TECHNICAL EFFICIENCY IN THE INDIAN TEXTILES INDUSTRY:
A NONPARAMETRIC ANALYSIS OF FIRM-LEVEL DATA

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Abstract

Technical Efficiency (TE) of Indian textile firms is obtained using non-parametric Data Envelopment Analysis (DEA). TE scores are then analyzed to get the answers to the following questions:

- *What are the levels of TE of individual firms when measured against a benchmark constructed from the entire data set i.e., against the global frontier for India as a whole?*

- *Can we infer anything about the size-regional efficiency relationship of firms in the textile industry in India?*

- *Can we say anything about the trend of technology gap i.e., the difference between the regional frontier and the global frontier?*

- *Is there any systematic difference in the regional efficiency of the firms for different location/ownership/organization for the years taken into consideration?*

- *Can we draw any conclusion about the work culture of the states taken into account from the conditional regional efficiency for the different states taken into account?*
  The results obtained can be summarized through the following points:

- *regional efficiency of Tamil Nadu is the best amongst the six major states considered;*

- *the smallest average size class of firms has the highest group efficiency;*

- *that wholly privately owned (WPO) category of firms has both the largest average size and also has the highest group efficiency amongst ownership categories. Hence, evidence of size-regional efficiency relationship is ambiguous;*

- *we find a clear trend of rising regional efficiency over time. Hence, technology gap across regions seems to be diminishing over time.*

Introduction

The objective of this paper is to measure *technical efficiency* (TE) of Indian textile firms for selected years using DEA. We also use the concept of metafrontier production function defined by Hayami and Ruttan (1971, pp. 82) to see whether technology indeed varies among different locations, ownership patterns, organizational patterns etc. of textile industry. Battese and Rao (2002) and Battese, Rao and O'Donnell (2004) provide frameworks for comparisons when efficiency is measured using parametric stochastic frontier models. Rao, O'Donnell and Battese (2003) provide both frameworks and an empirical application using FAO agricultural data on 97 countries, comprise of about 99 per cent of global agricultural production and 99 per cent of total population of the world also. They provide framework for both non-parametric DEA and parametric stochastic frontier methods as well. Das, Ray and Nag (2005) use the concept of metafrontier as a national or grand frontier to study branch level labour-use efficiency of a major public sector bank in India. The major questions we ask in this study are as follows:

- What are the levels of TE of individual firms when measured against a benchmark constructed from the entire data set i.e., against the global frontier for India as a whole?

- Can we infer anything about the size-regional efficiency relationship of firms in the textile industry in India?

- Can we say anything about the trend of technology gap i.e., the difference between the regional frontier and the global frontier?

- Is there any systematic difference in the regional efficiency of the firms for different location/ownership/organization for the years taken into consideration?

- Can we draw any conclusion about the work culture of the states taken into account from the conditional regional efficiency for the different states taken into account?

The DEA Models

The performance of each individual firm in the sample is measured against two different frontiers: one based on firms from all the different groups in the sample and the

other based only on firms from the group to which it belongs. The first can be regarded as the national or *grand* frontier and the other as the *group* frontier. The grand and the group frontiers can be defined as follows. Define the index set *I={1,2,..., N}* where each observed data point is an element of *I*. Now consider a partition $I = \bigcup I_r$ where I_r includes only observations from group *r*. Then, under the standard assumptions of convexity and free disposability of inputs *(x)* and outputs *(y)* the empirically constructed group and grand production possibility sets are

$$S^r = \{(x, y) : x \geq \sum_{j \in I_r} \lambda_j x^j ; y \leq \sum_{j \in I_r} \lambda_j y^j ; \sum_{j \in I_r} \lambda_j = 1; \lambda_j \geq 0; (j \in I_r)\} \text{(For group } r)$$

and

$$S^G = \{(x, y) : x \geq \sum_{j \in \bigcup I_r} \lambda_j x^j ; y \leq \sum_{j \in \bigcup I_r} \lambda_j y^j ; \sum_{j \in \bigcup I_r} \lambda_j = 1; \lambda_j \geq 0; (j \in \bigcup I_r)\},$$

respectively. It may be noted that while each S^r is a subset of S^G, the latter is bigger than the union of the individual group production possibility sets. This is illustrated by a simple diagram in Figure 1 for a 1-input, 1-output 2-group example.

