Productivity As If Space Mattered: An Application to Factor Markets Across China

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Introduction

- Research Question: How do regional labour markets explain productivity dispersion across firms?
- Motivation
  - Large productivity differences across firms and countries (Syverson, 2011)
  - One dimension often overlooked: differences in production conditions
  - Presence of distinct factor market, especially for labour (Lewis, 1954)
  - Regional variation in skill distribution and wages, e.g. China, US
- Multi-region, multi-industry GE model identifies firm's response to local labour market conditions
  - Firm's search: local distribution of worker types and wages matters
  - Free entry into industries and regions $\rightarrow$ density of activities

Introduction

- Structural estimation strategy
  - Recovers regional industry labour costs and incorporates labour costs into productivity estimation
  - Identification: variation in regional wages, skills and firm's hiring
- Application to China
  - Large regional variation in education and wages
  - Data from 2004 manufacturing census and 2005 population census
  - Report average wages and skills across 284 prefectures and firm hiring patterns in 19 2-digit industries
- Findings
  - Huge regional differences in labour costs
  - Explains 3-17% of differences and 4-40% of variance of unexplained productivity
  - Low labour cost regions attract more industry activity per capita

Related literature

- Industry performance and skill diversity
  - Grossman and Maggi (2000): theoretical model. Differences in skill dispersion across countries determine comparative advantage
  - Morrow (2010): multi-sector model w/technological choice and general distributions. Estimates from developing countries show skill diversity explains productivity and export differences within industries

- Empirical work consistent with theory
  - Iranzo et al.(2008): Italian E-E matched data. An increase in firm-level skill dispersion is associated with higher TFP
  - Parrotta et al. (2011): Danish E-E matched data. Employee education diversity $\rightarrow$ productivity (industry and ownership FEs)
  - Bombardini et al. (2011): Literacy across 29 countries. Dispersed skill distribution $\rightarrow$ specialize in low skill complementarity industries

Relation to Work on China

- Fits within growing literature on Chinese productivity
  - Ma et al. [2011] exporting positively correlated with TFP, exporting ex post increases TFP
  - Brandt et al. [2009] new entry accounts for two thirds of TFP growth. This dominates factor accumulation
  - Hsieh and Klenow [2009] India and China have lower productivity relative to the US due to resource misallocation
- Regional differences might help explain stylized Chinese export facts of Manova and Zhang [2012]

Model Setting

- Firms face a neoclassical production combining capital, materials and labour:

$$F_j^T(M, K, L) \equiv \eta_j^{-1} \cdot (M)^{\alpha_M^T} (K)^{\alpha_K^T} (L)^{\alpha_L^T} \tag{1}$$

  - L is effective labour produced from $\mathbb{S}$ skill types (education bins)
  - Industry specific technology (α_M^T, α_K^T, α_L^T)
  - Idiosyncratic cost shifter η_j (will map on to error term)

- In industry T, firms combine labour into teams:

$$L \equiv \left(H_{1\,T}^{\theta} + H_{2\,T}^{\theta} + \ldots + H_{\mathbb{S}\,T}^{\theta} \right)^{1/\theta_T} \tag{2}$$

  - H_i: type specific human capital
  - θ^T: substitutability of types (< 1 Complements, > 1 Substitutes)

Model Setting

- In region R, there are region specific:
  - Distribution of worker types $a_R = (a_{R,1}, \ldots, a_{R,\mathbb{S}})$
  - Wages $w_R = (w_{R,1}, \ldots, w_{R,\mathbb{S}})$
- To hire workers, firms pay a fixed search cost f effective labour units to draw a distribution of workers a_R
- Firms minimize total hiring and labour costs s.t. human capital technology $\Rightarrow$ cost of one unit of labour c_R^T
- Firms then maximize profits s.t. production function and factor prices $\Rightarrow$ optimal skill composition $s_{R,ij}^T$

