Productivity Growth in China's Large and Medium-Sized Industrial Firms: Patterns, Causes, and Implications

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TFP Growth

- y: actual output
- S_j: share of costs by input x_j
- Growth accounting equation:

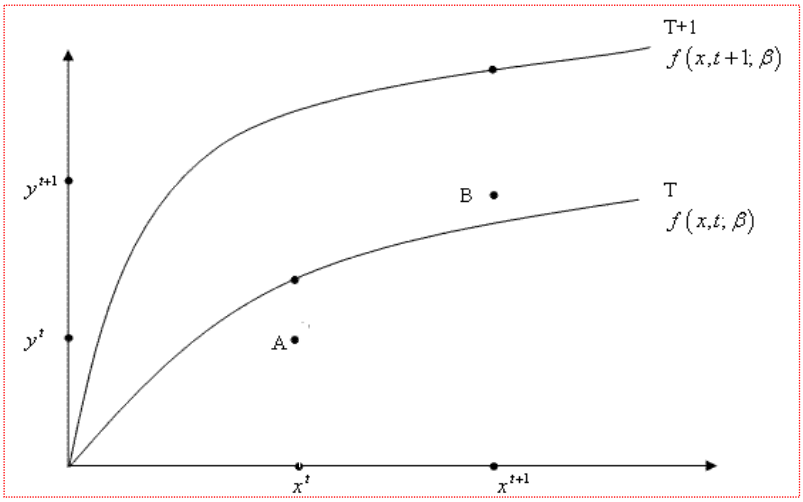
$$\dot{TFP} = \dot{y} - \sum_j S_j \dot{x}_j$$

TFP Growth = FTP + TE Growth + AE + SE

- Total Factor Productivity (TFP) Growth due to:
  - **FTP: Frontier Technology Progress**
  - **TE Growth: Rate of Change in Technical Efficiency relative to the frontier output level**
  - **AE: Allocating Efficiency**
  - **SE: Scale Economy**
- **Frontier Production Function with Technical Inefficiency:**

$$y = f(x,t)\exp(-u)$$

FTP and TE: An Illustration



FTP: Frontier Technology Progress

- f(x, t): frontier production function
- X: vector of inputs
- t: time trend
- FTP: output increase over time due to broadly defined technology progress such as the use of new technology, new management, new institutions, etc., given the same levels of inputs

$$FTP = \partial \ln f\left(x,t\right) / \partial t$$

TE: Technical Efficiency (Relative to Frontier) and TE Growth

- **TE: Ratio of actual output to frontier output:**

$$TE = \exp\left(-u\right) = \frac{y}{f\left(x,t\right)}$$

- **TE Growth:**

$$\dot{TE} = -du/dt$$

AE: Allocative Efficiency in the Employment of Inputs

- λ_j: normalized output elasticity of input j
- S_j: share of costs by input j
- x_j: input j
- AE: Allocative Efficiency due to more cost-effective employment of inputs (e.g. marginal return greater than marginal costs of inputs)

$$AE = \sum_j (\lambda_j - S_j)\dot{x}_j$$

Scale Economy (SE)

- RTS: total return to scale, sum of output elasticity of all inputs.
- λ_j: normalized output elasticity of input j
- x_j: input j
- Scale Economy:

$$SE = (RTS - 1)\sum_j \lambda_j \dot{x}_j$$

Time-Varying Log Stochastic Frontier Production Function

$$\ln y_{i\tau} = \alpha_0 + \sum_j \alpha_j \ln x_{ji\tau} + \alpha_T t + \frac{1}{2}\sum_j \sum_l \beta_{jl} \ln x_{li\tau} \ln x_{jit}$$

$$+ \frac{1}{2}\beta_{TT} t^2 + \sum_j \beta_{Tj} t \ln x_{ji\tau} + v_{i\tau} - u_{i\tau}; \qquad \text{j,l} = \text{L,k};$$

$$v_{i\tau} \sim iid\ N\left(0, \sigma_v^{\,2}\right)$$

$$u_{i\tau} = u_i \exp\left[-\eta\left(t - T\right)\right] \qquad u_i \sim N^{+}\left(\mu, \sigma_u^{\,2}\right)$$