Let the points P_1 through P_4 show the input-output bundles of four firms from group *P*. Similarly, Q_1 through Q_4 are the input-output bundles of firms from group *Q*. The group frontiers are shown by the broken lines $AP_1P_3P_4C$ for group *P* and by $BQ_1Q_2Q_3D$ for group *Q*. By contrast, the grand frontier is the outer envelop of the two frontiers shown by the broken line $AP_1P_3Q_2Q_3D$. Note that points in the area P_3EQ_2 lie above both group frontiers, but (by virtue of convexity) are below the grand frontier. While judged against their own group frontier the technical efficiency of each the points $Q_1, Q_2,$ and Q_3 equals unity while the corresponding efficiency of Q_4 is $\frac{JQ_4}{JK}$. When judged against the grand frontier, Q_2 and Q_3 remain efficient. On the other hand the efficiency of Q_1 falls from unity to $\frac{BQ_1}{BN}$ while the efficiency of Q_4 does not change. Thus the *group efficiency* of the group *Q* measured at the points $Q_2, Q_3,$ and Q_4 equals unity (even though point Q_4 is inefficient) while at the point Q_1, the group efficiency is $\frac{BQ_1}{BN}$. The geometric mean of the group efficiency measures at these different points may be used as an overall index of the *group efficiency* of *Q*. From group *P* the points P_1 and P_2 lie both on the group and the grand frontier. The point P_4 is on the group frontier but has

technical efficiency $\frac{RP_4}{RS}$. In the case of point P_2 technical efficiency is $\frac{FP_2}{FG}$ relative to the group frontier and $\frac{FP_2}{FH}$ when measured against the grand frontier. Thus, at this point a measure of group efficiency is $\frac{FG}{FH}$. It is interesting to note that point E lies on both of the group frontiers but not on the grand frontier. Thus, at this point both groups would have the same level of group (in) efficiency.

Figure 1: Group and Grand Frontiers
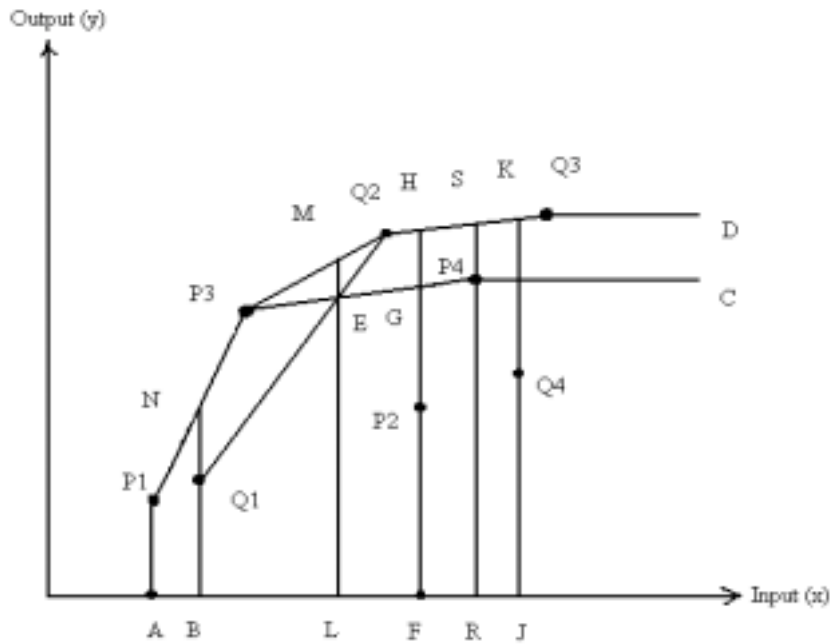
We first consider the DEA model for measuring efficiency relative to the group frontier. For the firm j in group r producing output $y^j{}_r$ from the input $x^j{}_r$, the group efficiency is $TE_r^j = \frac{1}{\varphi_r^j}$ while the grand efficiency is $TE_G^j = \frac{1}{\varphi_G^j}$ where

$$\varphi_r^j = \max \varphi : (x_r^j, \varphi y_r^j) \in S^r \text{ and } \varphi_G^j = \max \varphi : (x_r^j, \varphi y_r^j) \in S^G.$$