Firm's Labour Demand

- Optimal share of worker of type i hired by firm j in industry T and region R is:

$$\underbrace{\ln s_{R,ij}^{T}}_{\text{Share Hired}} = -\frac{k}{\beta^{T}} \underbrace{\ln w_{R,i}}_{\text{Wages}} + \frac{\theta^{T}}{\beta^{T}} \underbrace{\ln a_{R,i}}_{\text{Supply}} + \frac{k\theta^{T}}{\beta^{T}} \underbrace{\ln \underline{m}_{i}^{T}}_{\text{Ind-Type HK}} + \underbrace{Fixed_{R}^{T}}_{\text{Messy FE}} \quad (3)$$

  - θ^{T}: substitutability of types (< 1 Complements, > 1 Substitutes)
  - k: job match quality
    ($\Psi(h) \equiv 1 - h^{-k}$: quality improves as $k \searrow 1$)
  - $\beta^{T} \equiv \theta^{T} + k - k \cdot \theta^{T}$

- **First stage estimation**: $\widehat{\theta^{T}}$, $\widehat{k}$ and $\widehat{\underline{m}_{i}^{T} / \underline{m}_{S}^{T}}$

Effective Labour Cost

- With regional data $\{a_R\}, \{w_R\}$, we can recover (differenced) unit cost of labour: $\Delta \ln c_R^T$
- Cost of one unit of effective labour ($L = 1$) is:

$$c_R^T = \left[\sum_{i \text{ hired}} \left[a_{R,i} \left(\underline{m}_i^T \right)^k w_{R,i}^{1-k} / f\left(k-1\right) \right]^{\theta^T/\beta^T} \right]^{\left(\beta^T/\theta^T\right)/(1-k)} \tag{4}$$

  - Model parameters k, $_T$ and β_T
  - Regaional wages w_R and distribution of worker types a_R
  - Human capital $\underline{m}^T = \left(\underline{m}_1^T, \ldots, \underline{m}_S^T \right)$

Productivity and Location

- Rewrite production function for regional costs $\widehat{\Delta \ln c_R^T}$:

$$\Delta \ln Y_j = \frac{\alpha_M}{1-\alpha_L} \cdot \Delta \ln M_j + \frac{\alpha_K}{1-\alpha_L} \cdot \Delta \ln K_j - \frac{\alpha_L}{1-\alpha_L} \cdot \widehat{\Delta \ln c_R^T} \quad (5)$$

- **Second stage estimation**: $\widehat{\alpha_M}, \widehat{\alpha_K}, \widehat{\alpha_L}$ and $(\Delta \ln Y_j - \widehat{\Delta \ln Y_j})$

- GE closed with free entry into regions (zero expected profits)

$$\text{Spatial Zero Profit Condition}: \quad \mathrm{E}\left[\pi_{Rj}^T\right] = F_e, \quad \forall R, T.$$

- Low costs attract firms, while entry competes profits down to zero

Calculating Productivity Differences

- Suppose firms in 2 regions: same K, M and wage bill W
- Unit labour costs of c_{1T} and c_{2T}
- Effective labour employed: $L_1 = W/c_{1T}$ and $L_2 = W/c_{2T}$

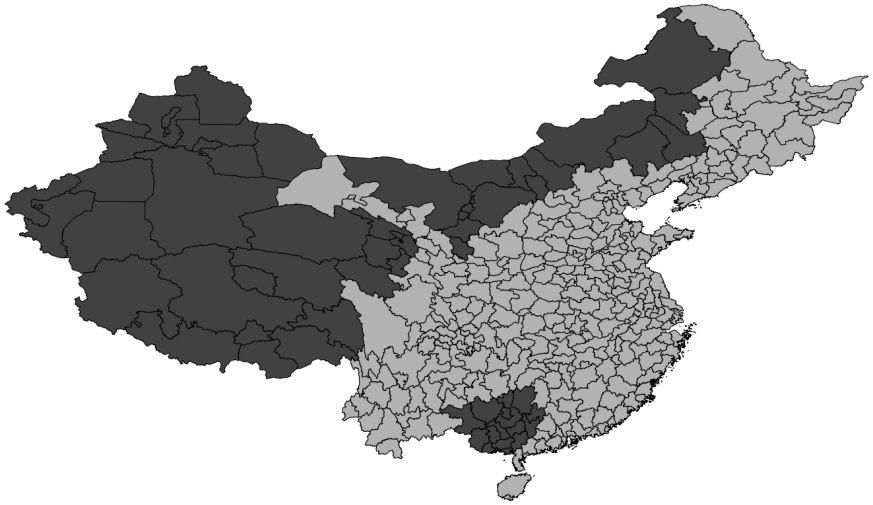
$$\frac{Y_1}{Y_2} = \frac{M^{\alpha_M^T} K^{\alpha_K^T} L_1^{\alpha_L^T}}{M^{\alpha_M^T} K^{\alpha_K^T} L_2^{\alpha_L^T}} = \left(\frac{c_{2T}}{c_{1T}}\right)^{\alpha_L^T} \tag{6}$$

