TECHNICAL EFFICIENCY AND ITS DETERMINANTS IN CHINESE MANUFACTURING SECTOR

by

Yanrui Wu

DISCUSSION PAPER 02.15

DEPARTMENT OF ECONOMICS

THE UNIVERSITY OF WESTERN AUSTRALIA
35 STIRLING HIGHWAY
CRAWLEY, WA 6009
AUSTRALIA

Technical Efficiency and Its Determinants in Chinese Manufacturing Sector

Yanrui Wu

Department of Economics
University of Western Australia
35 Stirling Highway
Crawley WA 6009
yanrui.wu@uwa.edu.au

Technical Efficiency and Its Determinants in Chinese Manufacturing Sector

Abtract

This paper examines technical efficiency and its determinants in Chinese manufacturing industries using survey data at the sector level. A stochastic frontier approach is applied to estimate technical efficiency rates for individual sectors. In particular, the empirical analysis focuses on regional comparisons of manufacturing performance and the determinants of technical efficiency among the sectors. The findings are used to draw policy implications for regional economic development.

Key Words: frontier approach, technical efficiency, manufacturing, determinants.

JEL Classification: C2, O4, O53.

Technical Efficiency and Its Determinants in Chinese Manufacturing Sector[1]

Studies on productive performance in China have employed firm-level or aggregate data. The latter are at either national or provincial level. Few investigations deal with the sectors directly.[2] This paper attempts to fill the void in the literature. It presents a study of efficiency performance at the sector level using 1995 industrial survey data. This study extends previous research at the firm-level using the same survey material.[3] The rest of the paper begins with a review of the existing literature in Section 1. The methodological issues are discussed in Section 2. Empirical models and data issues are described in Section 3. The determinants of technical efficiency are examined in Section 4. Finally, concluding remarks are presented in Section 5.

1. Existing Studies

Several existing studies at the firm level are based on a longitudinal survey database of about 800 state-owned firms.[4] The database was compiled by the Chinese Academy of Social Sciences through two surveys. The first survey covers the period of 1980-1989 and the second 1990-1994. Authors have applied both conventional and frontier production functions to examine productive performance in Chinese firms. Examples include Groves et al. (1994), Liu and Liu (1996), Wu (1998), and Liu and Zhuang (1998). The dominant view is that efficiency has improved in state-owned

---

[1] This paper contains part of research outcome from a project funded by the Ford Foundation (Beijing Office). The project was led by Professor Li Shantong, Development Research Centre, Beijing. I thank Professor Li and team member, Hou Yongzhi for helpful discussions and Liu Peilin from Peking University for excellent research assistance.

[2] For example, national and regional studies include Lau and Brada (1990), Jefferson et al. (1992), Hu and Khan (1997), Wu (1995, 2000). Borensztein and Ostry (1996).

[3] Such as Yao (1998), Yao and Zhang (2001).

enterprises since China's economic reform program was initiated two decades ago. It is also concluded that enterprise efficiency is affected by firm attributes such as incentives, location, wage system and vintage of capital.

More recent studies are based on the 1995 National Industrial Survey Database. For example, Yao (1998) presented a study of technical efficiency in 14,670 firms. He focused on the non-state owned enterprises. His study was extended to cover 37,769 firms by Yao and Zhang (2001). They compared productive performance between state-owned and non-state owned enterprises and between large and small firms. They also considered the impact of foreign direct investment, geographical location and R&D investment on efficiency performance. More recently, Dougherty and McGuckin (2002) investigated the effects of privatisation and decentralization on productivity performance in 20,992 large and medium Chinese firms.

This study differs from previous work in several ways. First, it focuses on the industry and regional level. Thus, it uses data at the 4-digit sectoral level. The analyses cover 60 three-digit sectors. The sample has more than 5,000 observations. Second, the aim of this study is to examine the determinants of technical efficiency. A two-stage approach is employed in this study. In the first stage, standard frontier production functions are estimated and thus region- and sector-specific technical efficiency rates are derived. In the second stage, Tobin models are used to investigate the impact of region- and sector-specific factors on technical efficiency. Tobin models are applied because the dependent variable ie. technical efficiency, has an upper bound value of one. This issue has however been ignored in other studies (eg Yao and Zhang 2001). The details of the modeling issues are described next.