A point-wise measure of the technical efficiency of group r is $\beta_r^j = \dfrac{TE_G^j}{TE_r^j}.$ An overall measure of the efficiency of group r is

$$TE(r) = \left(\prod_{j \in r} \beta_r^j \right)^{\frac{1}{n_r}}, \text{ where } n_r \text{ is the number of firms in group } r.$$

Justification of Such Analysis in the Context of Indian Industry

India is a vast country with a number of states and union territories with their distinctive sociological, economic, political and infrastructural features. The physical strength of an average Punjabi is more than that of many other states of India. Work culture of the people of the states like Gujarat, Maharashtra etc. is far better than that of West Bengal (Das et al, 2005). Easy access to natural resources and other infrastructural facilities helpful in achieving lower cost per unit of output is not evenly distributed all over the country. Stability of political power and democratic nature of the overall political environment is also different for different states. Different political parties with the varying political and economic agenda form governments in different states. Militancy of labor unions varies considerably across different parts of the country. All these factors are important determinants of the performance of a firm as reflected by its level of efficiency located in any particular region. The production function for different regions need not be different if all of the above factors could be take into accounts. But most of them are qualitative in nature and unobservable as well, and as a result we couldn't take into them account as factors of production. Hence, it is not wrong to assume that the production technology (defined in terms of the observed inputs and outputs) is itself different for different regions like states for differences in the quality of human capital, work culture and overall working environment, infrastructural facilities etc. Some of them do vary for different ownership as well as organizational pattern. We investigate how far variation in the above three factors namely state, ownership pattern and organizational pattern affects the levels of technical efficiency of individual firms.

Description of Data, Inputs and Output

We use establishment-level data from the Annual Survey of Industries for the years 1993-4, 1998-9, 1999-2000 and 2001-02 for our study. The data covers more than 75 per cent of the entire textile industry, which covers units related to the production of cotton,

woolen, silk, terry cotton, and other natural fibers like jute, coir, mesta etc. It is only for "Spinning, weaving and finishing of textiles" (NIC Code 171 as per NIC'98).

To perform metafrontier analysis for studying the effects of different location we have considered only six major textile-producing states namely Gujarat, Maharashtra, Punjab, Rajasthan, Tamil Nadu and West Bengal. Similarly, we consider all of the six ownership patterns namely ***wholly central government (WCG), wholly state and/or local government (WSLG), central government and state and/or local government jointly (JCSLG), joint sector public (JSPU), joint sector private (JSPR)*** and ***wholly private ownership (WPO)*** as given by the CSO. But there is a high concentration in the distribution of firms as per their ownership pattern. Almost ninety percent of the firms are in ***wholly private ownership*** category for all of the four sample years taken into consideration. As for the organizational pattern we have taken six major viz.**, *individual proprietorship (IP), partnership (Part), public limited company (PULC), private limited company (PRLC), co-operative society (COOPS)*** and the remaining are grouped in ***others*** category. Summary statistics for these location, ownership pattern and organizational pattern are given in Table 1a, Table 1b and Table 1c respectively.

We conceptualize a *one* output-*three* input technology. The variables considered are:

Output: the total ex-factory value of products and by-products produced by the firm during the year in question; ***Intermediate Inputs*:** the nominal value of inputs (both indigenous and imported ones, including power, fuels etc.) used by the firm during the year; ***Capital* :** the net value of fixed assets of the firm at the beginning of a year, and ***Labor:*** the total number of mandays worked during the year.

Empirical Findings

Our empirical analysis shows that

- regional efficiency of Tamil Nadu is the best amongst the six major states considered;
- the smallest average size class of firms has the highest group efficiency;
- that wholly privately owned (WPO) category of firms has both the largest average size and also has the highest group efficiency amongst ownership categories. Hence, evidence of size-regional efficiency relationship is ambiguous;

- we find a clear trend of rising regional efficiency over time. Hence, technology gap across regions seems to be diminishing over time.

