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Evaluating the comparative efficiency of Chinese third-party logistics providers using data envelopment analysis

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Abstract

Purpose – The purpose of this paper is to develop a benchmark of performance standards for Chinese third-party logistics providers (3PLs) in the emerging market. It also intends to identify various factors that significantly affect the operational efficiency of the Chinese 3PLs and propose ways to improve the competitiveness of 3PLs.

Design/methodology/approach – This paper proposes data envelopment analysis (DEA) to measure the operational efficiency of ten leading 3PLs in China, relative to prior periods and their key competitors. In particular, this paper develops both the Charnes, Cooper and Rhodes model and the Banker, Charnes and Cooper model that are designed to derive weights without being fixed in advance. It also uses step-wise regression analysis to identify factors influencing the performances of Chinese 3PLs.

Findings – First, the declining efficiency within some Chinese 3PLs coincides with a steep decline in domestic transportation activities due to the SARS outbreak and the slow adaptation of state-owned enterprise into a more market-based economy. Second, the sales opportunity and the level of technical expertise are directly correlated with the operational efficiency of 3PLs, whereas the size of 3PLs has no direct bearing on the 3PL's performance. Third, in contrast with the 3PL industry in the USA, the Chinese 3PLs tend to focus on traditional service offerings such as port management, transportation, and warehousing rather than playing the role as the integrator or the lead service provider.

Originality/value – This paper is the first attempt to utilize DEA to develop performance benchmarks for 3PLs in the emerging foreign market. The proposed DEA can be easily modified or extended to similar settings in other Asian countries such as India and East European countries.

Keywords Distribution management, Data analysis, Emerging markets, China

Paper type Research paper

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Introduction

Since, China joined the World Trade Organization in late-2001, its trade with foreign countries including the USA has surged along with the growth of logistics activities. As China has emerged as a major logistics hotspot in Asia, a growing number of multinational firms (MNFs) conducting business in China look for ways to enhance the logistics efficiency through the use of third-party logistics providers (3PLs). As of Armstrong (2005), the total 3PL market in Asia-Pacific countries including China was estimated to be $90 billion a year. A recent 3PL survey conducted by Langley *et al.* (2004) also indicated that the percentage of 3PL users in Asia-Pacific countries jumped sharply from 58 percent in 2003 to 84 percent in 2004. In conjunction with this rate of growth, the 3PL market in China is projected to double its 1999 market size of $55.8 billion and reach $120.8 billion by 2010 (Trunick, 2005). Despite such a phenomenal growth in the 3PL market, many MNFs conducting business in China have expressed concern over mounting supply chain costs in China as a result of inadequate logistics infrastructure, congestion at ports and industrial roads, lack of logistics management talents, stiff regulations, bureaucratic red-tapes, and corrupt business practices. If supply chain costs continue to remain uncontrolled, China's leverage as a low-cost haven will be reduced and its rising economic status will become jeopardized. In particular, considering a disproportionately higher percentage of logistics costs in China, the logistics efficiency has greater importance in China than in the USA. As of 2002, the total logistics expenditure in China accounted for 21.5 percent of the Chinese gross domestic product (GDP), whereas the total logistics expenditure in the USA comprised of a mere 9.3 percent of the US GDP (Rodrigues *et al.*, 2005; Wang, 2006).

In other words, without eliminating the sources of logistics inefficiency, China's 3PL market will lose its steam and would become stagnant. To take a closer look at the competitiveness of China's 3PL industry and to identify sources of logistics inefficiency, it is worthwhile evaluating the current performance of Chinese 3PLs relative to their competitors and then developing a benchmark standard for both existing 3PLs and future 3PL market entrants in China. Thus, the primary objective of this paper is to measure the operational efficiency of Chinese 3PLs, relative to prior periods and their competitors by using data envelopment analysis (DEA). In general, DEA is referred to as a linear programming technique that converts multiple incommensurable inputs and outputs of each decision-making unit (DMU) into a scalar measure of operational efficiency, relative to its competing DMUs. Herein, DMUs refer to the collection of private firms, non-profit organizations, departments, administrative units, and groups with the same (or similar) goals, functions, standards and market segments. DEA is designed to identify the best practice DMU without a priori knowledge of which inputs and outputs are most important in determining an efficiency measure (i.e. score) and assessing the extent of inefficiency for all other DMUs that are not regarded as best practice DMUs (Charnes *et al.*, 1978).

Since DEA provides a relative measure, it will only differentiate the least efficient DMU from the set of all DMUs. Thus, the best practice (most efficient) DMU is rated as an efficiency score of one, whereas all other less efficient DMUs are scored somewhere between zero and one. To summarize, DEA determines the following (Sherman and Ladino, 1995):

- the best practice DMU that uses the least resources to provide its products or services at or above the quality standard of other DMUs;
- the less-efficient DMUs compared to the best practice DMU;
- the amount of excess resources used by each of the less efficient DMUs; and
- the amount of excess capacity or ability to increase outputs for less-efficient DMUs without requiring additional resources.

In measuring the operational efficiency of Chinese 3PLs, we chose DEA over other alternative techniques, such as Cobb Douglas functions and analytic hierarchy process, because DEA reflects the multiple aspects of organizational performances, does not require a priori weights of performance measures, and provides valuable insights as to how operational efficiency can be improved. The next section specifies the DEA input and output measures. The discussions on DEA input and output measures are then followed by a section that exhibits how the DEA model is mathematically expressed and how it works. The section also presents the experimental results of the DEA model. The last section concludes with a summary of research findings and their managerial implications.