---

[4] See Wu (1993) for a literature review.

2. Analytical and Data Issues

The empirical analysis follows a two-stage approach. In the first stage, the econometric model used in this study, hereafter called the frontier model, is related to the concept of output-oriented technical efficiency first proposed by Farrell (1957) and popularised by Aigner, Lovell and Schmidt (1977), and Meeusen and van den Broeck (1977).[5] The important difference between the traditional growth accounting method and the production frontier technique is that the latter allows for production below the best practice output.

Analytical Framework

The simple version of the above-described model can be presented as follows:

$$y_i^F = f(x_i) \quad , \qquad i = 1,...,N \tag{1}$$

where y_i^F represents the frontier production level or the so-called 'best practice' output for the ith economy or sector, given technology f(•). Then, any observed output y_i, given input x_i, may be expressed as

$$y_i = y_i^F TE_i = f(x_i) TE_i \tag{2}$$

where TE_i indicates technical efficiency, defined as the ratio of the observed output over the best practice output.

In the second stage, technical efficiency (TE_i) is regressed against a set of sector and region-specific attributes that affect efficiency performance. As the dependent variable, ie. technical efficiency rate, is bounded between zero and one, Tobin models are employed at this stage.

[5] Comprehensive surveys of efficiency measurement techniques are documented in Fried, Lovell and Schmidt (1993) and Lovell (1996), for instance.

The Empirical Model

The empirical version of the model employed in the first stage can be expressed as follows

$$\log Y = \delta_0 + \delta_1 \log W + \delta_2 \log A + \delta_3 \log E + \delta_4 (\log W)^2 + \delta_5 (\log A)^2 + \delta_6 (\log E)^2$$

$$+ \delta_7 \log W \log A + \delta_8 \log W \log E + \delta_9 \log A \log E + v - u \qquad (3)$$

where Y, W, A and E represent gross value of output, value of working capital, gross value of assets and number of employees, respectively; v is the standard error term and u is the positive truncation of a normal distribution with mean of μ and variance σ_u^2; and v and u are independent. Alternatively, one can also consider a model in which value-added is a function of labour and net value of assets. Model (3) can be estimated by the maximum likelihood method using the computer program, FRONTIER 4.1.[6] Given the estimates of the parameters in equation (3), technical efficiency rate for the ith sector or region is computed as the conditional expectation of e^{-u_i} with respect to ε_i, i.e.

$$TE_i = E[\exp(-u_i) \mid \varepsilon_i] \quad \text{where} \quad \varepsilon_i = v_i - u_i \qquad (4)$$

Summary of the Data Sample

The empirical work is based on the material of the Third National Industrial Census. The Census conducted in 1995 collected detailed information of a large group of firms located in 30 Chinese regions. It is the most comprehensive database for industrial and regional studies. The sample used in this study covers 60 three-digit sectors and 30 regions. A total of 5160 observations is used in the final estimations.

[6] Readers may refer to Coelli (1992) for further details about the FRONTIER program.

3. Technical Efficiency and Its Determinants

This section first applies the empirical model to estimate technical efficiency. It then examines the determinants of technical efficiency.

Technical Efficiency Estimates

Stage-one analyses are based on Equation (3) defined in the preceding section. Several optional models have been estimated and tested (see Table 1). A series of tests show that the translog model with variable returns to scale and gross value of output as the dependent variable is the preferred one. The final analysis is based on this model.