- Output ratio accounts for substitution into K and M
- Requires effective labour cost and second stage production parameter estimate

Data

- 2005 population census: regional characteristics such as wages $\{w_{R,i}\}$ and the distribution of workers across education levels $\{a_{R,i}\}$
- 2004 manufacturing census: firm-level characteristics and the distribution of workers across education levels for each firm $\left\{s^T_{R,ij}\right\}$

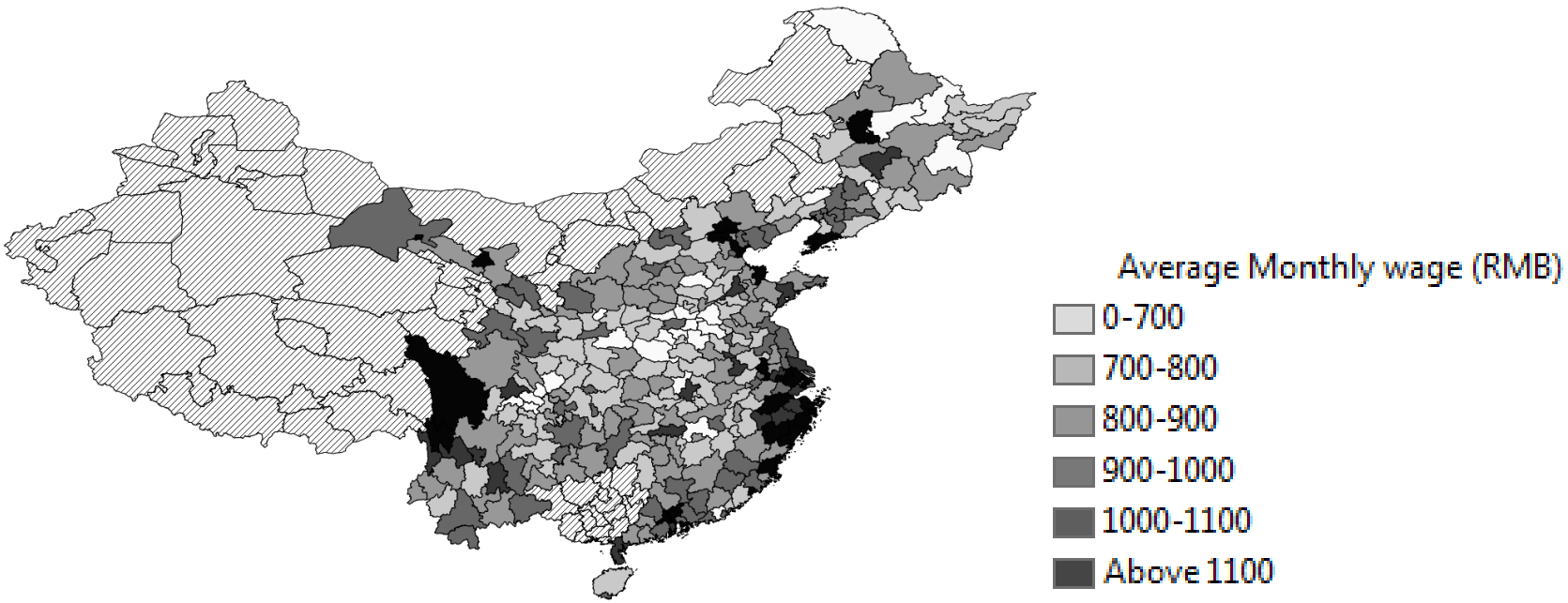
- Identification is through regional variation:
  - Reveals how firm demand for skills varies with local conditions
  - Merge manufacturing survey to estimate firm level productivity