Literature review

Reflecting the increasing popularity of logistics outsourcing and a subsequent growth of 3PL services, an extensive body of the literature has developed relating to 3PL trends, extent of 3PL usage, 3PL benefits, and 3PL selection criteria. In general, 3PL refers to a for-hire, independent service provider performing all or part of logistics activities for the buyer, the seller, and the manufacturer of raw materials, parts/components, goods in process, or finished products without taking the title of those goods (Menon *et al.*, 1998; Maltz and Ellram, 2000). Sheffi (1990) is one of the first to conceptualize 3PL services and project the emergence of the 3PL industry. Lieb and Randall (1992) started their landmark study by examining the extent to which US manufacturers used 3PL services; the specific areas of 3PL services that were frequently used; and the managerial benefits accrued from the use of 3PL services. This study was continued and extended by Lieb and Randall (1996, 1999), Sink *et al.* (1996), Lieb and Kopczak (1997), Murphy and Poist (1998), Lieb and Miller (2002), Lieb and Kendrick (2002, 2003) and Lieb and Bentz (2004, 2005), who examined the extent of 3PL usage, 3PL market trends, and the prospects of the 3PL industry from the perspectives of 3PL chief executive officers and users for the last decade. More recently, Knemeyer and Murphy (2005) and Sahay and Mohan (2006) investigated the impact of 3PL relationships on 3PL selection, contractual arrangements, and extent of its usage. These studies, however, primarily focused on the 3PL industry in the USA and did not recognize the emergence of the 3PL industry in foreign markets. To overcome such a drawback, Lieb *et al.* (1993) conducted an empirical analysis to compare the status of the US 3PL industry to that of the European industry. Lieb and Kopczak (1997) also examined how US 3PLs established their foothold in the European market. To better understand the dynamics of emerging 3PL markets in a particular foreign country, Dapiran *et al.* (1996) investigated the extent of 3PL usage in Australia. Similarly, Bhatnagar *et al.* (1999) zeroed in on 3PL opportunities in Singapore, while Sohail *et al.* (2004) looked into the burgeoning sub-Saharan African market that was often overlooked by many 3PLs. More recently, Jaarfar and Rafiq (2005) studied the prevalent practices and trends of the 3PL industry in the UK. Despite numerous merits, none of the prior studies developed a benchmark of 3PL performance standards which is critical to sustaining the growth of the 3PL industry on a global scale. Although, Min and Joo (2006) recently attempted to measure the performance of selected 3PLs and then develop a benchmark standard, their study was limited to US-based 3PLs in the US domestic market.

To fill a significant void in the 3PL knowledge base, this paper intends to develop a 3PL performance benchmark and specific guidelines for continuous improvement in 3PL services within the burgeoning Chinese market. To accomplish this, we propose a DEA which was successfully explored in measuring the comparative efficiency of logistics entities/organizations such as airlines (Schefczyk, 1993), less-than-truckload motor carriers (Poli and Scheraga, 2000), international ports (Tongzon, 2001), trucking firms (Min and Joo, 2003), reverse logistics channels involving municipal solid wastes (Haas *et al.*, 2003), international airlines (Scheraga 2004a, b), and international container terminals (Min and Park, 2005). For an extensive list of other DEA applications, the interested readers should refer to Seiford (1990) and Gabriel (2001).

With the exception of Scheraga (2004a) and Min and Park (2005), a vast majority of DEA studies have failed to identify endogenous and exogenous factors that significantly affect the operational efficiency of logistics organizations. To look beyond these earlier studies, we conduct multiple regression analyses that allow 3PLs to identify the underlying causes of their operational efficiency and/or inefficiency relative to the leading competitors in the Chinese market.

DEA model design and experiments

Derivation of input and output measures

The assessment of operational efficiency using DEA begins with the selection of appropriate input and output measures that can be aggregated into a composite index of overall performance standards. Although any resources used by DMU should be included as input, we selected four different metrics as inputs that represent physical resources and financial values: net fixed assets including properties and equipment (e.g. warehouses, terminals, trucks, airplanes, trailers, containers, and computers), salaries and wages (including fringe benefits) of employees, operating expenses other than salaries and wages, and current liabilities such as accounts payable. Since, 3PLs (especially asset-based 3PLs) often sell their services by lending their assets to the client, net fixed assets can be a key resource for increasing sales and subsequent revenue. Thus, net fixed assets reflect an efficiency of asset management and should be chosen as one of the inputs. Owing to the labor-intensive nature of the logistics industry, typical 3PLs hire a large group of personnel comprised of managers, drivers, order pickers, cargo handlers, fork-lift operators, pilots, among others, on either a part-time or full-time basis. Thus, their payroll represents one of the major costs of doing business. In other words, since salaries and wages reflect the efficiency of direct investment in human resources, they were regarded as input. Operating expenses (excluding personnel costs) include numerous variable costs, such as fuel, oil, lubricants, vehicle parts, tires, tubes, licensing fees (including software), utilities, taxes, insurance premiums, and document processing fees all of which comprise of another key resource for sustaining uninterrupted logistics operations. Thus, operating expenses were included as input. Since, 3PLs often use current liabilities as a major source of financing their current assets which need to be built up to serve clients, current liabilities often reflect the financial health of 3PLs and consequently should be considered an input.

In regards to the output side, the overall performance of 3PLs can be measured by operating income which best reflects the operational efficiency of 3PLs. To elaborate, operating income is the amount of profit realized from a company's own operations, but excluding operating expenses (such as cost of goods sold) and depreciation from gross income. Operating income is required to calculate operating margin, which describes a company's operating efficiency (Investopedia, 2007). Thus, operating income is useful for comparing the quality of a company's operations to its competitors (About.com, 2007). Other well-known financial ratios such as revenue, profit margin, and return-on investment (ROI) are not considered relevant. Revenue is not a good surrogate measure for evaluating 3PL's operating efficiency, since it reflects the 3PL's earnings quality but can be inflated by its scale and high prices. Profit margin is excluded from output, since a less profitable firm may be more efficient in utilizing its assets than a more profitable firm. For example, a favorable change in fuel prices, insurance premiums, and tax rates can increase profitability, but not necessarily the operational efficiency (e.g. equipment utilization or labor productivity) of a 3PL. In fact, Sherman (1984) observed that profit measure was not a good indicator of how efficiently resources are used to provide customer service such as logistics services. ROI is useful for measuring the efficiency of investment, but not necessarily the company's operating efficiency. Considering such shortcomings of other financial ratios, we chose operating income as the key output.