Table 1 Summary of Optional Regressions

Models	Returns to scale	Functional form	No. of regressions
Dependent variable = gross value of output			
1	variable	Translog	60
2	Constant	Translog	60
3	variable	Cobb-Douglas	60
4	Constant	Cobb-Douglas	60
Dependent variable = value-added			
5	variable	Translog	60
6	Constant	Translog	60
7	variable	Cobb-Douglas	60
8	constant	Cobb-Douglas	60

A summary of technical efficiency estimates is presented in Table 2. On average, China's industrial sector only achieved less than 80 per cent of its potential performance in 1995. The best performers include transport machinery manufacturing (379) and sugar processing (133). The worst performers are consumer electronics(417) and electronic and telecommunications equipment repair sectors (418). In general, the coastal regions performed better than the central and western regions. The gap is larger in sectors such as shipbuilding (376), broadcasting and television equipment (413) and consumer electronics (417). In general, at the two-digit level, food processing (13) and food manufacturing (14) perform better than other sectors. As expected, among the coastal region, the better performers are provinces along the eastern coastal zone such as Jiangsu, Zhejiang, Guangdong, Fujian and Shandong.

Determinants of Technical Efficiency

This section extends the preceding section by examining the determinants of technical efficiency. Technical efficiency can be affected by many factors. Given the availability of data, we focus on the following factors.

Depreciation The extent of capital depreciation influences the speed of technological change and hence efficiency performance. This variable is measured by the ratio of the net value of fixed assets over the gross value of fixed assets. Its expected sign is negative (Table 3).

Productive assets Among Chinese firms, substantial resources are devoted to non-productive activities such as medical services and education. To capture the effect of non-productive assets on efficiency, a variable measuring the ratio of gross value of productive assets over gross value of fixed assets is introduced. Its sign is expected to be positive.

Table 2 Technical Efficiency Estimates by Sector

Code	Sector	Observation	Coastal	Central	Western	Overall
131	Grain and feed processing	188	0.7690	0.7479	0.7393	0.7542
132	Vegetable oil processing	53	0.9443	0.9439	0.9437	0.9440
133	Sugar manufacturing	48	0.9906	0.9906	0.9905	0.9906
134	Slaughtering and meat and eggs processing	95	0.9862	0.9859	0.9860	0.9860
135	Aquatic processing	76	0.9789	0.9789	0.9789	0.9789
136	Salt processing	22	0.6617	0.6861	0.5288	0.6393
139	Other food processing	27	0.9420	0.9428	0.9411	0.9420
141	Cake and candy processing	167	0.8510	0.8415	0.8363	0.8442
142	Dairy products	27	0.9604	0.9607	0.9572	0.9595
143	Canned food	114	0.8964	0.8966	0.8916	0.8955
144	Bakery products	104	0.6491	0.6025	0.6363	0.6308
145	Condiment manufacturing	116	0.9850	0.9851	0.9848	0.9850
149	Other food manufacturing	162	0.9838	0.9837	0.9837	0.9837
171	Primary fibre processing	84	0.5885	0.5010	0.3760	0.5117
172	Cotton textiles	179	0.7486	0.6717	0.6783	0.7064
174	Woolen textiles	130	0.6754	0.5751	0.5940	0.6256
176	Hemp textiles	67	0.6746	0.6941	0.5422	0.6537
177	Silk textiles	114	0.6743	0.5915	0.5385	0.6212
178	Knitting	109	0.6644	0.5212	0.4183	0.5565
179	Other textiles	27	0.8112	0.7918	0.7745	0.7959
261	Raw chemical materials	135	0.8184	0.7863	0.7620	0.7935
262	Chemical fertilizers	151	0.7035	0.6225	0.5611	0.6390
263	Chemical pesticides	51	0.7013	0.5742	0.5303	0.6220
265	Organic chemical products	154	0.6968	0.6243	0.5631	0.6433
266	Synthetic material manufacturing	173	0.6799	0.6383	0.6117	0.6545
267	Special chemical product manufacturing	163	0.7080	0.6226	0.5777	0.6469
268	Chemical products for daily use	212	0.6786	0.6663	0.5766	0.6501
271	Crude chemical medicine manufacturing	27	0.8029	0.7723	0.8044	0.7931
272	Chemical medicament manufacturing	29	0.7046	0.6438	0.7294	0.6926