Regional Income

- Regional wage dispersion of workers: $w_R = (w_{R,1}, \ldots, w_{R,S})$

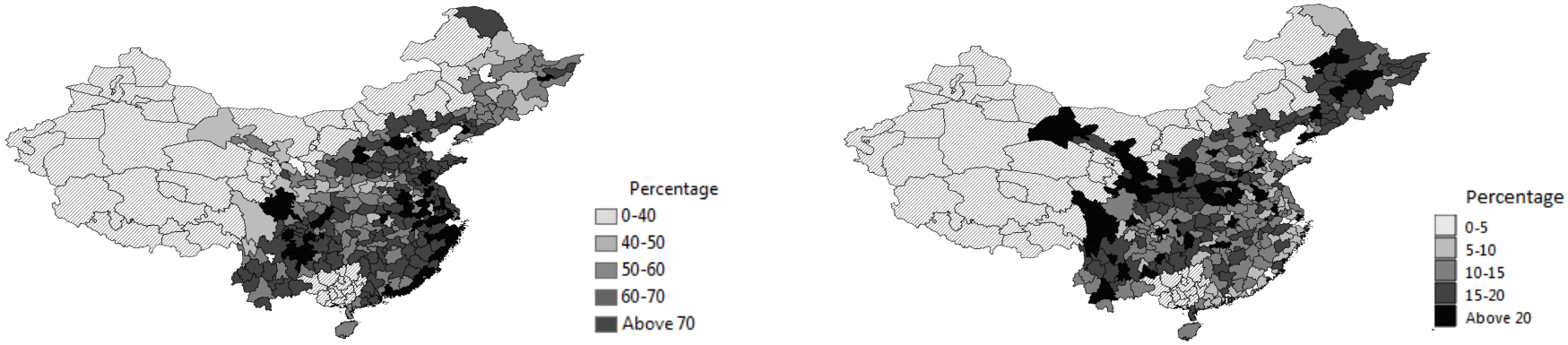
Figure: Average Monthly Income of Employees



Regional Education

- Regional distributions of worker types $a_R = (a_{R,1}, \ldots, a_{R,S})$

Figure: Low and High Educational Attainment Across China (2005)



(a) % Labor Force $\leq$Junior High School (b) % Labor Force $\geq$Junior College