Specification of the DEA model

Depending on the production possibilities and characteristics of input/output data sets, we can consider several different types of DEA models: the Charnes, Cooper and Rhodes (CCR) model; the Banker, Charnes and Cooper (BCC) model; the free disposal hull model (see, e.g. Cooper *et al.*, 2000 for details of differences in these DEA models). Among these, we adopted both the CCR model and the BCC model that were designed to derive weights without being fixed in advance and handle positive inputs/outputs. The CCR model differs from the BCC model in that the former considers constant returns to scale of activities, whereas the BCC model considers variable returns to scale of activities and thus mitigates the impact of economies of scale on the operational efficiency. The basic version of the DEA model is mathematically expressed as:

$$\text{Maximize efficiency score } (jp) = \frac{\sum_{r=1}^{t} u_r y_{rjp}}{\sum_{i=1}^{m} v_i x_{ijp}} \tag{1}$$

$$\text{Subject to } \frac{\sum_{r=1}^{t} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \quad j = 1, \ldots, n, \tag{2}$$

$$u_r, v_i \geq \varepsilon, \quad \forall r \text{ and } i, \tag{3}$$

where, y_{rj} – amount of output r produced by DMU j, x_{ij} – amount of input i used by DMU j, u_r – the weight given to output r, v_i – the weight given to input i, n – the number of DMUs, t – the number of outputs, m – the number of inputs, ε – a small positive number.

To ease computational complexity associated with the fractional nonlinear form of the above equations, equations (1)-(3) can be converted into a linear program as follows:

$$\text{Maximize efficiency score } (jp) = \sum_{r=1}^{t} u_r y_{rjp}, \tag{4}$$

$$\text{Subject to } \sum_{i=1}^{m} v_i x_{ijp} = a, \tag{5}$$

$$\sum_{r=1}^{t} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \quad j = 1, \ldots, n, \tag{6}$$

$$-u_r \leq -\varepsilon, \quad r = 1, \ldots, t, \tag{7}$$

$$-v_i \leq -\varepsilon, \quad i = 1, \ldots, m, \tag{8}$$

where a – an arbitrarily set constant (e.g. 100).

By solving the above equations (4)-(8), the efficiency of DMU (jp) is maximized subject to the efficiencies of all DMUs in the set with an upper bound of 1. The above model is solved n times to evaluate the relative efficiency of each DMU. Notice that the weights u_r and v_i are treated as unknown variables whose values will be optimally determined by maximizing the efficiency of the targeted DMU jp. An efficiency score (jp) of 1 indicates that the DMU under consideration is efficient relative to other DMUs, while an efficiency score of less than one indicates the DMU under consideration is inefficient. In a broader sense, an efficiency score represents the Chinese 3PL's ability to transform a set of inputs (given resources) into a set of outputs. The above model also identifies a peer group (efficient DMU with the same weights) for the inefficient DMU (Boussofiane *et al.*, 1991).

A complete DEA analysis focusing on output maximization with constant returns to scale was conducted by applying a linear program formulated in equations (4)-(8) to actual data gathered from a sample of ten Chinese 3PLs with five consecutive years of performance measures. All of the selected 3PLs have been listed in the Shanghai and Shenzhen stock market. These 3PLs were targeted for evaluation because they were state-owned enterprise (SOE) logistics firms that were likely to suffer from bureaucratic inefficiencies. Indeed, Wang (2006) observed that the operational and managerial efficiency of SOE logistics firms was low compared to privately-owned domestic firms. By reviewing core competencies and specialties, the ten 3PLs were classified into one of three categories: port management (e.g. customs brokerage, import/export documentation), transportation services (e.g. freight payment, shipment consolidation, freight forwarding, carrier selection, and rate negotiation), and warehousing services (order fulfillment, inventory control) as summarized in Table I (see, e.g. Wang, 2006 for a national standard system for logistics firms in China developed by the State

Standardization Committee). Herein, it can also be assured that the minimum number of DMUs is at least twice the total number of inputs and outputs in the proposed DEA model. Otherwise, the results of the DEA model would produce too many efficient DMUs with an efficiency score of 1 and create over-fit problems (Drake and Howcraft, 1994).

DEA scores for Chinese 3PLs

By using the spreadsheet and Frontier Analyst (1998) software, we initially obtained the DEA scores with constant returns to scale for the selected 3PLs, as summarized in Table II. However, the DEA scores on the assumption of constant returns to scale activities may reflect scale efficiency and thus cannot measure pure technical efficiency (Banker *et al.*, 1984). Considering this shortcoming of the CCR model that was designed to estimate both technical efficiency and scale efficiency together, we also employed the BCC model to calculate the pure technical efficiency under the assumption of variable returns to scale. The DEA-BCC scores obtained from the DEA Solver PRO 6.0 (2007) are summarized in Table II. Although, there are some discrepancies between the DEA-CCR and the DEA-BCC scores, the *t*-test (t-value $= 8.004$) of those two efficiency scores revealed that efficiency scores measured by CCR and BCC models were not significantly different at $\alpha = 0.01$ (t-value $= 8.004$, p-value < 0.01). A Pearson correlation coefficient between efficiency scores derived from DEA-CCR and DEA-BCC analyses was 0.573 (p-value < 0.01) that indicated that those two efficiency scores have a somewhat strong positive relationship.