Data Sources

- National Bureau of Statistics China annual survey on large and medium-sized industrial enterprises during 1995-2002 with about 22,000 firms each year
- After data cleaning the total observations for the imbalanced panel data set is 177,086 with about 21,000 for each year over 8 years
- The significance of sample enterprises in the Chinese economy:
  - Number of enterprises is about 12% of all industrial enterprises with sales above 5 million RMB
  - About 16.7% of the total industrial employment
  - About 40% of the total industrial value added
  - Total value added is about 14% to 19% of GDP
- Price deflators
  - Estimated output deflator
  - Estimated fixed capital deflator

Variables Used in Estimation

- y: deflated industrial value added
- K: deflated net value of fixed capital
- L: average number of employees
- S_K: (interest expenses plus current depreciation)/Total costs
- S_L: (wages + bonuses + expenses on labor welfare and insurances)/Total Costs

Table A.1 Distribution of Usable Obervations by Ownership: 1995-2002

	1995	1998	2002
private	5	176	1,302
collective	4,008	3,577	2,138
mixed	1,233	2,934	6,135
foreign	1,000	1,579	2,935
HK-M-Taiwan	936	1,454	2,495
state-owned	15,361	12,573	7,215
total	22,543	22,293	22,220

TFP Growth by Industry

IND2	1996	1997	1998	1999	2000	2001	2002	Average
[37]Transport equipment	-5.4	-0.3	12.3	11.1	14.3	26.6	35.4	17.8
[42]Instruments	4.2	2.1	32.2	16.8	19.6	16.0	15.8	16.0
[23]Printing	19.4	9.4	16.2	17.1	4.7	21.1	9.5	13.8
Average	-4.3	-0.7	3.0	7.5	11.2	8.2	14.0	6.8
[46]Tap water	-5.4	-12.6	2.6	-1.8	-12.4	2.5	-3.1	-4.0
[44]Power	-13.0	-7.1	-9.6	-5.0	-4.1	-4.0	4.4	-4.1
[25]Petroleum processing	-22.6	-13.9	-22.1	-9.1	-8.6	8.4	17.9	-4.6

TFP Growth due to FTP

IND2	1996	1997	1998	1999	2000	2001	2002	Average
[41]Electronics and telecom	13.68	16.87	20.04	23.11	26.56	29.84	33.25	26.33
[32]Pressing ferrous	3.29	9.48	15.65	21.88	28.15	34.41	40.73	24.43
[37]Transport equipment	1.31	7.13	13.07	19.00	25.07	31.15	37.19	23.03
Average	2.80	5.94	9.01	12.30	15.30	18.89	22.60	13.95
[25]Petroleum processing	-7.73	-5.35	-2.45	0.55	3.22	6.16	8.83	1.40
[7]Petroleum extraction	2.72	1.43	-0.11	1.06	3.57	0.22	-1.69	0.98
[44]Power	-5.19	-3.93	-2.30	-0.73	0.76	2.40	3.89	0.17

TE: Actual to Frontier Output

IND2	1996	1997	1998	1999	2000	2001	2002	Average
[16]Tobacco	0.60	0.57	0.57	0.55	0.53	0.51	0.50	0.55
[8]Ferrous mining	0.58	0.55	0.47	0.51	0.49	0.48	0.50	0.51
[22]Paper-making	0.49	0.47	0.48	0.47	0.45	0.44	0.42	0.46
Average	0.32	0.32	0.32	0.31	0.30	0.30	0.29	0.31
[40]Electric equipment	0.17	0.17	0.16	0.16	0.16	0.15	0.15	0.16
[42]Instruments	0.15	0.14	0.16	0.15	0.15	0.15	0.15	0.15
[41]Electronics and telecom	0.13	0.13	0.14	0.13	0.11	0.11	0.10	0.12

TFP Growth due to TE Growth

IND2	1996	1997	1998	1999	2000	2001	2002	Average
[46]Tap water	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.7
[44]Power	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
[10]Non-metal mining	-2.4	-2.3	-2.4	-2.3	-2.2	-2.2	-2.4	-2.3
Average	-6.4	-6.5	-6.6	-6.7	-7.0	-7.4	-7.9	-7.1
[15]Beverage	-10.7	-11.0	-11.1	-11.5	-11.8	-12.1	-12.6	-11.6
[29]Rubber	-9.6	-10.5	-11.3	-11.1	-12.3	-13.2	-15.3	-12.1
[41]Electronics and telecom	-14.5	-14.3	-13.9	-14.6	-15.2	-15.2	-15.9	-15.0

