenous price of the good & the pollution tax rate.
$C(\cdot)$: convex production cost, with $C'(\cdot) > 0$, $C''(\cdot) \geq 0$, $C_{qa} \leq 0$.
$e(q(\theta), a(\theta))$: firm θ's pollution emission. $e_q > 0$, $e_a < 0$, $e_{qa} < 0$.

Firms FOC

$$\begin{cases} p - C_q(q^*(\theta), a^*(\theta)) - \tau e_q(q^*(\theta), a^*(\theta)) = 0 \\ -C_a(q^*(\theta), a^*(\theta)) - (1 - s(\theta)) - \tau e_a(q^*(\theta), a^*(\theta)) = 0 \end{cases} \tag{2}$$

Conceptual Model

Subgame Perfect Equilibrium: Step 1. Government

Local government chooses $s(\theta)$ (abatement subsidy) to maximize its utility aggregating the impacts in its jurisdiction $U(g, D)$, where:

$$g = t\int_{\underline{\theta}}^{\bar{\theta}} q(s(\theta))d\theta + \tau\int_{\underline{\theta}}^{\bar{\theta}} e(q(s(\theta)), a(s(\theta)))d\theta - \int_{\underline{\theta}}^{\bar{\theta}} a(s(\theta))d\theta \quad (3)$$

$$D = \int_{\underline{\theta}}^{\bar{\theta}} D(e(q(s(\theta)), a(s(\theta))), \theta)d\theta \quad (4)$$

t, τ: exogenous tax rates of the good and the pollutant
g: total budget after abatement technology inv. for public good
D: pollution damage inside the jurisdiction
$U_g > 0,\ U_{gg} \leq 0,\ U_D < 0,\ U_{DD} < 0,\ D_e > 0,\ D_\theta > 0,\ D_{e\theta} > 0$

$$\max_{s(\theta)} U(g, D) \quad (5)$$

Hypotheses

Locational Impact: Higher health-risk, Lower emission

$$\frac{\partial e(q(s(\theta)), a(s(\theta)))}{\partial \theta} < 0 \tag{6}$$

if $U_g \tau < -U_D D_e$ (economy/damage trade-off)

Abatement Technology Installation

- reduce emission ⇒ more abatement tech. w| higher health-risk index
- stimulates production ⇒ reduce abatement investment

Data: China 2010-2015

- firm's quarterly pollution levy (MEP: Intensive Monitoring System)
- "health-risk index" (time-invariant)
  - dis. to the provincial downstream border along the river network
  - dis. to the nearest main stem river & the nearest tributary
  - dis. to the nearest residential area with high population density
- other time-invariant variables
  - dis. to the closest road & railroad
  - elevation and soil type of firm's location
- time-variant control variables
  - abatement technology adoption in production capacity
  - firms' total assets, numbers of employees, value added
  - county-level sector-wise production, average wages, GDPs
  - governmental expenditures and revenues, demographic info
  - local public good provision (school, hospital, transportation, security...)
  - temperature, precipitation, humidity data

Firm's Location Summary of Distances by Industrial Sectors

Empirical Model

Equation: Fixed Effect?

$$Levy_{it} = \alpha + \beta \boldsymbol{Dis_i} + \boldsymbol{\delta u_i} + \gamma \boldsymbol{X_{it}} + e_i + e_t + e_{it} \tag{7}$$

Empirical Model

Equation: Fixed Effect?

$$Levy_{it} = \alpha + \beta \boldsymbol{Dis_i} + \boldsymbol{\delta u_i} + \gamma \boldsymbol{X_{it}} + e_i + e_t + e_{it} \quad (7)$$

Variables

$\boldsymbol{Dis_i}$:
distances to downstream, main stem river, tributary, & residential area

$\boldsymbol{u_i}$:
distances to road & railroad, terrain and soil type

$\boldsymbol{X_{it}}$:
abatement technology data, economic and demographic info, local financing, weather, etc.