The results indicate that the operational efficiency of the entire 3PL sector declined for the first three years (2000-2002) of the evaluation period, although it rebounded in 2003 and 2004. In particular, the rate of decline in DEA scores for transportation service-oriented 3PLs was dramatic. The transportation service-oriented 3PLs were hit hard by the outbreak of "SARS" viruses which limited transportation activities and led to an underutilization of transportation equipment. In addition, with rising fuel costs, the transportation cost in China rose gradually during the last several years (Wang, 2006). Regardless, it is intriguing to note that the overall DEA score for the transportation service-oriented 3PLs was the highest compared to other 3PL sectors, although there was a wide gap in DEA scores between good performers (e.g. overseas Fa-Zhan Logistics and Ningbo Ocean Shipping Logistics) and poor performers (Tie-Long Logistics and China Ocean Hai-Sheng Logistics). A similar pattern can be found among the port management-oriented 3PLs as evidenced by a wide gap in DEA

Table I.
The categories of the selected 3PLs

Category	3PLs
Port management	Shenzhen Chi-Wan Port Logistics (P1)
	Yantian Port Logistics (P2)
	Shanghai Container Port Logistics (P3)
	Jinzhoy Port Logistics (P4)
	Tianjin Port Logistics (P5)
Transportation services	Tie-Long Logistics (T1)
	Overseas Fa-Zhan Logistics (T2)
	Ningbo Ocean Shipping Logistics (T3)
	China Ocean Hai-Sheng Logistics (T4)
Warehousing services	China Inventory and Shipping Ltd (W1)

3PL	Year	Efficiency DEA-CCR	DEA-BCC	Scale efficiency
Shenzhen Chi-Wan Port Logistics (P1)	2000	0.149	0.349	0.427
	2001	0.141	0.325	0.434
	2002	0.236	0.360	0.656
	2003	0.360	0.430	0.837
	2004	0.444	0.468	0.949
Yantian Port Logistics (P2)	2000	0.297	0.647	0.460
	2001	0.936	1.000	0.936
	2002	0.987	1.000	0.987
	2003	1.000	1.000	1.000
	2004	1.000	1.000	1.000
Shanghai Container Port Logistics (P3)	2000	0.450	0.493	0.913
	2001	0.374	0.375	0.997
	2002	0.300	0.316	0.949
	2003	0.292	0.951	0.307
	2004	0.281	1.000	0.281
Jinzhoy Port Logistics (P4)	2000	0.302	0.660	0.458
	2001	0.143	0.567	0.252
	2002	0.000	0.367	0.000
	2003	0.171	0.452	0.378
	2004	0.259	0.483	0.536
Tianjin Port Logistics (P5)	2000	0.271	0.420	0.645
	2001	0.248	0.355	0.699
	2002	0.218	0.281	0.776
	2003	0.205	0.280	0.732
	2004	0.119	0.140	0.850
Tie-Long Logistics (T1)	2000	0.597	1.000	0.597
	2001	0.210	0.797	0.263
	2002	0.224	0.805	0.278
	2003	0.220	0.640	0.344
	2004	0.278	0.639	0.435
Overseas Fa-Zhan Logistics (T2)	2000	1.000	1.000	1.000
	2001	0.953	0.962	0.991
	2002	0.626	0.656	0.954
	2003	0.719	0.828	0.868
	2004	0.654	0.785	0.833
Ningbo Ocean Shipping Logistics (T3)	2000	0.704	1.000	0.704
	2001	1.000	1.000	1.000
	2002	0.612	0.781	0.784
	2003	0.327	0.537	0.609
	2004	0.270	0.522	0.517
China Ocean Hai-Sheng Logistics (T4)	2000	0.302	1.000	0.302
	2001	0.175	0.785	0.223
	2002	0.201	0.785	0.256
	2003	0.192	0.819	0.234
	2004	0.149	0.917	0.162
China Inventory and Shipping Ltd (W1)	2000	0.304	1.000	0.304
	2001	0.201	0.946	0.212
	2002	0.165	0.908	0.182
	2003	0.116	0.607	0.191
	2004	0.144	0.522	0.276

Note: DEA-CCR represents a technical efficiency score and DEA-BCC represents a pure technical efficiency score

Table II. DEA scores for the Chinese 3PLs scores between Yantian Port Logistics and Shenzhen Chi-Wan Port Logistics. Thus, we may conclude that the operational efficiency of 3PLs in China was influenced by the management styles and business strategies of individual 3PLs rather than the particular industry practices and settings.

Based on the above observations, we may categorize Chinese 3PLs as four distinctive types that were described below:

(1) *Stable 3PL*. A 3PL such as Yantian Port Logistics sustained the same level of operational efficiency throughout the evaluation period. These 3PLs can be considered benchmarks or best-practice 3PLs.

(2) *Gradually-rising 3PL*. A 3PL such as Shenzhen Chi-Wan Port Logistics which managed to enhance its operational efficiency one year after another, although its inputs were substantially underutilized. In particular, the average underutilization rate of salaries and wages were 77.09 percent (Table III). This implies that their human resources are either poorly managed or overpaid.

(3) *Instable 3PLs*. The 3PLs whose performances fluctuated widely from year to year. This type of 3PL includes Shanghai Container Port Logistics, Jinzhoy Port Logistics, Tie-Long Logistics, Overseas Fa-Zhan Logistics, and China Ocean Hai-Sheng Logistics.

(4) *Gradually-declining 3PLs*. A 3PLs such as Tianjin Port Logistics, Ningbo Ocean Shipping Logistics, and China Inventory and Shipping Ltd, that struggled to reach their potentials and continue to suffer from a declining efficiency. These 3PLs are considered non-performers whose future could be in great jeopardy, unless they find a way to improve their operational efficiency and become more competitive. In particular, these 3PLs seemed to lose grip of human resource and financial management as evidenced by the substantial underutilization of salaries, wages and current liabilities (Table III).