273	Traditional Chinese medicine and material	30	0.7903	0.8301	0.8653	0.8248
274	Veterinary medicine manufacturing	27	0.9438	0.9441	0.9424	0.9436
275	Biomedicine product manufacturing	27	0.8124	0.7456	0.6963	0.7600
281	Fibrin fibre manufacturing	54	0.6751	0.5550	0.5111	0.6092
282	Synthetic fibre manufacturing	90	0.7331	0.6702	0.6102	0.6869
285	Fishing gear and material manufacturing	58	0.9066	0.9030	0.9065	0.9057
351	Boilers and prime movers	127	0.9225	0.9203	0.9194	0.9211
352	Metal-processing equipment manufacturing	130	0.8085	0.7884	0.7698	0.7925
353	General machinery	221	0.9259	0.9217	0.9214	0.9234
354	Bearings and valves	54	0.9506	0.9453	0.9450	0.9474
356	Other component manufacturing	233	0.8178	0.7892	0.7789	0.7991
357	Forging and casting	56	0.9391	0.9349	0.9348	0.9366
358	Ordinary machine repair	28	0.7405	0.7220	0.6780	0.7167
359	Other ordinary machine manufacturing	27	0.6808	0.5468	0.4977	0.5954
371	Railroad transport machinery	118	0.7118	0.6985	0.6701	0.6978
372	Automobiles	149	0.7648	0.7449	0.6925	0.7434
373	Motorcycles	48	0.9353	0.9339	0.9338	0.9345
374	Bicycles	22	0.9132	0.9216	0.9095	0.9145
376	Shipbuilding	61	0.6206	0.4860	0.3408	0.5488
377	Aircraft and aeronautics	34	0.9595	0.9618	0.9573	0.9598
378	Transportation machinery repair	140	0.7367	0.7280	0.6614	0.7170
379	Other transport machinery manufacturing	29	0.9994	0.9994	0.9994	0.9994
411	Telecommunications equipment	93	0.9225	0.9230	0.9185	0.9218
412	Radar manufacturing	24	0.6524	0.7768	0.6719	0.6840
413	Broadcasting and television equipment	23	0.6701	0.4958	0.4483	0.5729
414	Computer manufacturing	39	0.6059	0.4443	0.6851	0.5622
415	Electronic parts	66	0.6190	0.4676	0.3793	0.5272
416	Electronic components	28	0.9607	0.9604	0.9583	0.9600
417	Consumer electronics	55	0.5737	0.3355	0.2593	0.4443
418	Electronics and telecoms equipment repair	42	0.4474	0.3440	0.6330	0.4183
419	Other electronic equipment manufacturing	23	0.6279	0.4630	0.5309	0.5537
	Mean		0.7883	0.7457	0.7277	0.7610

Agglomeration effect Agglomeration effect reflects the positive externalities due to the presence of many firms in the same region. It is measured by the geometric mean of sectoral shares in terms of output and number of firms. Its sign is expected to be positive.

Labour compensation Productive efficiency and labour compensation are interrelated. Average wage is used to reflect the impact of labour compensation on efficiency. Its sign is expected to be positive

Incentive system The ratio of bonus and allowance payment over total wage captures the effect of the incentive system on performance among the industries. Its sign is expected to be positive. The more bonus and allowance payment accounts for the total wage, the more incentive there is for employees to work harder and hence perform efficiently.

Table 3 *Efficiency Determinants*

Variables	Expected sign	Sign of estimated value
Capital depreciation	negative	negative
Productive assets	positive	positive
Agglomeration	positive	positive
Compensation	positive	positive
Incentive	positive	negative
Taxation system	negative	negative
Dummy for the western	negative	negative
Dummy for the central	negative	negative

Taxation system The tax system can affect productive efficiency especially in China where the system is not well developed yet. This variable is measured by the ratio of tax over value-added. Its expected sign is negative.

Apart from the factors specified above, two dummy variables representing the western and central regions are also included in the second stage regressions. According to the regression results, the coefficients of most variables have the expected sign (see Table 5). The coefficients of the incentive variable appear to be negative but statistically insignificant. The coefficients of the dummy variables further confirm that the central and western regions are not as efficient as the coastal regions.