Reference:

- Battese, G. E. and D. S. P. Rao (2002), "Technology Gap, Efficiency and a Stochastic Metafrontier Function", Accepted for Publication in *International Journal of Business and Economics*, 1, 2, 87-93.
- Battese, G. E., Rao, D. S. P. and C. J. O'Donnell (2004) "A Metafrontier Production Function for Estimation of Technical Efficiencies and Technology Gaps for Firms Operating Under Different Technologies", *Journal of Productivity Analysis*, 21, 1, 91-103.
- Das, A., Ray, Subhash C. and A. Nag (2005), "Labor-Use Efficiency in Indian Banking: A Branch Level Analysis" Working Paper, 2004-05, University of Connecticut, Department of Economics.
- Hayami, Y. and V. W. Ruttan (1971), "Agricultural Development: An International Perspective", Johns Hopkins University Press, Baltimore, pp. 82.
- Rao, D. S. P., O'Donnell, C. J. and George E. Battese (2003), "Metafrontier Functions for the Study of Inter-Regional Productivity Differences", CEPA Working Papers Series, WP012003, School of Economics, University of Queensland, Australia.

Table 1a: Summary Statistics for Different States

State	Variable	Average Value (in '000 Rs. Except for Labour)			
		1993-94	1998-99	1999-00	2001-02
Gujarat	Output	136140	256887	245507	278734
	II$	88969	203094	197521	214245
	Capital	46841	183591	198346	247337
	Labour*	116	107	117	87
	% of Firms	13.82	10.42	13	12.36
Maharashtra	Output	215859	432851	398861	361953
	II	106419	320960	297331	270457
	Capital	62649	324222	303898	257478
	Labour	214	265	227	169
	% of Firms	10.33	9.71	11.45	9.94
Punjab	Output	113086	305175	401346	319813
	II	78838	230404	305316	248829
	Capital	63587	212304	232001	170092
	Labour	92	160	192	138
	% of Firms	9.16	5.85	5	4.66
Rajasthan	Output	131793	178613	247943	225184
	II	89917	136960	187670	175245
	Capital	36687	100673	136621	126340
	Labour	78	112	140	111
	% of Firms	9.91	10.35	7.78	7.53
Tamil Nadu	Output	150371	199892	181905	169262
	II	73189	145871	141786	129509
	Capital	37279	78539	77258	71342
	Labour	109	110	103	87
	% of Firms	23.14	26	27	28.6
West Bengal	Output	281631	444773	511845	487229
	II	121470	275923	326361	318621
	Capital	67534	159313	183162	169206
	Labour	690	754	799	644
	% of Firms	3.23	5.21	4.77	4.77
All India	Output	146123	260286	263760	251721
	II	86636	189299	198029	191281
	Capital	43841	153579	157655	161008
	Labour	138	184	169	130
	% of Firms	100	100	100	100
*$ II stands for Intermediate Input, * Labour is in '000 of mandays*					

Table 1b: Summary Statistics for Different Ownership Pattern

Ownership	Variable	Average Value (in '000 Rs. Except for Labour)			
		1993-94	1998-99	1999-00	2001-02
WCG	Output	135904	105334	90356	81427
	II$	65950	84086	77196	70262
	Capital	28144	51671	39544	49733
	Labour*	345	345	330	266
	% of Firms	3.11	3.78	3.6	2.70
WSLG	Output	146666	148323	136313	117447
	II	98663	110055	107500	95541
	Capital	25050	42188	38395	35997
	Labour	318	230	218	182
	% of Firms	3.23	4.57	6.77	3.28
JCSLG	Output	112585	63658	88876	8441
	II	76205	52021	75714	11992
	Capital	23512	48332	24768	6857
	Labour	165	82	91	139
	% of Firms	0.97	0.87	0.44	0.35
JSPU	Output	138279	217843	193864	114821
	II	91491	176479	158093	101409
	Capital	30381	96394	90515	73560
	Labour	268	201	183	126
	% of Firms	3.07	3.93	3.82	3.28
JSPR	Output	153009	398146	626774	408730
	II	96570	271766	453485	262702
	Capital	49925	228651	344941	121036
	Labour	214	235	292	120
	% of Firms	1.43	3.07	2.27	1.32
WPO	Output	146992	272334	272563	265588
	II	86708	197352	203802	201490
	Capital	45691	165257	168019	173486
	Labour	118	172	156	125
	% of Firms	88.2	83.8	85.11	89.13
*$ II stands for Intermediate Input, * Labour is in '000 of mandays*					