TFP Growth due to AE

IND2	1996	1997	1998	1999	2000	2001	2002	Average
[7]Petraleum extraction	7.594	3.733	6.594	4.172	4.867	1.753	4.435	4.440
[23]Printing	6.426	5.464	4.784	4.797	2.374	3.699	2.373	3.976
[8]Ferrous mining	0.263	0.940	1.134	-0.143	2.836	3.404	9.573	3.062
Average	-0.412	0.198	-0.205	-0.046	0.370	-0.260	0.285	0.019
[15]Beverage	-2.664	-2.070	-2.476	-3.098	-0.951	-1.195	-1.213	-1.874
[25]Petroleum processing	-6.626	-2.700	-2.989	-3.405	-1.977	-0.257	0.145	-2.229
[44]Power	-3.747	-0.158	-4.459	-2.808	-2.993	-2.680	-0.647	-2.378

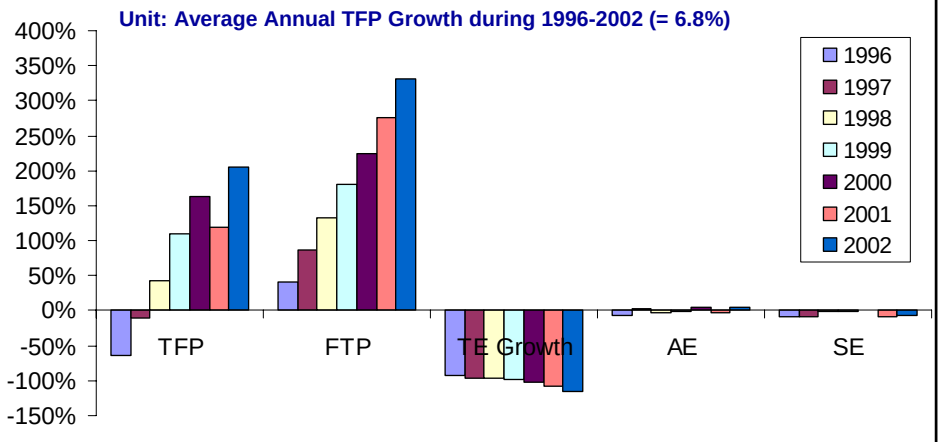
Return to Scale (RTS) by Industry

IND2	1996	1997	1998	1999	2000	2001	2002	Average
[16]Tobacco	1.373	1.392	1.398	1.406	1.421	1.441	1.456	1.417
[15]Beverage	1.089	1.081	1.066	1.047	1.010	0.971	0.940	1.022
[18]Garments	0.958	0.966	0.978	0.993	1.004	1.006	1.012	0.993
Average	0.925	0.925	0.924	0.911	0.894	0.889	0.881	0.903
[42]Instruments	0.690	0.700	0.713	0.717	0.722	0.721	0.723	0.715
[20]Timber	0.665	0.677	0.693	0.708	0.713	0.728	0.724	0.708
[45]Gas production	0.524	0.548	0.588	0.630	0.674	0.688	0.714	0.657

TFP Growth due to SE

IND2	1996	1997	1998	1999	2000	2001	2002	Average
[16]Tobacco	7.31	0.15	0.95	3.98	-0.15	-0.36	-1.61	1.07
[36]Special equipment	-2.40	-0.48	0.78	2.91	-0.55	2.77	0.75	0.59
[9]Nonferrous mining	0.78	-2.07	3.15	-0.05	-0.09	0.96	1.66	0.57
Average	-0.58	-0.63	-0.07	-0.04	0.06	-0.53	-0.52	-0.33
[21]Furniture	-7.79	-0.89	-2.21	-1.96	-0.41	-3.69	-2.20	-2.60
[45]Gas production	-7.05	-12.81	-6.77	-2.99	-6.69	2.55	-1.11	-3.35
[20]Timber	-11.21	-4.76	0.04	-4.67	-3.85	-2.98	-0.96	-3.53

Dynamics of TFP Growth



Patterns of Productivity Revolution

- Average annual growth of TFP in China's large and medium industrial enterprises sector is as high as 6.8% with a rising trend during 1996-2002.
- The contribution to TFP growth by Frontier Technology Progress reached as much as 14 percentage points a year on average.
- The decline in Technical Efficiency (Relative to the Frontier) reduced the growth of TFP by 7.1 percentage points a year on average.
- Allocative Efficiency contributed on average only 0.02 percentage points a year to the growth of TFP.
- Scale Dis-Economy slowed the growth of TFP by 0.33 percentage points a year.
- At the turn of the century, the most important part of China's industry is in the middle of an industrial productivity revolution driven by both FTP (globalization, catching up & innovation) and potentials for TE growth (competition and reform).