In summary, sectoral and regional analyses show that there is still ample scope for efficiency improvement at the industry level and that efficiency gains may be possible by narrowing the gap between the coastal provinces and the rest of the country. According to the findings in this section, labour compensation, incentive and taxation systems and agglomeration effect are important factors influencing efficiency performance. In addition, capital depreciation and non-productive activities are also important determinants of productive efficiency.

4. Conclusions

This study applies the stochastic frontier model to examine efficiency performance and its determinants in Chinese manufacturing sectors. For the first time, Chinese survey data at the four-digital level are employed in this study. Analysis of the sectoral and regional data demonstrates that there is still ample scope for efficiency improvement at the industry level and that efficiency gains may be possible by closing the gap between the coastal provinces and the rest of the country. This paper also shows that labour compensation, taxation incentives and agglomeration effect are important factors influencing efficiency performance. In addition, capital depreciation and non-productive activities are also important determinants of productive efficiency.

Bibliography

Aigner, D.J., C.A.K. Lovell and P.J. Schmidt, 1977, "Formulation and estimation of stochastic frontier models", Journal of Econometrics 6(1), 21-37.

Battese, George and Tim Coelli, 1995, "A model for technical inefficiency effects in a stochastic frontier production function", Empirical Economics 20, 325-32.

Borensztein, Eduardo and Jonathan D. Ostry, 1996, "Accounting for China's growth performance", American Economic Review (Papers and Proceedings) 86, 225-28.

Coelli, Tim J., 1992, "A computer program for frontier production function estimation: FRONTIER, version 2.0", Economics Letters 39, 29-32.

Dougherty, S.M. and R.H. mcGuckin, 2002, "The effects of federalism and privatisation on productivity in Chinese firms", Economic Program Working Paper Series 01-02, The Conference Board, New York.

Farrell, Michael J., 1957, "The measurement of productive efficiency", Journal of the Royal Statistical Society, Series A, General 120, 253-82.

Fleisher, Belton M. and Jian Chen, 1997, "The coast-noncoast income gap, productivity and regional economic policy in China", Journal of Comparative Economics 25, 220-36.

Fong, Raymond W.L. and Christopher S.P. Tong, 1998, "Technological change of China's township and village enterprises (TVPs) and its corresponding spatial disparity: a combined DEA-Poolong approach", mimeo, Hong Kong Baptist University.

Fried, H., C.A. K. Lovell and S. Schmidt (eds), 1993, The measurement of productive efficiency, Oxford University Press.

Groves, T., Y. Hong, J. McMillan and B. Naughton, 1994, "Autonomy and incentives in Chinese state enterprises", Quarterly Journal of Economics 109, 1-27.

Hu, Zuliu. F. and Mohsin S. Khan, 1997, "Why is China growing so fast?", IMF Staff Papers 44, 103-31.

Jefferson, Gary H., Thomas G. Rawski and Yuxin Zheng, 1992, "Growth, efficiency and convergence in China's state and collective industry", Economic Development and Cultural Change 40(1), 239-66.

Kalirajan, K.P. M.B. Obwona and S. Zhao, 1996, "A decomposition of total factor productivity growth: the case of Chinese agricultural growth before and after reforms", American Journal of Agricultural Economics 78, 331-38.

Lau, Kam-tim and Josef C. Brada, 1990, "Technological progress and technical efficiency in Chinese industrial growth: a frontier production function approach", China Economic Review 1, 113-24.

Li, Jingwen, Gong Feihong and Zheng Yisheng, 1995, "Productivity and China's economic growth, 1953-1990", in Productivity, efficiency and reform in China's economy edited by K.Y. Tsui, T.T. Hsueh and Thomas G. Rawski, Chinese University of Hong Kong.

Liu, Z. and G.S. Liu, 1996, "The efficiency impact of the Chinese industrial reforms in the 1980s", Journal of Comparative Economics 23, 237-55.

Liu, Z. and Juzhong Zhuang, 1998, "Evaluating partial reforms in the Chinese state industrial sector: a stochastic frontier cost function approach", International Review of Applied Economics 12(1), 9-24.

Lovell, C.A. Knox, 1996, "Applying efficiency measurement techniques to the measurement of productivity change", Journal of Productivity Analysis 7, 329-40.