Table 1c: Summary Statistics for Different Organizational Pattern

Organization	Variable	Average Value (in '000 Rs. Except for Labour)			
		1993-94	1998-99	1999-00	2001-02
IP	Output	25405	10315	11353	11546
	II$	21017	8110	9263	9696
	Capital	1195	1707	8264	1782
	Labour*	18	6	12	7
	% of Firms	7.64	7.14	6.97	5.11
Part	Output	61323	58615	37616	35307
	II	46474	39628	28238	28370
	Capital	4722	6219	12655	6977
	Labour	30	16	24	16
	% of Firms	26.04	17.13	15.85	13.45
PULC	Output	328110	495817	512421	472519
	II	172726	358468	381457	350047
	Capital	120482	308646	321285	327183
	Labour	299	291	285	232
	% of Firms	28.77	41.4	43.14	39.66
PRLC	Output	79599	138356	107143	164817
	II	58174	98903	82306	134439
	Capital	20600	91506	51607	84653
	Labour	63	157	72	65
	% of Firms	22.76	18.63	21.13	29.71
COOPS	Output	-	145391	110113	102584
	II	-	124392	94983	85096
	Capital	-	54032	47288	48926
	Labour	-	146	129	93
	% of Firms	-	6.14	5.28	5.11
Others	Output	106189	99800	98197	68820
	II	67592	78083	77837	55501
	Capital	21434	44448	40219	37070
	Labour	194	227	260	173
	% of Firms	14.78	9.56	7.63	6.95
*$ II stands for Intermediate Input, * Labour is in '000 of mandays*					

Table 2a: Average Technical Efficiency for Different States

State	Year	No. of Firms	Based on Own Frontier	Based on Global Frontier	Regional Efficiency
Gujarat	1990-91				
	1993-94	329	0.24	0.02	0.10
	1998-99	146	0.52	0.15	0.29
	1999-2000	177	0.64	0.31	0.48
	2001-02	214	0.60	0.44	0.74
Maharashtra					
	1993-94	246	0.15	0.026	0.17
	1998-99	136	0.30	0.14	0.48
	1999-2000	156	0.51	0.30	0.59
	2001-02	173	0.63	0.46	0.73
Punjab					
	1993-94	218	0.21	0.04	0.19
	1998-99	82	0.80	0.14	0.18
	1999-2000	68	0.60	0.38	0.64
	2001-02	81	0.80	0.49	0.61
Rajasthan					
	1993-94	236	0.11	0.04	0.32
	1998-99	145	0.58	0.15	0.25
	1999-2000	106	0.66	0.33	0.50
	2001-02	131	0.60	0.48	0.80
Tamil Nadu					
	1993-94	551	0.019	0.016	0.88
	1998-99	364	0.18	0.13	0.76
	1999-2000	368	0.46	0.33	0.71
	2001-02	498	0.57	0.47	0.82
West Bengal					
	1993-94	77	0.44	0.026	0.06
	1998-99	73	0.69	0.20	0.29
	1999-2000	65	0.69	0.49	0.71
	2001-02	83	0.84	0.60	0.72

Table 2b: Average Technical Efficiency for Different Ownership Pattern

State	Year	No. of Firms	Based on Own Frontier	Based on Global Frontier	Regional Efficiency
WCG	1993-94	74	0.18	0.01	0.08
	1998-99	53	0.61	0.08	0.13
	1999-2000	49	0.59	0.21	0.35
	2001-02	47	0.70	0.37	0.53
WSLG	1993-94	77	0.63	0.02	0.04
	1998-99	64	0.40	0.11	0.26
	1999-2000	65	0.73	0.29	0.39
	2001-02	57	0.75	0.44	0.59
JCSLG	1993-94	23	0.77	0.017	0.022
	1998-99	12	0.85	0.08	0.09
	1999-2000	6	0.97	0.28	0.29
	2001-02	6	0.67	0.19	0.28
JSPU	1993-94	73	0.58	0.02	0.03
	1998-99	55	0.67	0.13	0.19
	1999-2000	52	0.79	0.31	0.40
	2001-02	57	0.76	0.39	0.51
JSPR	1993-94	34	0.71	0.017	0.023
	1998-99	43	0.74	0.14	0.19
	1999-2000	31	0.79	0.3	0.41
	2001-02	23	0.70	0.42	0.59
WPO	1993-94	2100	0.03	0.03	1.0
	1998-99	1174	0.16	0.16	0.996
	1999-2000	1160	0.336	0.336	0.9994
	2001-02	1548	0.49	0.49	0.998