Factors Driving China's Industrial Productivity Revolution

- Privatization
- Financial sector development
- Competition
- FDI and globalization
- Urbanization & industrialization
- Business cycle

Privatization and Capital Markets

Table 1.1 Distribution of Total Liabilities in Sample Enterprises by Ownership: 1995-2002 (RMB Billion)

	1995	1998	2002	Change in 95-02	Change/Level in 96
private	0	11	95	95	9500.0%
collective	227	287	219	-8	-3.0%
mixed	231	514	1,642	1,411	505.7%
foreign	152	329	619	467	201.3%
HK-M-Taiwan	164	276	389	225	118.4%
state-owned	2,512	3,193	2,758	246	9.0%
Total	3,286	4,610	5,722	2,436	65.7%
private	0.0%	0.2%	1.7%	1.7%	
collective	6.9%	6.2%	3.8%	-3.1%	
mixed	7.0%	11.1%	28.7%	21.7%	
foreign	4.6%	7.1%	10.8%	6.2%	
HK-M-Taiwan	5.0%	6.0%	6.8%	1.8%	
state-owned	76.4%	69.3%	48.2%	-28.2%	
Total	100.0%	100.0%	100.0%	100.0%	

Table 26 Number of Enterprises by Profitability and Entry-Exit Status: 1995-2002

		1995	1996	1997	1998	1999	2000	2001	2002
Number of profit-making enterprises	exit	2,485	1,177	2,434	1,648	1,335	2,608	1,258	
	new		2,802	1,533	2,408	2,523	1,160	3,890	2,300
	stay	12,229	10,540	10,493	9,849	11,017	11,235	11,221	14,968
	once		516	599	710	368	378	565	
	whole sample	14,714	15,035	15,059	14,615	15,243	15,381	16,934	17,268
Number of loss-making enterprises	exit	1,651	1,048	1,745	1,722	943	1,182	649	
	new		981	574	838	642	360	864	687
	stay	6,178	5,642	5,293	4,674	4,474	3,631	3,258	4,265
	once		268	286	444	161	184	193	
	whole sample	7,829	7,939	7,898	7,678	6,220	5,357	4,964	4,952
Number of enterprises	exit	4,136	2,225	4,179	3,370	2,278	3,790	1,907	
	new		3,783	2,107	3,246	3,165	1,520	4,754	2,987
	stay	18,407	16,182	15,786	14,523	15,491	14,866	14,479	19,233
	once		784	885	1,154	529	562	758	
	whole sample	22,543	22,974	22,957	22,293	21,463	20,738	21,898	22,220
Share of loss-making enterprises	exit	39.9%	47.1%	41.8%	51.1%	41.4%	31.2%	34.0%	
	new		25.9%	27.2%	25.8%	20.3%	23.7%	18.2%	23.0%
	stay	33.6%	34.9%	33.5%	32.2%	28.9%	24.4%	22.5%	22.2%
	once		34.2%	32.3%	38.5%	30.4%	32.7%	25.5%	
	whole sample	34.7%	34.6%	34.4%	34.4%	29.0%	25.8%	22.7%	22.3%

Explaining TE, TE Growth, FTP, TFP

- **Finance (liability/asset):**
  - **negative on TE and TE growth but positive on FTP and TFP;**
- **Firm size (market share at 3-digit industry-level):**
  - **positive on TE and TE growth but negative on FTP/insignificant on TFP;**
- **Concentration (hfindex at 3-digit industry-level for top 4 firms):**
  - **negative for TE, TE growth, and TFP but positive for FTP;**
- **Non-state ownership (type):**
  - **positive for TE, TE growth, and TFP and mixed on FTP;**

Explaining TE

Table 12a-1 Regressions Explaining TE controlling for Time, Industry and Region Effects