Sources of efficiency or inefficiency

Once the level of operational efficiency of each 3PL was revealed, it was then necessary to identify a set of factors (endogenous and exogenous variables) that have a significant impact on the operational efficiency of 3PLs. The identification of these factors would allow 3PLs to clarify the root causes of their inefficiencies and eventually help them improve their operational efficiency. With this in mind, we regressed 3PLs' DEA scores against four potential factors: investment in fixed assets; sales revenue as a percentage of total revenues; personnel cost reflecting investment in human resources; the level of technical expertise as a percentage of employees with extensive logistics training and experiences which may dictate a 3PL's success in capturing the market share and serving clients. To elaborate, investment in fixed assets was considered for its impact on the operational efficiency of Chinese 3PLs given that all the 3PLs considered in this study were asset-based 3PLs. Sales revenue was factored into the operational efficiency of Chinese 3PLs, since we would like to examine whether growing 3PL sales opportunities in the emerging Chinese 3PL market helped the 3PLs streamline their service offerings and contributed to their operational efficiency. Personnel cost was taken into consideration for its effect on the operational efficiency of Chinese 3PLs, since it could be used as a surrogate measure for assessing the labor productivity of Chinese 3PLs and its subsequent impact on operational efficiency.

Table III. Potential improvement for the DEA-BCC model

3PL/year	Input variables Net fixed asset	Salaries and wages	Operating expenses	Current liabilities	Output variables Operating income
Shenzhen (P1) 2000	−65.11	−81.05	−74.52	−65.11	0
P1 2001	−69.43	−85.40	−79.91	−67.55	0
P1 2002	−63.96	−79.25	−72.68	−63.96	0
P1 2003	−56.99	−72.30	−61.99	−56.99	0
P1 2004	−56.81	−67.43	−53.20	−53.20	0
Yantian (P2) 2000	−56.42	−58.96	−63.52	−35.30	0
P2 2001	0	0	0	0	0
P2 2002	0	0	0	0	0
P3 2003	0	0	0	0	0
P4 2004	0	0	0	0	0
Shanghai (P3) 2000	−50.69	−77.75	−72.84	−50.69	0
P3 2001	−72.04	−78.47	−71.05	−62.48	0
P3 2002	−75.51	−78.84	−69.87	−68.45	0
P3 2003	−4.85	−32.35	−23.66	−16.03	0
P4 2004	0	0	0	0	0
Jinjhoy (P4) 2000	−63.66	−40.22	−65.73	−33.96	0
P4 2001	−74.69	−43.30	−75.03	−46.14	66.30
P4 2002	−75.01	−65.68	−74.63	−63.28	999.90
P4 2003	−77.34	−79.23	−74.63	−63.28	8.55
P4 2004	−75.08	−71.87	−65.44	−51.70	0
Tianjin (P5) 2000	−57.97	−83.03	−82.61	−57.97	0
P5 2001	−64.48	−84.89	−81.54	−64.48	0
P5 2002	−71.86	−88.14	−86.01	−71.86	0
P5 2003	−71.97	−86.27	−83.58	−71.97	0
P5 2004	−85.98	−89.13	−86.17	−85.98	0
Tie-Long (T1) 2000	0	0	0	0	0
T1 2001	−20.25	−27.31	−70.09	−20.25	20.82
T1 2002	−19.46	−37.60	−40.73	−19.46	13.24
T1 2003	−35.97	−40.24	−35.97	−35.97	0
T1 2004	−36.08	−36.08	−36.08	−36.08	0

(*continued*)

Table III.

3PL/year	Input variables				Output variables
	Net fixed asset	Salaries and wages	Operating expenses	Current liabilities	Operating income
Overseas (T2) 2000	0	0	0	0	0
T2 2001	−3.82	−27.36	−23.40	−6.36	0
T2 2002	−34.43	−52.69	−51.99	−43.80	0
T2 2003	−17.22	−62.28	−54.55	−72.03	0
T2 2004	−21.54	−70.41	−67.11	−80.91	0
Ningbo (T3) 2000	0	0	0	0	0
T3 2001	0	0	0	0	0
T3 2002	−30.26	−44.86	−21.88	−21.88	0
T3 2003	−46.28	−46.28	−46.28	−46.28	0.32
T3 2004	−47.79	−48.95	−47.79	−68.67	0
China Ocean (T4) 2000	0	0	0	0	0
T4 2001	−21.47	−21.47	−21.47	−35.00	42.71
T4 2002	−21.46	−34.43	−21.46	−50.54	39.32
T4 2003	−18.13	−30.34	−18.13	−50.71	49.14
T4 2004	−8.28	−33.65	−8.28	−56.31	114.70
China Inv (W1) 2000	0	0	0	0	0
W1 2001	−5.44	−5.44	−8.68	−41.08	72.32
W1 2002	−9.20	−9.20	−16.51	−64.41	78.18
W1 2003	−39.27	−55.38	−33.27	−83.35	56.03
W1 2004	−47.81	−61.90	−47.81	−91.86	16.50

Notes: Negative values of input variables show underutilization of resources and zero indicates full utilization. Absolute values of output variables show the extent of potential improvement in outputs and zero indicates no room for potential improvement

Finally, since the 3PL industry has gradually evolved into the "knowledge management" industry as evidenced by the recent service offerings based on advanced technology such as warehouse management systems and radio frequency identification, we would like to investigate how significantly the level of technical expertise influences the operational efficiency of Chinese 3PLs.