Empirical Model

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Variables

Dis_i:
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Equation: Within-Between Random Effect (Mundlak (1978))

$$Levy_{it} = \alpha + \beta \boldsymbol{Dis_i} + \boldsymbol{\delta u_i} + \gamma_1(\boldsymbol{X_{it}} - \overline{\boldsymbol{X_i}}) + \gamma_2 \overline{\boldsymbol{X_i}} + e_i + e_{it} \quad (8)$$

Example

Table 1: Locational Impact on Charged Pollution Levy: China 2010-2015

distance	Power	Metal	Cement	Paper	Chemical
downstream	-64.10***	-64.58***	-21.46***	-11.89***	-39.21***
	(2.184)	(4.984)	(1.550)	(1.963)	(4.329)
major river	-3.735**	-8.777***	-2.869***	-2.450***	-3.274***
	(1.316)	(1.646)	(0.681)	(0.493)	(0.986)
tributary	-78.46***	-86.27***	-22.94***	-11.21***	-30.47***
	(6.879)	(8.429)	(2.813)	(2.277)	(5.208)
residential area	12.15***	10.73***	5.655***	1.677***	5.085***
	(0.839)	(0.969)	(0.640)	(0.343)	(0.670)
N	69236	74708	20848	32296	45328

Standard errors in parentheses. Dep.Var: levy in Yuan; Key Indep.Var: distances in Meter
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Example

Table 2: Locational Impact on Charged Pollution Levy: China 2010-2015

distance	Manufacture	Food/Bev	Medical	Sewage	Clothing
downstream	-19.20***	-7.574***	-18.93***	-2.710***	-13.32***
	(3.675)	(1.355)	(3.503)	(0.590)	(3.077)
major river	-0.785**	-0.484***	-1.999**	-0.349***	-0.981*
	(0.258)	(0.119)	(0.622)	(0.0905)	(0.386)
tributary	-11.92***	-4.233***	-13.63**	-1.562***	-3.711**
	(2.382)	(0.999)	(4.322)	(0.435)	(1.353)
residential area	2.858***	0.772***	2.188***	0.314***	2.186***
	(0.701)	(0.181)	(0.510)	(0.0926)	(0.554)
N	46476	39280	11412	93488	29220

Standard errors in parentheses. Dep.Var: levy in Yuan; Key Indep.Var: distances in Meter

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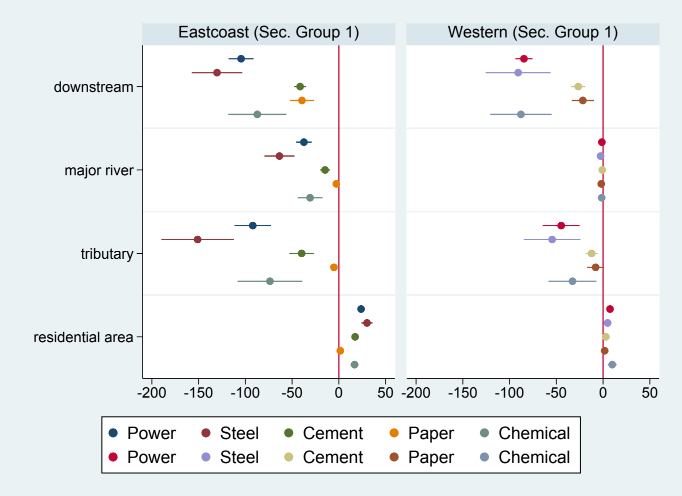
Eastcoast/Western China: Coef. by Sectors (Group 1)



East/West China Sec. Group 2 | Central China | Northeastern China

Other Specifications

with square terms

$$Levy_{it} = \alpha + \beta_1 \boldsymbol{Dis_i} + \beta_2 \boldsymbol{Dis_i^2} + \gamma_1 (\boldsymbol{X_{it}} - \overline{\boldsymbol{X_i}}) + \gamma_2 \overline{\boldsymbol{X_i}} + e_i + e_{it} \quad (9)$$

result table (sec. group 1) result table (sec. group 2)