	TE (whole sample)		TE (by industry)	
Independent Variables	coefficient	z-ratio	coefficient	z-ratio
Constant	0.4415	[125.58]***	0.4531	[117.19]***
Liabilities-Assets ratio	-0.1258	[65.84]***	-0.1299	[61.32]***
Market Share	-0.0723	[3.35]***	-0.0585	[2.44]**
Square of Market Share	0.2734	[3.54]***	0.1623	[1.89]*
Market Concentration	-0.3325	[9.72]***	-0.2586	[6.81]***
type=private	0.0646	[20.90]***	0.0684	[19.98]***
type=collective	0.0433	[25.68]***	0.0491	[26.33]***
type=Mixed	0.0449	[32.74]***	0.0475	[31.22]***
type=Foreign	0.0797	[33.33]***	0.0734	[27.90]***
type=HK/Mac/TW	0.067	[27.31]***	0.066	[24.40]***
type=SOE	0		0	
year==1995	0.0863	[70.71]***	0.0817	[60.06]***
year==1996	0.0717	[60.02]***	0.0673	[50.54]***
year==1997	0.0583	[49.73]***	0.0543	[41.57]***
year==1998	0.0424	[36.92]***	0.0386	[30.15]***
year==1999	0.0412	[36.68]***	0.0392	[31.34]***
year==2000	0.0338	[30.44]***	0.0328	[26.44]***
year==2001	0.0165	[15.63]***	0.0154	[13.09]***
year==2002	0		0	
Observations	164870		164870	

Absolute value of z statistics in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

type=soe ,ind2=17(Texile) ,place2=37 (Shandong) are omited as benchmark.

Coefficients for Year, Industry and Region dummies not reported in this table.

Industry-Specific Effect on TE

Table 12a-2 Marginal Effect of Industry on TE

	TE (whole sample)		TE (by industry)	
Industry	coefficient	z-ratio	coefficient	z-ratio
[16]Tobacco	26.74%	[27.32]***	10.91%	[10.18]***
[43]Other Manufacturing	21.29%	[4.13]***	18.56%	[3.24]***
[27]Medical	11.39%	[25.96]***	1.85%	[3.85]***
[12]Timber Logging	7.69%	[6.58]***	24.57%	[19.18]***
[37]Transport equipment	7.43%	[20.27]***	2.04%	[5.07]***
[17]Texile	0.00%		0.00%	
[44]ElectricPower	-5.36%	[12.61]***	13.17%	[28.29]***
[06]Coal Mining	-6.25%	[8.83]***	12.34%	[15.92]***
[25]Petroleum Processing	-7.69%	[8.73]***	7.21%	[7.44]***
[46]TapWater	-16.68%	[19.39]***	19.56%	[20.78]***
[45]Gas Production	-22.51%	[17.75]***	3.64%	[2.62]***
Constant	44.15%	[125.58]***	45.31%	[117.19]***

Region-Specific Effect on TE

Table 12a-3 Marginal Effect of Region on TE

	TE (whole sample)		TE (by industry)	
Region	coefficient	z-ratio	coefficient	z-ratio
[32]JiangSu	3.09%	[10.23]***	3.66%	[11.08]***
[31]ShangHai	1.84%	[5.11]***	2.04%	[5.18]***
[33]ZheJiang	1.30%	[3.56]***	1.60%	[4.01]***
[44]GuangDong	1.02%	[3.21]***	0.47%	[1.34]
[35]FuJian	0.40%	[0.80]	0.70%	[1.27]
[37]ShanDong	0.00%		0.00%	
[46]HaiNan	-7.30%	[6.88]***	-8.03%	[6.92]***
[14]ShanXi	-7.55%	[11.84]***	-7.67%	[11.00]***
[22]JiLin	-8.15%	[15.77]***	-8.96%	[15.83]***
[62]GanSu	-8.16%	[9.50]***	-8.59%	[9.15]***
[21]LiaoNing	-8.61%	[22.81]***	-9.72%	[23.54]***
Constant	44.15%	[125.58]***	45.31%	[117.19]***

Explaining TE Growth

Table 13a Regressions Explaining TE Growth Controlling for Time, Industry and Region Effects