Identification of factors impacting 3PL performances

In an effort to find the causal relationship between the aforementioned factors and 3PL performances, we conducted a step-wise multiple regression analysis that is mathematically expressed as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \mu \quad (9)$$

where Y stands for the predicted score for the dependent variable, the 3PL's operational efficiency, β_0 stands for the constant, β_1, β_2, β_3, β_4 are regression coefficients, X_1, X_2, X_3, X_4 represent independent variables (investment in fixed assets, sales revenue, personnel cost, the level of technical expertise), and μ are errors under the assumption that the estimated coefficients are asymptotically normally distributed and the errors are normally distributed.

To check and see if there exists multicollinearity among four independent variables, we measured tolerance and the variance inflation factor (VIF) for those four variables using *SPSS Base 15.0 User's* Guide (2007) statistical software. The tolerances for X_1, X_2, X_3, X_4 are 0.760, 0.637, 0.630, and 0.513, respectively. VIFs for X_1, X_2, X_3, X_4 are 1.315, 1.570, 1.587, and 1.951, respectively. According to the VIF criteria suggested by Bowerman and O'Connell (1990), this regression model is relatively unbiased, since the average VIF of this regression model is very close to 1 ($\overline{\text{VIF}} = 1.60575$). That is to say, these collinearity diagnostics indicated that multicollinearity among the independent variables was not a serious cause for concerns for this multiple regression model. The results obtained from a step-wise regression procedure revealed that two factors (namely, sales revenue and the level of technical expertise) were strongly correlated with the 3PL's operational efficiency as evidenced by relatively high values of $R = 0.883$ and $R^2 = 0.780$, adjusted $R^2 = 0.754$ (Table IV). In other words, the operational efficiency of 3PLs in China was well explained by both 3PL's sales revenue and its level of technical expertise).

In addition, the F-test indicated that there is a significant relationship between the two factors and the 3PLs' operational efficiency (F-statistical value = 30.095, p-value = 0.00).

The results of the t-tests for regression coefficients showed that both sales revenue and the level of technical expertise significantly influenced a 3PL's operational efficiency at $\alpha = 0.05$, whereas both investment in fixed assets and personnel cost did not significantly affected a 3PL's operational efficiency (Table V). That is to say, although the firm size (or economies of scale) may not make the Chinese 3PL more

Table IV. R and R^2 values of the step-wise regression equation

Model	R	R^2	Adjusted R^2	Standard error of the estimate
1	0.883	0.780	0.754	0.137

efficient, the accumulated sales revenue provides the 3PLs with an opportunity to better utilize their resources and subsequently enhance their operational efficiency. Also, it appears that investment in knowledge management in terms of greater employee training opportunity and retention of logistics talents might have positively influenced the 3PL's operational efficiency. This finding makes sense since today's 3PLs have increased their roles as knowledge managers by giving them more responsibility which consists of integrating the entire spectrum of supply chain activities.

Concluding remarks and future research directions

In parallel, with rapid economic growth, the demand for 3PL services has skyrocketed in China. As the 3PL industry has begun to blossom, 3PLs in China proliferated rapidly and intensified their level of competition. Thus, 3PLs (either new market entrants or existing players) that cannot deal with the mounting pressures by failing to manage their resources efficiently, increase market shares, and enhance operational efficiencies, will be unlikely to survive in the increasingly competitive 3PL market. In an effort to help the Chinese 3PLs formulate winning strategies, this paper proposed DEA that was designed to analyze the operational efficiency of 3PLs, identify potential sources of inefficiency, and provide useful information (hindsight) for the continuous improvement of operational efficiency. This paper also summarizes several major findings of this benchmarking study and develops practical guidelines for improving the operational efficiency of Chinese 3PLs.

First, despite the promising outlook of the 3PL industry in China, seven out of ten investigated 3PLs experienced a declining operational efficiency during the period of 2001 and 2003 (Table II). This declining efficiency within some Chinese 3PLs coincides with a steep decline in domestic transportation activities due to the SARS outbreak and the slow adaptation of SOE into a more market-based economy. In particular, all but one transportation service-oriented 3PL registered a steep decline in their efficiency scores during the period of 2001-2003. Such a decline in efficiency may have stemmed from China's crippling transportation regulations, high underutilization of fixed assets, and relatively low-logistics outsourcing rates (16-18 percent) in the Chinese manufacturing sector. However, considering dramatic differences in efficiency scores among Chinese 3PLs in the same sector, the operational inefficiency of the 3PLs does not seem to be directly tied to any particular industry sector. For example, transportation service-oriented 3PLs, such as Overseas Fa-Zheng Logistics, sustained an impeccable record of efficiency throughout the investigation period. Thus, it is considered to be a 3PL benchmark, despite the fact that it is in the transportation sector.

A second finding is that the sales opportunity and the level of technical expertise are directly correlated with the operational efficiency of 3PLs, whereas the size of 3PLs has no direct bearing on the 3PL's performance. In particular, the 3PL success in China

Table V.
t-Test results on the regression coefficients

Factors	Standardized coefficients β	Std. error of the estimate	*t*-statistic value	*p*-value
2	0.316	0.196	2.236	0.039
4	1.032	0.378	7.314	0.000

seemed to depend upon the 3PL's ability to nurture and retain-talented logistics personnel. This finding is somewhat congruent with the recent observation made by Lieb (2005) that the 3PL success in the USA was tied to the recruitment and retention of talented logistics personnel. Given the newness of outsourcing and supply chain concepts to the Chinese logistics industry, building a critical mass of expertise in logistics and supply chain management would be a major challenge for the Chinese 3PLs. Perhaps, the short-term solution for searching for logistics talents is to partner with the foreign-based 3PLs by establishing joint ventures.

Lastly, in contrast with the 3PL industry in the USA, the Chinese 3PLs tend to focus on traditional service offerings such as port management, transportation, and warehousing rather than playing the role as the integrator or the lead service provider. This limited service offering may have negatively affected the Chinese 3PLs' sales and the subsequent revenue growth opportunities that, in turn, appear to have hindered their operational efficiency. Also, the limited service offering might have made the Chinese 3PLs more vulnerable to the downturn of particular industry sectors such as transportation services.