First Stage: General Machinery

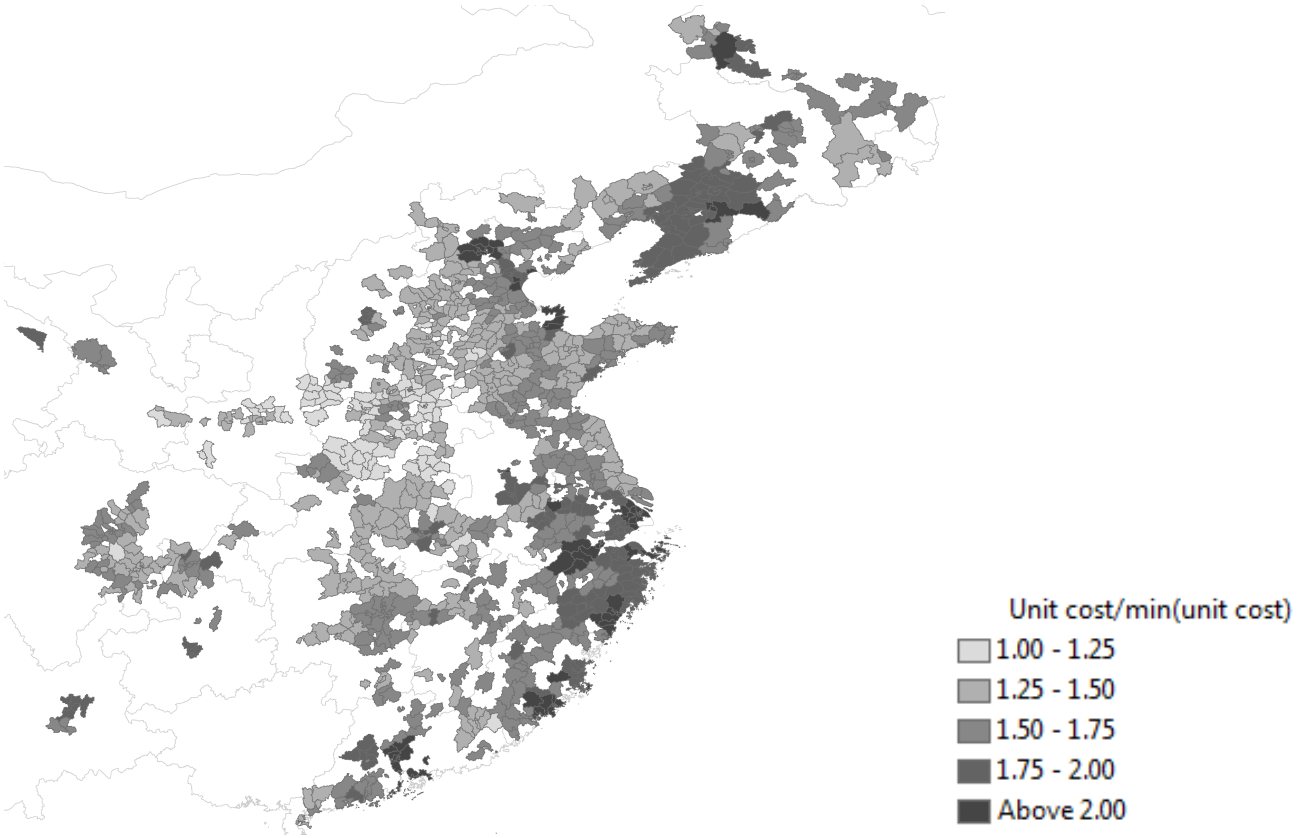
Primary Variables	ln (% Hired)
ln $(w_{R,i})$	-2. 687***
ln $(a_{R,i})$	1. 794***
$\underline{m}_1$ ($\leq$Junior HS:Female)	-10. 170***
$\underline{m}_2$ ($\leq$Junior HS:Male)	-6. 171***
$\underline{m}_3$ (Senior High School)	-3. 180***
Regional Controls	
$\underline{m}_1 *$% Non-Ag Hukou	-5. 957***
$\underline{m}_2 *$% Non-Ag Hukou	-3. 072***
$\underline{m}_3 *$% Non-Ag Hukou	-3. 218***
$\underline{m}_4 *$% Non-Ag Hukou	-7. 026***
Observations: 62,908. R^2 : 0.139	

Firm Controls	
$\underline{m}_1 *$ Urban Dummy	-1. 384***
$\underline{m}_2 *$ Urban Dummy	-0. 980***
$\underline{m}_3 *$ Urban Dummy	0. 427***
$\underline{m}_4 *$ Urban Dummy	2. 336***
$\underline{m}_1 *$% Foreign Equity	-2. 448***
$\underline{m}_2 *$% Foreign Equity	-1. 864***
$\underline{m}_3 *$% Foreign Equity	0. 311***
$\underline{m}_4 *$% Foreign Equity	3. 847***
$\underline{m}_1 *$ ln (Firm Age)	0. 934***
$\underline{m}_2 *$ ln (Firm Age)	0. 403***
$\underline{m}_3 *$ ln (Firm Age)	0. 143***
$\underline{m}_4 *$ ln (Firm Age)	0. 351***
Includes Regional Fixed Effects	

Standard errors in parentheses. Significance: *** p<.01, ** p<.05, * p<.1.