	TE Growth (whole sample)		TE Growth (by industry	
Independent Variables	coefficient	z-ratio	coefficient	z-ratio
Constant	-0.0728	[87.05]***	-0.0947	[86.22]***
Liabilities-Assets ratio	-0.0563	[98.35]***	-0.0165	[46.09]***
Market Share	-0.0544	[6.48]***	-0.0265	[7.40]***
Square of Market Share	0.1158	[4.09]***	0.0674	[5.19]***
Market Concentration	-0.0591	[5.28]***	-0.1016	[16.30]***
type=private	0.0272	[26.92]***	0.0044	[7.44]***
type=collective	0.0191	[45.08]***	0.0023	[6.53]***
type=Mixed	0.0224	[54.15]***	0.0038	[14.89]***
type=Foreign	0.0359	[64.64]***	0.0141	[23.81]***
type=HK/Mac/TW	0.0286	[48.05]***	0.0132	[22.79]***
type=SOE	0		0	
year==1995	0.0039	[7.19]***	0.0077	[44.73]***
year==1996	0		0	
year==1997	-0.0059	[11.13]***	-0.0077	[46.08]***
year==1998	-0.0092	[17.03]***	-0.0156	[89.52]***
year==1999	-0.0123	[22.60]***	-0.023	[129.07]***
year==2000	-0.0193	[35.22]***	-0.0312	[171.07]***
year==2001	-0.0256	[46.81]***	-0.0392	[208.48]***
year==2002	-0.0333	[60.40]***	-0.0476	[246.13]***
Observations	164065		164065	

Absolute value of z statistics in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

type=soe ,ind2=17(Texile) ,place2=37 (Shandong) are omited as benchmark.

Coefficients for Year, Industry and Region dummies not reported in this table.

Explaining FTP

Table 14a Regressions Explaining FTP Controlling for Time, Industry and Region Effects

	FTP (whole sample)		FTP (by industry)	
Independent Variables	coefficient	z-ratio	coefficient	z-ratio
Constant	0.2037	[534.46]***	0.2058	[277.02]***
Liabilities-Assets ratio	0.0117	[46.17]***	0.0189	[38.38]***
Market Share	0.0241	[6.51]***	-0.0173	[2.40]**
Square of Market Share	-0.0239	[1.92]*	0.202	[8.30]***
Market Concentration	0.025	[5.06]***	-0.0546	[5.67]***
type=private	0.0106	[23.74]***	0.0091	[10.47]***
type=collective	0.0079	[42.10]***	0.0086	[23.54]***
type=Mixed	0.0007	[4.07]***	0.0009	[2.47]**
type=Foreign	-0.0167	[68.16]***	-0.0204	[42.69]***
type=HK/Mac/TW	-0.0078	[29.75]***	-0.0139	[27.11]***
type=SOE	0		0	
year==1995	-0.2179	[893.94]***	-0.2131	[448.55]***
year==1996	-0.1898	[782.91]***	-0.1851	[391.78]***
year==1997	-0.1587	[660.05]***	-0.1551	[330.76]***
year==1998	-0.1288	[536.40]***	-0.126	[269.23]***
year==1999	-0.0982	[411.34]***	-0.0959	[206.16]***
year==2000	-0.0658	[275.43]***	-0.0639	[137.13]***
year==2001	-0.0328	[140.58]***	-0.0316	[69.43]***
year==2002	0		0	
Observations	164870		164870	

Absolute value of z statistics in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

type=soe ,ind2=17(Texile) ,place2=37 (Shandong) are omited as benchmark.

Coefficients for Year, Industry and Region dummies not reported in this table.

Explaining TFP

Table 15a Regressions Explaining TFP Growth Controlling for Time, Industry and Region Effects

	TFP Growth at Industry Level	
Independent Variables	coefficient	z-ratio
Constant	0.0023	[1.95]*
Liabilities-Assets ratio	0.0066	[8.29]***
Market Share	0.0895	[7.52]***
Square of Market Share	0.0284	[0.71]
Market Concentration	-0.1228	[7.85]***
type=private	0.0005	[0.35]
type=collective	0.0036	[5.96]***
type=Mixed	0.0014	[2.53]**
type=Foreign	0.0018	[2.33]**
type=HK/Mac/TW	-0.0025	[3.06]***
type=SOE	0	
year==1996	0	
year==1997	0.0122	[17.42]***
year==1998	0.0707	[100.01]***
year==1999	0.1512	[212.46]***
year==2000	0.1399	[194.53]***
year==2001	0.153	[213.04]***
year==2002	0.1647	[227.29]***
Observations	144293	

Absolute value of z statistics in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

type=soe ,ind2=17(Texile) ,place2=37 (Shandong) are omited as benchmark.

Coefficients for Industry and Region dummies not reported in this table.

Implications

- **Clear evidences of rapid TFP growth driven by FTP**
- **Clear evidences of large gaps in TE across ownership, region, and industry**
- **Clear evidences that privatization, competition and globalization contributed to China's industrial productivity revolution.**
- **The evidences uncovered here support the view that China's economic growth is sustainable as it is based on productivity catch-up, entry-exit dynamics, competition and privatization**

Thank you