- pollution increases as predicted
- the increase in pollution is higher as the "health-risk index" decreases

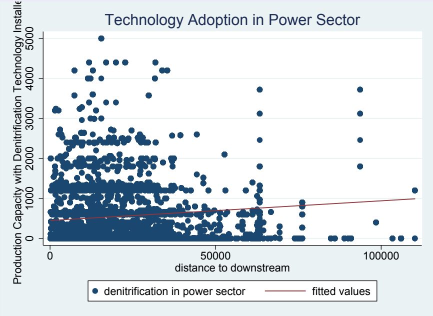
log(Levy) as the dependent var.

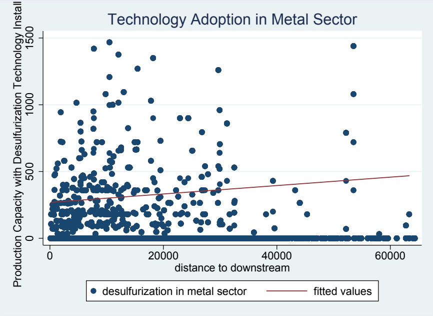
$$log(Levy_{it}) = \alpha + \beta_1 \boldsymbol{Dis_i} + \beta_2 \boldsymbol{Dis_i^2} + \gamma_1 (\boldsymbol{X_{it}} - \overline{\boldsymbol{X_i}}) + \gamma_2 \overline{\boldsymbol{X_i}} + e_i + e_{it} \quad (10)$$

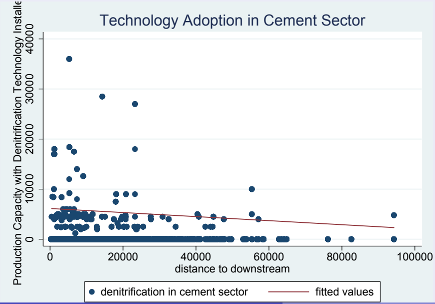
result table (sec. group 1) result table (sec. group 2)

- every km closer to the downstream, pollution increases by $\sim 0.1\%$
- the increase in pollution occurs at a faster rate

Abatement Technology and Adoption Location







	power	metal	cement
desul.		-969.6**	
(MW)		(322.1)	
denitri.	-836.1***		14.16**
(ton)	(78.73)		(4.887)
N	69236	74708	20848

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

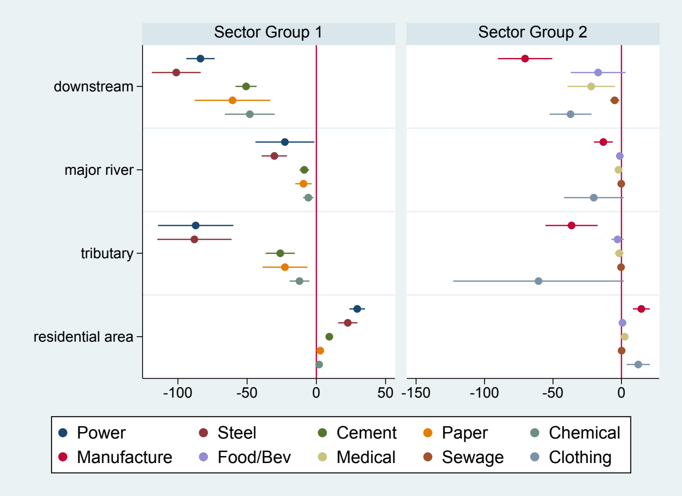
Policy Implications

- recap
- solution?
  - incorporating feedback
  - inter-jurisdictional negotiation
  - financial transfer

Your questions and comments are welcome!