Industry	k	Std Err	θ^T	Std Err	β^T	Std Err
General Machinery	2.50	(0.14)	1.22	(0.03)	0.68	(0.03)

Unit Labour Costs

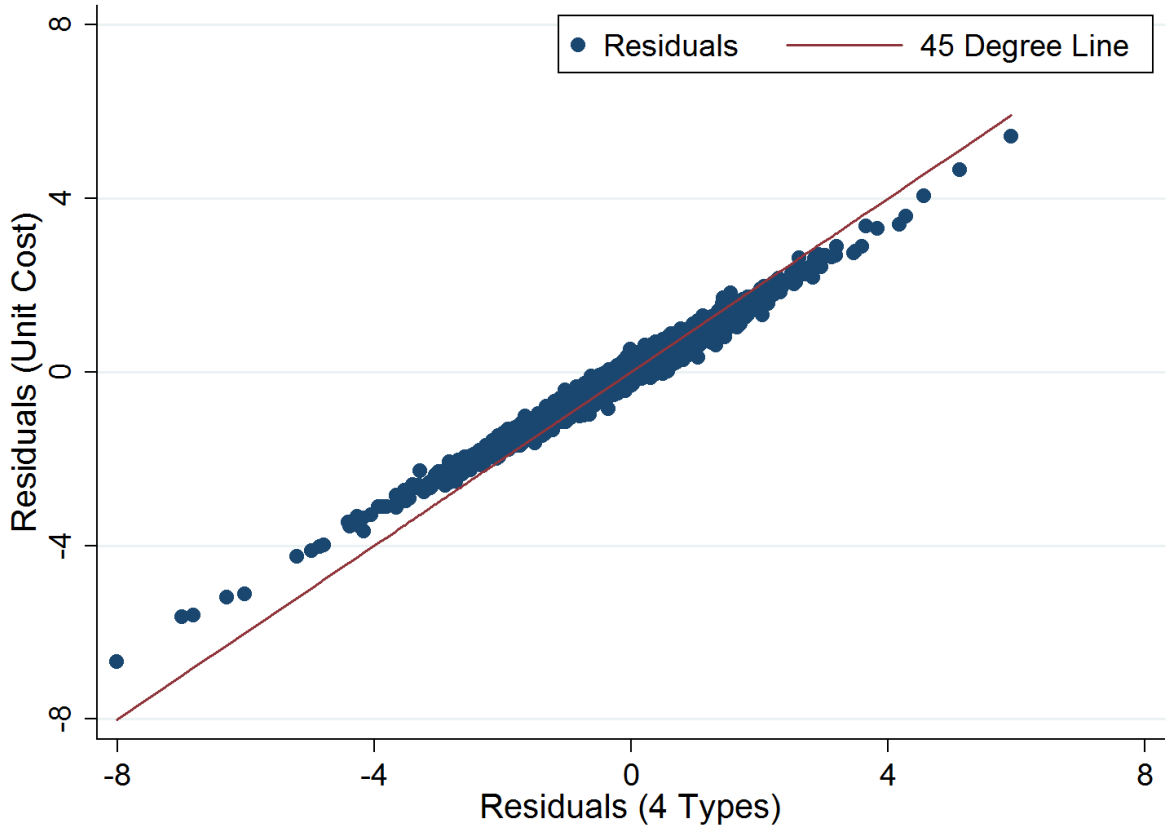


	75%/25% Unit Labour Cost	Labour Share	75%/25% Productivity
General Machinery	1.41	0.17	1.06