Maddison, Angus, 1998, Chinese economic performance in the long run, OECD Development Centre, Paris.

Malmquist, Sten, 1953, "Index numbers and indifference curves", Trabajos de Estatistica 4, 209-42.

Mao, Weining and Won W. Koo, 1996, "Productivity growth, technological progress and efficiency change in Chinese agricultural production from 1984 to1993", mimeo, North Dakota State University, Fargo.

McMillan, J., J. Whalley and L. Zhu, 1989, "The impact of China's economic reforms on agricultural productivity growth", Journal of Political Economy 97(4), 781-807.

Meeusen, W. and J. van den Broeck, 1977, "Efficiency estimation from Cobb-Douglas production functions with composed error", International Economic Review 18(2), 435-44.

Solow, R.M., 1957, "Technical change and the aggregate production function", Review of Economics and Statistics 39(3), 312-20.

State Statistical Bureau, various issues, Statistical yearbook of China, Statistical Publishing House of China, Beijing.

World Bank, 1997, China 2020: development challenges in the new century, Washington, DC.

Wu, Yanrui, 1993, "Productive Efficiency in Chinese Industry: A Review", Asian-Pacific Economic Literature 7(2), pp.58-66.

Wu, Yanrui, 1995, "Total Factor Productivity Growth, Technological Progress and Technical Efficiency Change in China: A Three Sector Analysis", Journal of Comparative Economics 21(2), pp.207-229.

Wu, Yanrui, 1998, "Redundancy and Firm Characteristics in Chinese State-Owned Enterprises", Asia Pacific Journal of the Economics and Business 2(1), 33-44.

Wu, Yanrui, 2000, "Is China's Economic Growth Sustainable: A Productivity Analysis", China Economic Review 11 (3), 278-296.

Yao, Yang and Qi Zhang, 2001, "Analysis of technical efficiency in Chinese industry", working paper 200103, National Centre for Economic Research, Tsinghua University.

Yao, Yang, 1998, "Impact of non-state owned sector on technical efficiency performance in Chinese industry", unpublished manuscript, China Centre for Economic Research, Peking University (in Chinese).

DISCUSSION PAPERS

Department of Economics

The University of Western Australia

Discussion Paper	Author	Title
02-14	Wu, Y.	Demand for Feedgrain in China: Implications for Foodgrain Consumption and Trade
02-13	Stammer, D.	The Shann Memorial Lecture Change in the Australian Economy: What it Means for Australians...and...What it Means for Australian Economists
02-12	Lee, M. Tcha, M.	An analysis of Fiscal Policy and Economic Growth: the Case of Transition Economies
02-11	Tcha, M. Kuriyama, T.	Welfare Effects of Protection and Economies of Scale – the Case of the Australian Automotive Industry
02-10	Clements, K. W.	Three Facts About Marijuana Prices
02-09	Tcha, M. Pershin, V.	Reconsidering Performance at the Summer Olympics and Revealed Comparative Advantage
02-08	Chiswick, B.R. Lee, Y.L. Miller, P.W.	Longitudinal Analysis of Immigrant Occupational Mobility: A Test of the Immigrant Assimilation Hypothesis
02-07	Chiswick, B.R. Lee, Y.L. Miller, P.W.	Immigrants' Language Skills: The Australian Experience
02-06	Chiswick, B.R. Lee, Y.L. Miller, P.W.	Family Matters: The role of the Family in Immigrants' Destination Language Acquisition
02-05	Chiswick, B.R. Lee, Y.L. Miller, P.W.	Immigrants' Language Skills and Visa Category
02-04	Connolly, T. Butler, D.	Searching for the "Regret" in "Regret Theory"
02-03	Groenewold, N. Hagger, A. Madden, J.R.	The Efficiency of Federal Inter-Regional Transfers Under a Regime of Politically-Maximizing Regional Governments

Discussion Paper	Author	Title
02-02	Groenewold, N. Tang, S.H.K. Wu, Y.	The Dynamic Interrelationships Between the Greater China Share Markets
02-01	Lan, Y.	Aspects of Exchange-Rate Economics