Thank you

Central China: Coefficients by Sectors



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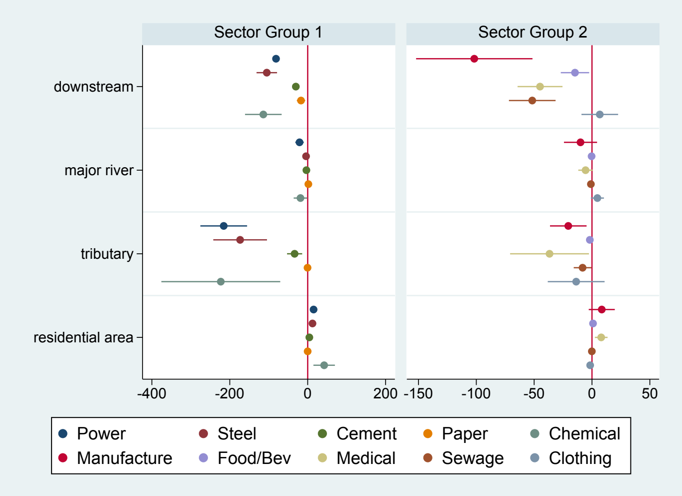
Northeastern China: Coefficients by Sectors



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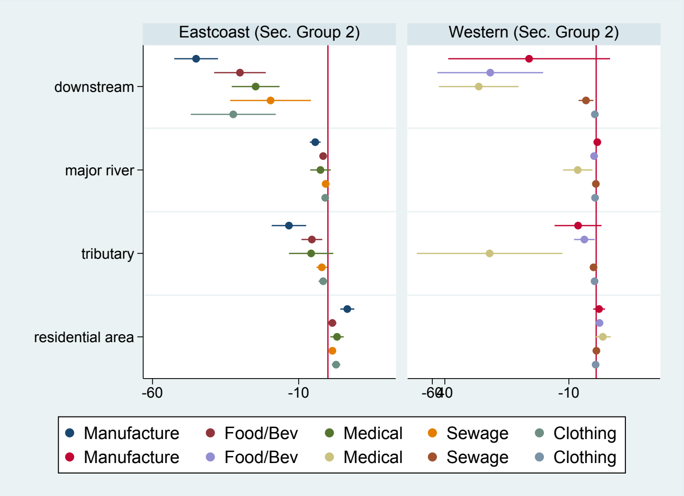
Eastcoast/Western China: Coef. by Sectors (Group 2)



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Regression Coefficients: with squared terms (Sec. Group 1)

Table 3: Locational Impact on Charged Pollution Levy (with the square terms)

distance	Power	Metal	Cement	Paper	Chemical
downstream	-97.59***	-112.6***	-43.91***	-34.03***	-76.48***
	(4.423)	(8.575)	(3.587)	(6.642)	(10.09)
downstream^2	0.000940***	0.00119***	0.000578***	0.000548***	0.000974***
	(0.0000962)	(0.000117)	(0.0000814)	(0.000137)	(0.000179)
major river	-22.41***	-22.22***	-6.842***	-4.783***	-9.914***
	(2.848)	(3.159)	(1.043)	(0.882)	(1.882)
major river^2	0.000170***	0.000150***	0.0000539***	0.0000436***	0.0000664***
	(0.0000257)	(0.0000250)	(0.00000914)	(0.0000101)	(0.0000153)
tributary	-132.6***	-168.4***	-31.96***	-30.27***	-52.19***
	(9.187)	(20.62)	(4.124)	(5.970)	(7.165)
tributary^2	0.00319***	0.00827***	0.000600***	0.00153***	0.00113***
	(0.000522)	(0.00179)	(0.000174)	(0.000342)	(0.000197)
residential area	21.28***	17.59***	8.277***	2.882**	7.295***
	(1.191)	(1.701)	(0.737)	(1.041)	(2.212)
residential area^2	-0.0000754***	-0.0000607***	-0.0000242***	-0.0000162	-0.0000268
	(0.00000700)	(0.0000113)	(0.00000374)	(0.0000122)	(0.0000271)
N	69236	74708	20848	32296	45328

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

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Regression Coefficients: with squared terms (Sec. Group 2)