- Productivity ratio: $1.41^{0.17} = 1.06$

Industry	Unit Cost Ratios		Productivity Ratios	
	75%/25%	90%/10%	75%/25%	90%/10%
Beverages	1.51	2.24	1.06	1.12
Electrical Equipment	1.38	1.88	1.08	1.17
Food Manufacturing	1.81	3.30	1.09	1.19
General Machinery	1.41	1.92	1.06	1.12
Iron and Steel	1.34	1.72	1.13	1.26
Leather & Fur	1.92	2.69	1.04	1.05
Med & Prec Equip	1.80	2.69	1.13	1.22
Metal Products	1.33	1.71	1.07	1.14
Non-ferrous Metal	1.45	1.89	1.17	1.30
Non-metallic Products	1.42	1.96	1.08	1.15
Paper	1.66	2.78	1.07	1.15
Plastic	1.35	1.72	1.09	1.16
Printing	1.37	1.72	1.03	1.05
Radio TV PC & Comm	1.44	2.13	1.06	1.13
Rubber	2.16	3.97	1.04	1.07
Specific Machinery	1.99	3.68	1.08	1.15
Textile	1.37	1.89	1.04	1.07

Second Stage: Productivity Dispersion



	Unit Cost σ^2	4 Types σ^2	Avg Reduction
General Machinery	0.440	0.589	0.158

- Note residuals are in logs, absolute levels sizable

	Unit Cost σ^2	4 Types σ^2	Avg Reduction
Beverages	0.414	0.538	0.176
Electrical Equipment	0.399	0.670	0.265
Food Manufacturing	0.366	0.614	0.278
General Machinery	0.440	0.589	0.158
Iron & Steel	0.325	0.463	0.188
Leather & Fur	0.225	0.659	0.434
Med, Prec Equip & clocks	0.445	0.456	0.070
Metal Products	0.484	0.686	0.223
Non-ferrous Metal	0.272	0.425	0.236
Non-metallic products	0.436	0.558	0.154
Paper	0.363	0.655	0.300
Plastic	0.222	0.638	0.434
Printing	0.488	0.562	0.100
Radio, TV, PC & Comm	0.727	0.937	0.209
Rubber	0.553	0.564	0.079
Specific Machinery	0.513	0.611	0.099
Textile	0.389	0.453	0.112

Density of Economic Activities

Dependent Variable: $\ln\left(\text{Value Added per Capita}_R^T\right)$							
Industry	$\ln\left(c_R^T\right)$	SE	Port Dist	SE	Const	SE	R^2
Beverages	-0.696^b	(.27)	-0.122	(.20)	18.96^a	(3.4)	.03
Electrical Equipment	-0.057	(.40)	-1.567^a	(.26)	11.98^b	(4.8)	.22
Food Manufacturing	-0.553^b	(.23)	-0.397^b	(.18)	15.49^a	(2.2)	.04
General Machinery	-0.705^c	(.40)	-1.314^a	(.34)	19.68^a	(4.9)	.11
Iron and Steel	-1.245^b	(.57)	-0.576^a	(.19)	16.30^a	(2.2)	.06
Leather & Fur	-1.255^a	(.25)	-1.028^b	(.42)	25.81^a	(3.1)	.27
Med & Prec Equip	-0.267	(.30)	-1.135^b	(.43)	13.13^a	(3.4)	.07
Metal Products	-0.236	(.46)	-1.239^a	(.26)	13.24^a	(4.9)	.14
Non-ferrous Metal	-1.977^a	(.54)	-0.468^c	(.28)	27.29^a	(4.6)	.10
Non-metallic Products	-0.827^a	(.29)	-0.910^a	(.16)	20.89^a	(3.4)	.11
Paper	-0.911^a	(.20)	-0.320	(.25)	20.04^a	(2.1)	.12
Plastic	-0.556	(.35)	-1.406^a	(.22)	16.86^a	(4.0)	.22
Printing	0.103	(.66)	-0.123	(.26)	8.54	(7.1)	.01

Note: a, b and c denote 1, 5 and 10% significance level respectively.

Conclusion

- Local markets important for input use, productivity and location
- Model to identify firms' optimal response to local labour markets
  - Allows *quantification* of local factor market variation
  - Hinges on local distribution of worker types and wages
- Interquartile differences across China: Labour costs (30-80%), Productivity differences (3-17%) and (4-40% of σ^2).
  - Lower cost regions attract more industry activity per capita
  - Implications for firm performance, production function estimation