In conclusion, this paper differentiates among stable, instable, emerging, and fading groups of Chinese 3PLs on the basis of DEA efficiency scores. The DEA efficiency score gives management a warning signal that the lower the DEA score is, the greater the likelihood that a 3PL will fail. Thus, DEA is very useful for identifying the least efficient 3PLs which require the closest attention. Furthermore, provided that a growing number of 3PL users have begun to perceive 3PLs as their "resource providers," 3PLs should prove to their potential customers that their resource utilization in terms of DEA scores is comparatively higher than their competitors; thus, DEA becomes an important tool for selecting the right 3PL. However, the proposed DEA model can be extended to include multiple outputs (including non-financial measures such as service quality) and a greater number of the Chinese 3PLs including privately-owned and foreign-based 3PLs in China. In addition, in finding causal relationships between a set of variables and the 3PL operational efficiency, a Tobit regression technique proposed by Tobin (1958) can be used in lieu of a step-wise regression technique that was used in this study given that DEA efficiency scores are derived left-censured variables within an interval [0,1]. Pindyck and Rubinfeld (1991) and Schrega (2004b) argued that the use of ordinary least squares might yield biased and inconsistent parameter estimates, when dealing with left-censured variables.

References

About.com (2007), "Investing for beginners", available at: http://beginnersinvest.about.com/cs/investinglessons/l/bloperincmarg.htm

Armstrong, R. (2005), "Third-party logistics market analysis-2005", paper presented at the 28th Annual Warehousing Education and Research Council (WERC) Conference, Dallas, TX.

Banker, R.D., Charnes, A. and Cooper, W.W. (1984), "Some models for estimating technical and scale inefficiencies in data envelopment analysis", *Management Science*, Vol. 30, pp. 1078-92.

Bhatnagar, R., Sohal, A. and Millen, R.A. (1999), "Third party logistics services: a Singapore perspective", *International Journal of Physical Distribution & Logistics Management*, Vol. 29 No. 9, pp. 569-87.

Boussofiane, A., Dyson, R.G. and Thanassoulis, E. (1991), "Applied data envelopment analysis", *European Journal of Operational Research*, Vol. 52, pp. 1-15.

Bowerman, B.L. and O'Connell, R.T. (1990), *Linear Statistical Models: An Applied Approach*, 2nd ed., Duxbury, Belmont, CA.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978), "Measuring the efficiency of decision making units", *European Journal of Operational Research*, Vol. 2, pp. 429-44.

Cooper, W.W., Seiford, L.M. and Tone, K. (2000), *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software*, Kluwer Academic Publishers, Boston, MA.

Dapiran, P., Lieb, R.C., Millen, R. and Sohal, A. (1996), "Third party logistics services usage by large Australian firms", *International Journal of Physical Distribution and Logistics Management*, Vol. 26 No. 10, pp. 36-45.

DEA Pro Solver 6.0 (2007) DEA Pro Solver 6.0, Saitech, Inc., Holmdel, NJ.

Drake, L. and Howcroft, B. (1994), "Relative efficiency in the branch network of a UK bank: an empirical study", *Omega*, Vol. 22 No. 1, pp. 83-90.

Frontier Analyst (1998), *Efficiency Analysis Software User's Guide*, Banxia Software Ltd, Glasgow, professional edition.

Gabriel, T. (2001), "A bibliography of data envelopment analysis (1978-2001)", RUTCOR Research Report, Rutgers University, January.

Haas, D.A., Murphy, F.H. and Lancioni, R.A. (2003), "Managing reverse logistics channels with data envelopment analysis", *Transportation Journal*, Vol. 42 No. 3, pp. 59-69.

Investopedia (2007), available at: www.investopedia.com/terms/o/operatingincome.asp

Jaarfar, H.S. and Rafiq, M. (2005), "Logistics outsourcing practices in the UK: a survey", *International Journal of Logistics: Research and Applications*, Vol. 8 No. 4, pp. 299-312.

Knemeyer, A.M. and Murphy, P.R. (2005), "Exploring the potential impact of relationship characteristics and customer attributes on the outcomes of third-party logistics arrangements", *Transportation Journal*, Vol. 44 No. 1, pp. 5-19.

Langley, C.J. Jr, Allen, G.R. and Dale, T.A. (2004), "Third-party logistics study: results and findings of the 2004 ninth annual study", unpublished report sponsored by Capgemini Consulting, Georgia Tech and FedEx Supply Chain Services.

Lieb, R.C. (2005), "The 3PL industry: where it's been, where it's going", *Supply Chain Management Review*, Vol. 9 No. 6, pp. 20-7.

Lieb, R.C. and Bentz, B.A. (2004), "The use of third-party logistics services by large manufacturers: the 2003 survey", *Transportation Journal*, Vol. 43 No. 3, pp. 24-33.

Lieb, R.C. and Bentz, B.A. (2005), "The use of third-party logistics services by large manufacturers: the 2004 survey", *Transportation Journal*, Vol. 44 No. 2, pp. 5-15.

Lieb, R.C. and Kendrick, S. (2002), "The use of third party logistics services by large American manufacturers: the 2002 survey", *Supply Chain Forum: An International Journal*, Vol. 3 No. 2, pp. 2-10.

Lieb, R.C. and Kendrick, S. (2003), "The year 2002 survey: CEO perspectives on the current status and future prospects of the third-party logistics industry in the United States", *Transportation Journal*, Vol. 42 No. 3, pp. 5-16.

Lieb, R.C. and Kopczak, L. (1997), "A CEO perspective: the state of US logistics companies in Europe", *Supply Chain Management Review*, Vol. 1 No. 2, p. 34.

