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Evaluation of Supply Chain Operations Using Slacks-based Measure of Efficiency

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Abstract

In recent years, Effective supply chain management have been widely accepted as an important means for manufacturing or other organizations, to provide the best high-quality products and services in at least cost. Therefore, we utilize the slacks-based measure (SBM) of efficiency approach to solve the supply chain performance evaluation problem, and this property is known such as "dimension free" and "units invariant." In this paper we introduce SBM model for supply chain performance evaluation by considering intermediate production, where show input excesses, output shortfalls and efficiency or inefficiency supply chain simultaneously. Finally, this approach is illustrated by a numerical example on Chinese commercial banks, and compared with SC-DEA-CRS model [9].

Keywords : Data envelopment analysis (DEA); Supply chain management (SCM); Slacks-based measure (SBM); Performance evaluation.

1 introduction

A supply chain, which is a set of facilities, supplies, customers, products and methods of controlling inventory, purchasing and distribution, links suppliers and customers, beginning with the production of raw material by a supplier and ending with the consumption of a product by the customer, and Supply Chain Management (SCM) is related to the coordination of materials, products and information flows among suppliers, manufacturers, distributors, retailers and customers [7]. The accurate, reliable assessment of individual system components or of the overall supply chain system remain critical prerequisites to managerial decision-making, especially in the face of higher customer expectations, shrinking profit margins and little brand loyalty [3]. Effective performance evaluation should improve managers' overall understanding of the process being evaluated (e.g. inputs/outputs), influence behaviors throughout the system, and provide useful information to system members. A supply chain is fully coordinated when all decisions are aligned to approach global system objectives.

Data envelopment analysis (DEA) provides another possibility to evaluate relative efficiencies among decision making units (DMUs). Efficiency is measured in a relative manner, meaning that

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efficiency of DMUs is subject to analysis in relation to each other. DEA is regarded as a powerful non-parametric, linear programming technique that enables the development of an output-to-input ratio system to handle multiple inputs and outputs and go beyond basic single ratio productivity measurements. It constructs an efficient frontier that represents the minimum resources necessary for a firm to achieve at a given level of output, or the maximum output expansion at a given level of input resource. It has been adopted as a good way of measuring performance efficiency in the supply Chain Management ([1, 2, 4, 5, 6]). The major reason for absence of performance measurement tools for supply chains lies on the fact that most attentions are paid to the trade off or cooperation among supply chain members, rather than the technical efficiency of the overall supply chain. Therefore in this paper, we will show approach for two-stage supply chain performance evaluation by using the slack based measure (SBM) proposed by Tone [8], where invariant to the units of measure used for the different inputs and outputs.
The organization of this paper is organized as follows:
Section 2 as develop our approach for two-stage chain. Section 3 presents a real world application where the proposd model is employed to performance evaluation of banking chains in Chinese bank. Finally, concluding remarks are outlined in section 4.

2 SBM model in supply chain

Consider a two-stage supply chain shown in Fig.1. Suppose we have N supply chains, where stage S represents the supplier and stage M represents the manufacturer, and each supply chain, SC_j, $(j = 1, 2, \ldots, N)$ has P inputs to the supplier, X_{pj}, $(p = 1, 2, \ldots, P)$, and K outputs from this supplier, I_{kj}, $(k = 1, 2, \ldots, K)$. Theseafter these K outputs become the inputs to the manufacturer, and are referred to as intermediate products. The outputs from the manufacturer are denoted Y_{qj}, $(q = 1, 2, \ldots, Q)$. For the convenience of discussion, all supply chains under research are of homogeneity. That is to say, all supply chains consume the same types of input bunches to produce the same type of output bunches via the same production process. The SBM model of the d^{th}, $(d = 1, 2, \ldots, N)$ suppliers (the supplier in the d^{th} supply chain) is computed by the following model:

$$
\begin{aligned}
(SBM_{supplier})\ \ min\ \ \rho_s = & \frac{1-\frac{1}{P}\sum\limits_{p=1}^{P} S_p^-/X_{pd}}{1+\frac{1}{K}\sum\limits_{k=1}^{K} S_k^+/I_{kd}} \\
s.t. \qquad & \sum_{j=1}^{N} \lambda_j^s X_{pj} + S_p^- = X_{pd} \qquad p = 1, ..., P \\
& \sum_{j=1}^{N} \lambda_j^s I_{kj} - S_k^+ = I_{kd} \qquad k = 1, ..., K \\
& \lambda_j^s \geq 0, \qquad S_p^- \geq 0, \qquad S_k^+ \geq 0, \qquad \forall j, p, k.
\end{aligned}
\tag{2.1}
$$

where S_p^-, $(p = 1, \ldots, P)$ and S_k^+, $(k = 1, \ldots, K)$ denote the input excesses and output shortfalls vectors, and λ_j^s, $(j = 1, \ldots, N)$ is nonnegative vector. The SBM model of the d^{th} manufacturer is computed as follows:

$$
\begin{aligned}
(SBM_{manufacturer})\ \ min\ \ \rho_m = & \frac{1-\frac{1}{K}\sum\limits_{k=1}^{K} S_k^-/I_{kd}}{1+\frac{1}{Q}\sum\limits_{q=1}^{Q} S_q^+/Y_{qd}} \\
s.t. \qquad & \sum_{j=1}^{N} \lambda_j^m I_{kj} + S_k^- = I_{kd} \qquad k = 1, ..., K
\end{aligned}
\tag{2.2}
$$

$$
\begin{aligned}
&\sum_{j=1}^{N} \lambda_j^m Y_{qj} - S_q^+ = Y_{qd} \qquad q = 1, ..., Q \\
&\lambda_j^m \geq 0, \qquad S_k^- \geq 0, \qquad S_q^+ \geq 0, \qquad \forall j, k, q.
\end{aligned}
$$

where S_k^-, $(k = 1, \dots, K)$ and S_q^+, $(q = 1, \dots, Q)$ denote the input excesses and output shortfalls vectors and λ_j^m is defined in (1). The overal efficiency of the d_{th} supply chain is computed by the following model:

$$
\begin{aligned}
(SBM_{supply\ chain}) \quad min \quad \rho_d = & \frac{1 - \frac{1}{P}\sum\limits_{p=1}^{P} S_p^- / X_{pd} - \frac{1}{K}\sum\limits_{k=1}^{K} S_k^{-^*} / I_{kd}}{1 + \frac{1}{Q}\sum\limits_{q=1}^{Q} S_q^+ / Y_{qd} + \frac{1}{K}\sum\limits_{k=1}^{K} S_k^{+^*} / I_{kd}} \\
s.t. \quad & \sum_{j=1}^{N} \lambda_j X_{pj} + S_p^- = X_{pd} \qquad p = 1, ..., P \qquad\qquad (2.3) \\
& \sum_{j=1}^{N} \lambda_j I_{kj} = I_{kd} \qquad\qquad k = 1, ..., K \\
& \sum_{j=1}^{N} \lambda_j Y_{qj} - S_q^+ = Y_{qd} \qquad q = 1, ..., Q \\
& \lambda_j \geq 0, \qquad S_p^- \geq 0, \qquad S_q^+ \geq 0, \qquad \forall j, p, k.
\end{aligned}
$$

where $S_k^{+^*}$ and $S_k^{-^*}$ are the optimal output-and input-slacks for (1) and (2), and also S_p^-, $(p = 1, \dots, P)$ and S_q^+, $(q = 1, \dots, Q)$ denote the input excesses and output shortfalls vectors for supply cahin.

3 Application

Table 1 exhibits data for 17 banks, that is a typical two-member supply chain process,(Yang et al. [9]). There are three inputs to the first stage such as Fixed Assets(FA), Employee (EM), Expenditure(EX), are consumed to generate outputs such as Credit(CR) and Interbank Loan(IL). In the second stage, the Credit(CR) and Interbank loan(IL) are used to generate two outputs : Loan(LO) and Profit(PR).

Table 1
Data of 17 bank branches

NO.	Bank Branch	FA (¥10^8)	EM (10^3)	EX (¥10^8)	CR (¥10^8)	IL (¥10^8)	LO (¥10^8)	PR (¥10^8)
SC1	Hefei	1.0168	1.221	1.2215	166.9755	8.3098	122.1954	3.7569
SC2	Bengbu	0.5915	0.611	0.4758	50.1164	1.7634	19.4829	0.6600
SC3	Huainan	0.7237	0.645	0.6061	48.2831	3.4098	34.4120	0.7713
SC4	Huaibei	0.5150	0.486	0.3763	35.0704	2.3480	15.2804	0.3203
SC5	Maanshan	0.4775	0.526	0.3848	49.9174	5.4613	34.9897	0.8430
SC6	Tongling	0.6125	0.407	0.3407	23.1052	1.2413	32.5778	0.4616
SC7	Wuhu	0.7911	0.708	0.4407	39.4590	1.1485	30.2331	0.6732
SC8	Anqing	1.2363	0.713	0.5547	37.4954	4.0825	20.6013	0.4864
SC9	Huangshan	0.4460	0.443	0.3419	20.9846	0.6897	8.6332	0.1288
SC10	Fuyang	1.2481	0.638	0.4574	45.0508	1.7237	9.2354	0.3019
SC11	Suzhou	0.7050	0.575	0.4036	38.1625	2.2492	12.0171	0.3138
SC12	Chuzhou	0.6446	0.432	0.4012	30.1676	2.3354	13.8130	0.3772
SC13	Luan	0.7239	0.510	0.3709	26.5391	1.3416	5.0961	0.1453
SC14	Xuancheng	0.5538	0.442	0.3555	22.2093	0.9886	13.6085	0.3614
SC15	Chizhou	0.3363	0.322	0.2334	16.1235	0.4889	5.9803	0.0928
SC16	Chaohu	0.6678	0.423	0.3471	22.1848	1.1767	9.2348	0.2002
SC17	Bozhou	0.3418	0.256	0.1594	13.4364	0.4064	2.5326	0.0057

SC : Supply Chain

Table 2 reports the overall efficiency scores of supply chains and efficiency scores of the supplier and manufacturer by using SBM model.