Table 4: Locational Impact on Charged Pollution Levy (with the square terms)

distance	Manufacture	Food/Bev	Medical	Sewage	Clothing
downstream	-44.53***	-9.127*	-29.78***	-8.608***	-31.58***
	(10.24)	(4.209)	(6.223)	(2.094)	(6.493)
downstream^2	0.000593***	0.0000289	0.000242	0.000122***	0.000503***
	(0.000178)	(0.0000840)	(0.000160)	(0.0000334)	(0.000111)
major river	-3.167***	-1.535***	-5.068***	-0.765***	-1.910**
	(0.905)	(0.350)	(1.328)	(0.203)	(0.644)
major river^2	0.0000240**	0.0000109***	0.0000340***	0.00000685**	0.0000214*
	(0.00000733)	(0.00000272)	(0.00000956)	(0.00000223)	(0.00000926)
tributary	-24.71***	-10.15***	-36.08**	-3.574***	-7.835*
	(5.198)	(2.469)	(12.29)	(1.057)	(3.285)
tributary^2	0.00104***	0.000417***	0.00214*	0.000124**	0.000266*
	(0.000286)	(0.000120)	(0.000925)	(0.0000468)	(0.000136)
residential area	3.907***	1.001**	2.665	0.523***	2.739*
	(1.156)	(0.356)	(2.571)	(0.152)	(1.292)
residential area ^{2}	-0.0000126	-0.00000192	-0.00000536	-0.00000177**	-0.00000908
	(0.0000177)	(0.00000284)	(0.0000326)	(0.000000566)	(0.0000232)
N	46476	39280	11412	93488	29220

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

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Regression Coefficients: log(Levy) as the dep. var. (Sec. Group 1)

Table 5: Locational Impact on Charged Pollution Levy (dependent var: log(levy))

distance	Power	Metal	Cement	Paper	Chemical
downstream	-0.000103***	-0.000115***	-0.0000923***	-0.000129***	-0.000112***
	(0.00000346)	(0.00000758)	(0.00000545)	(0.0000177)	(0.0000101)
downstream^2	3.96e-10***	8.06e-10***	1.18e-09***	1.91e-09***	1.11e-09***
	(9.75e-11)	(2.33e-10)	(1.58e-10)	(4.06e-10)	(2.74e-10)
major river	-0.0000991***	-0.0000872***	-0.0000334***	-0.0000300**	-0.0000748***
	(0.00000655)	(0.00000998)	(0.00000948)	(0.0000103)	(0.0000102)
major river^2	7.61e-10***	7.07e-10***	2.40e-10*	2.72e-10	5.13e-10***
	(5.50e-11)	(8.90e-11)	(1.05e-10)	(1.64e-10)	(8.63e-11)
tributary	-0.000431***	-0.000447***	-0.000143***	-0.000200***	-0.000299***
	(0.0000440)	(0.0000451)	(0.0000241)	(0.0000445)	(0.0000341)
tributary^2	1.27e-08**	2.05e-08***	2.05e-09*	1.01e-08***	6.52e-09***
	(4.29e-09)	(4.61e-09)	(8.97e-10)	(2.97e-09)	(1.88e-09)
residential area	0.0000485***	0.0000446***	0.0000330***	0.0000127	0.0000387***
	(0.00000221)	(0.00000346)	(0.00000500)	(0.00000661)	(0.00000464)
residential area^2	-1.64e-10***	-1.66e-10***	-1.22e-10*	4.88e-11	-1.16e-10*
	(1.50e-11)	(2.71e-11)	(6.16e-11)	(8.72e-11)	(5.41e-11)
N	69236	74708	20848	32296	45328

Standard errors in parentheses
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Regression Coefficients: log(Levy) as the dep. var. (Sec. Group 2)