Table 2c: Average Technical Efficiency for Different Organizational Pattern

State	Year	No. of Firms	Based on Own Frontier	Based on Global Frontier	Regional Efficiency
IP	1993-94	182	0.22	0.05	0.21
	1998-99	100	0.52	0.15	0.28
	1999-2000	95	0.76	0.22	0.30
	2001-02	89	0.76	0.47	0.63
Part	1993-94	620	0.10	0.04	0.44
	1998-99	240	0.25	0.13	0.53
	1999-2000	216	0.31	0.27	0.86
	2001-02	234	0.49	0.47	0.96
PULC	1993-94	685	0.023	0.021	0.92
	1998-99	580	0.25	0.18	0.72
	1999-2000	588	0.46	0.42	0.91
	2001-02	690	0.57	0.52	0.90
PRLC	1993-94	542	0.19	0.02	0.09
	1998-99	261	0.16	0.13	0.82
	1999-2000	288	0.46	0.31	0.67
	2001-02	517	0.57	0.45	0.79
COOPS	1993-94	-	-	-	-
	1998-99	86	0.65	0.13	0.20
	1999-2000	72	0.71	0.27	0.38
	2001-02	89	0.74	0.42	0.57
Others	1993-94	352	0.10	0.02	0.19
	1998-99	134	0.53	0.09	0.18
	1999-2000	104	0.61	0.23	0.37
	2001-02	121	0.58	0.37	0.64

Table 3: Regional Efficiency (RE) of Different States for Wholly Privately Owned Firms as per their Organization

State	Organization	1993-94		1998-99		1999-2000		2001-02	
		No. of Firms	RE	No. of Firms	RE	No. of Firms	RE	No. of Firms	RE
Gujarat	IP	25	0.22	6	0.12	15	0.35	12	0.62
	Part	90	0.15	31	0.32	24	0.35	42	0.63
	PULC	83	0.05	58	0.35	68	0.60	82	0.82
	PRLC	98	0.09	43	0.26	62	0.46	75	0.74
	COOPS	-	-	0	-	1	0.30	0	-
	Others	18	0.15	2	0.21	2	0.31	1	0.60
Maharashtra	IP	10	0.26	3	0.51	3	0.46	3	0.67
	Part	34	0.39	7	0.57	13	0.41	9	0.67
	PULC	67	0.12	50	0.48	59	0.70	64	0.78
	PRLC	56	0.16	21	0.56	19	0.61	39	0.71
	COOPS	-	-	6	0.45	12	0.56	5	0.81
	Others	18	0.18	1	0.93	2	0.72	0	-
Punjab	IP	16	0.45	13	0.13	2	0.27	8	0.55
	Part	120	0.25	18	0.13	18	0.55	17	0.59
	PULC	22	0.06	23	0.26	23	0.87	29	0.65
	PRLC	39	0.12	14	0.19	12	0.63	20	0.62
	COOPS	-	-	0	-	0	-	0	-
	Others	7	0.14	0	-	3	0.27	0	-
Rajasthan	IP	50	0.55	30	0.25	21	0.37	18	0.79
	Part	97	0.50	44	0.26	25	0.50	19	0.88
	PULC	38	0.08	40	0.28	28	0.65	38	0.73
	PRLC	31	0.28	18	0.20	24	0.47	44	0.83
	COOPS	-	-	1	0.24	0	-	1	0.87
	Others	7	0.36	2	0.20	0	-	3	0.91
Tamil Nadu	IP	34	0.67	25	0.72	27	0.91	22	0.87
	Part	100	0.77	57	0.64	57	0.86	68	0.82
	PULC	192	0.96	162	0.77	167	0.63	174	0.82
	PRLC	162	0.92	77	0.79	82	0.74	194	0.81
	COOPS	-	-	1	0.89	0	-	3	0.91
	Others	33	0.78	11	0.75	8	0.81	13	0.82
West Bengal	IP	1	0.09	0	-	0	-	0	-
	Part	4	0.20	3	0.13	2	0.62	1	0.51
	PULC	46	0.06	48	0.34	43	0.74	56	0.77
	PRLC	8	0.05	9	0.30	5	0.61	10	0.68
	COOPS	-	-	0	-	0	-	0	-
	Others	1	0.02	0	-	2	0.55	1	1.0