Lieb, R.C. and Miller, J. (2002), "The use of third-party logistics services by large American manufacturers, the 2000 survey", *International Journal of Logistics: Research and Applications*, Vol. 5 No. 1, pp. 1-12.

Lieb, R.C. and Randall, H.L. (1992), "The use of third-party logistics services by large American manufacturers", *Journal of Business Logistics*, Vol. 13 No. 2, pp. 29-42.

Lieb, R.C. and Randall, H.L. (1996), "A comparison of the use of third-party logistics services by large American manufacturers, 1991, 1994, and 1995", *Journal of Business Logistics*, Vol. 17 No. 1, pp. 305-20.

Lieb, R.C. and Randall, H.L. (1999), "1997 CEO perspectives on the current and future prospects of the 3PL industry in the US", *Transportation Journal*, Vol. 38 No. 3, pp. 28-41.

Lieb, R.C., Millen, R.A. and van Wassenhove, L.N. (1993), "Third party logistics services: a comparison of experienced American and European manufacturers", *International Journal of Physical Distribution & Logistics Management*, Vol. 23 No. 6, pp. 35-44.

Maltz, A.B. and Ellram, L.M. (2000), "Selling inbound logistics services: understanding the buyer's perspective", *Journal of Business Logistics*, Vol. 21 No. 2, pp. 69-88.

Menon, M.K., McGinnis, M.A. and Ackerman, K.B. (1998), "Selection criteria for providers of third-party logistics services: an exploratory study", *Journal of Business Logistics*, Vol. 19 No. 1, pp. 121-37.

Min, H. and Joo, S.J. (2003), "Benchmarking the operational efficiency of major US trucking firms using data envelopment analysis", *Journal of Transportation Management*, Vol. 14 No. 2, pp. 22-34.

Min, H. and Joo, S.J. (2006), "Benchmarking the operational efficiency of major third-party logistics providers using data envelopment analysis", *Supply Chain Management: An International Journal*, Vol. 11 No. 3, pp. 259-65.

Min, H. and Park, B-I. (2005), "Evaluating the inter-temporal efficiency trends of international container terminals using data envelopment analysis", *International Journal of Integrated Supply Management*, Vol. 1 No. 3, pp. 258-77.

Murphy, P.R. and Poist, R.E. (1998), "Third-party logistics usage: an assessment of propositions based on previous research", *Transportation Journal*, Vol. 27 No. 4, pp. 26-35.

Pindyck, R. and Rubinfeld, D. (1991), *Econometric Models and Economic Forecasts*, McGraw-Hill, Inc., New York, NY.

Poli, P.M. and Scheraga, C.A. (2000), "The relationship between the functional orientation of senior managers and service quality in LTL motor carriers", *Journal of Transportation Management*, Vol. 12 No. 2, pp. 17-31.

Rodrigues, A.M., Bowersox, D.J. and Calantone, R.J. (2005), "Estimation of global and national logistics expenditures: 2002 data update", *Journal of Business Logistics*, Vol. 26 No. 2, pp. 1-16.

Sahay, B.S. and Mohan, R. (2006), "Managing 3PL relationships", *International Journal of Integrated Supply Management*, Vol. 2 Nos 1/2, pp. 69-90.

Schefczyk, M. (1993), "Operational performance of airlines: an extension of traditional measurement paradigms", *Strategic Management Journal*, Vol. 14 No. 4, pp. 301-17.

Scherega, C.A. (2004a), "The relationship between operational efficiency and customer service: a global study of third-eight large international airlines", *Transportation Journal*, Vol. 43 No. 3, pp. 48-58.

Scherega, C.A. (2004b), "Operational efficiency versus financial mobility in the global airline industry: a data envelopment and tobit analysis", *Transportation Research Part A*, Vol. 38 No. 5, pp. 383-404.

Seiford, L.M. (1990), "A bibliography of data envelopment analysis (1978-1990)", unpublished working paper, Department of Industrial Engineering and Operations Research, University of Massachusetts, Amherst, MA.

Sheffi, Y. (1990), "Third party logistics: present and future prospects", *Journal of Business Logistics*, Vol. 11 No. 2, pp. 27-39.

Sherman, H.D. (1984), "Improving the productivity of service businesses", *Sloan Management Review*, Vol. 125, pp. 11-23.

Sherman, H.D. and Ladino, G. (1995), "Managing bank productivity using data envelopment analysis", *Interfaces*, Vol. 25 No. 2, pp. 60-73.

Sink, H.L., Langley, C.J. and Gibson, B.J. (1996), "Buyer observations of the US third-party logistics market", *International Journal of Physical Distribution & Logistics Management*, Vol. 26 No. 3, pp. 38-46.

Sohail, M.S., Austin, N.K. and Rushdi, M. (2004), "The use of third-party logistics services: evidence from a Sub-Sahara African nation", *International Journal of Logistics: Research and Applications*, Vol. 7 No. 1, pp. 45-57.

SPSS Base 15.0 User's Guide (2007), *SPSS Base 15.0 User's Guide*, SPSS Inc., Chicago, IL.

Tobin, J. (1958), "Estimation of relationships for limited dependent variables", *Econometrica*, Vol. 26, pp. 24-36.

Tongzon, J. (2001), "Efficiency measurement selected Australian and other international ports using data envelopment analysis", *Transportation Research A*, Vol. 35, pp. 115-28.

Trunick, P.A. (2005), "China's growing pains", *Logistics Today*, May, pp. 46-51.

Wang, C.G. (2006), "China: CSCMP global perspectives", unpublished Report, Council of Supply Chain Management Professionals, Oak Brook, IL.

Further reading

Thanassoulis, E. (1999), "Data envelopment analysis and its use in banking", *Interface*, Vol. 29 No. 3, pp. 1-13.

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