Table 6: Locational Impact on Charged Pollution Levy (dependent var: log(levy))

distance	Manufacture	Food/Bev	Medical	Sewage	Clothing
downstream	-0.000124***	-0.0000516***	-0.0000817***	-0.000122***	-0.000111***
	(0.0000179)	(0.0000135)	(0.0000123)	(0.0000161)	(0.0000182)
downstream^2	1.29e-09***	1.86e-10	7.95e-10**	1.06e-09	2.09e-09***
	(3.43e-10)	(2.89e-10)	(2.61e-10)	(6.60e-10)	(5.44e-10)
major river	-0.0000220*	-0.00000633	-0.0000442**	-0.0000545*	-0.0000316
	(0.0000104)	(0.00000673)	(0.0000162)	(0.0000228)	(0.0000165)
major river^2	1.64e-10*	7.08e-12	2.88e-10*	8.48e-10	1.66e-10
	(8.23e-11)	(5.73e-11)	(1.37e-10)	(5.37e-10)	(4.52e-10)
tributary	-0.000233***	-0.0000366	-0.000219**	-0.000124***	-0.000000186
	(0.0000590)	(0.0000271)	(0.0000693)	(0.0000373)	(0.0000270)
tributary^2	1.42e-08**	6.30e-10	1.12e-08	3.45e-09**	-9.21e-10
	(5.04e-09)	(1.58e-09)	(6.66e-09)	(1.22e-09)	(1.14e-09)
residential area	0.0000267***	0.0000176***	0.0000138	0.0000315***	0.0000186**
	(0.00000675)	(0.00000399)	(0.0000112)	(0.00000776)	(0.00000688)
residential area^2	-1.11e-10	-9.29e-11*	-3.83e-11	-1.42e-10	-1.73e-10
	(9.52e-11)	(3.70e-11)	(1.32e-10)	(7.87e-11)	(1.04e-10)
N	46476	39280	11412	93488	29220

Standard errors in parentheses
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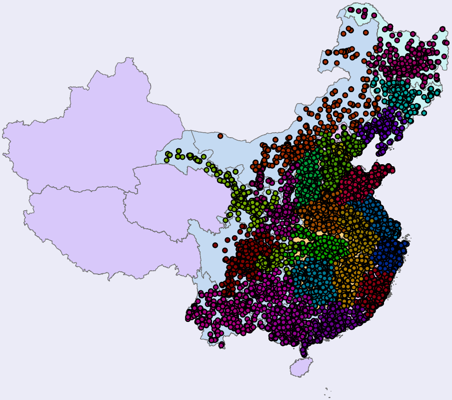
Location

firm's location



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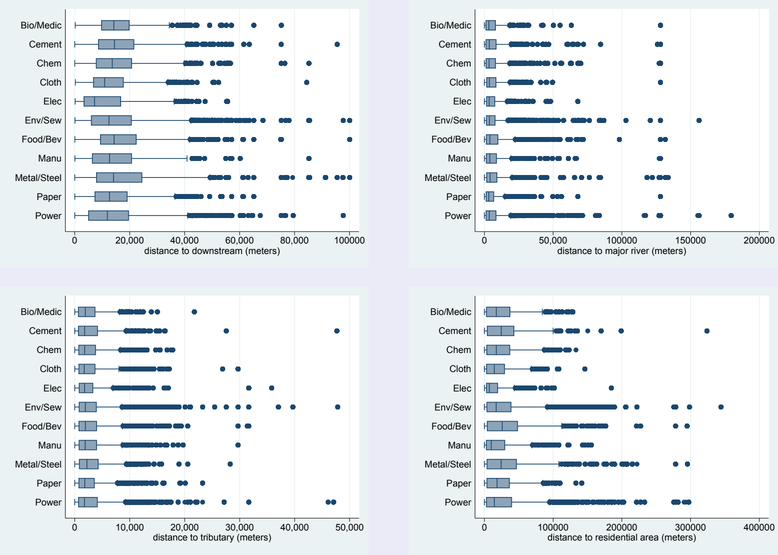
Summary of Distances by Industrial Sectors



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