Table 2
SBM scores for Overall Efficiency and Subsystems Efficiency

NO.	Bank Branch	ρ_s^*	ρ_m^*	ρ_d^*	s_1^{-*}	s_2^{-*}	s_3^{-*}	s_1^{+*}	s_2^{+*}
SC1	Hefei	1.0000	1.0000	1.0000	0.00	0.00	0.00	0.00	0.00
SC2	Bengbu	0.4034	0.4921	0.4042	0.00	0.00	0.00	0.00	0.00
SC3	Huainan	0.5338	0.5453	0.2558	0.37	0.24	0.25	0.40	0.22
SC4	Huaibei	0.5391	0.3323	0.1816	0.27	0.20	0.12	10.07	0.41
SC5	Maanshan	1.0000	0.4668	0.7455	0.00	0.00	0.00	0.00	0.00
SC6	Tongling	0.3253	1.0000	0.6587	0.00	0.00	0.00	0.00	0.00
SC7	Wuhu	0.2458	1.0000	0.2901	0.00	0.00	0.00	0.00	0.00
SC8	Anqing	0.4540	0.3637	0.1549	0.88	0.32	0.27	5.69	0.15
SC9	Huangshan	0.2191	0.3943	0.0917	0.13	0.14	0.13	2.55	0.18
SC10	Fuyang	0.3193	0.2438	0.1336	0.62	0.04	0.03	24.60	0.58
SC11	Suzhou	0.4542	0.2767	0.1401	0.45	0.28	0.12	15.73	0.51
SC12	Chuzhou	0.4871	0.3622	0.1623	0.41	0.17	0.18	7.83	0.22
SC13	Luan	0.3056	0.1877	0.0597	0.56	0.31	0.18	14.31	0.45
SC14	Xuancheng	0.2689	0.6254	0.1029	0.37	0.24	0.18	0.00	0.07
SC15	Chizhou	0.2197	0.3811	0.1068	0.04	0.05	0.06	5.16	0.17
SC16	Chaohu	0.2967	0.3594	0.0904	0.53	0.26	0.18	6.96	0.29
SC17	Bozhou	0.2280	0.0443	0.0351	0.08	0.02	0.01	7.74	0.23

Table 3 reports the overall efficiency scores of supply chains and subsystems, where is obtained by Yang et al.[9].(Note that two approaches calculated under the CRS assumption.)

Table 3
Subsystems efficiency and Overall Efficiency values, Yang et al.[9] Results

NO.	Bank Branch	θ_s^*	θ_m^*	θ_d^{CCR}	θ_d^*
SC1	Hefei	1.0000	1.0000	1.0000	1.0000
SC2	Bengbu	0.7705	0.7057	0.4510	0.4510
SC3	Huainan	0.6318	0.7385	0.5676	0.4320
SC4	Huaibei	0.6923	0.4264	0.4059	0.2911
SC5	Maanshan	1.0000	0.7729	0.9090	0.7342
SC6	Tongling	0.4979	1.0000	0.9558	0.4979
SC7	Wuhu	0.6550	1.0000	0.6858	0.5177
SC8	Anqing	0.5526	0.5953	0.3713	0.2947
SC9	Huangshan	0.4490	0.4759	0.2524	0.1741
SC10	Fuyang	0.7205	0.3442	0.2146	0.2146
SC11	Suzhou	0.6974	0.3725	0.2976	0.2578
SC12	Chuzhou	0.6150	0.5633	0.3442	0.3100
SC13	Luan	0.5238	0.2454	0.1373	0.1285
SC14	Xuancheng	0.4570	0.7794	0.3827	0.3363
SC15	Chizhou	0.5054	0.4648	0.2561	0.1621
SC16	Chaohu	0.4689	0.4192	0.2660	0.1963
SC17	Bozhou	0.6166	0.2368	0.1588	0.0827

As expected, the SBM efficiency score of overall supply chains and each subsystem efficiency is less than the SC-DEA-CRS model efficiency score from Yang et al. [9]. Also our approach is no larger than the CCR efficiency of the entire banking process (Column 5 in Table 3). If the optimal solution slacks from (2.1), (2.2) and (2.3) for efficiency of the d^{th} supply chain is all of them equivalent 0, i.e., no input excess and no output shortfall, then the *supply chain*$_d$ is called SBM-efficient($\rho_d^* = 1$), otherwise it is SBM-inefficient.

4 conclusions

After proceeding with international management, enterprises have to face the challenge of SCM mainly because of the rapid change in the business environment and severe competition in market and customers' diverse demand.Therefore In this paper, we utilizing SBM approach for efficiency evaluation of supply chains and subsystem, and then compare by Yang et al. [9] approach. Future research subjects include: (a) Application to dynamic situation that deals with efficiency change over time. (b) Measurements of economies of vertical integration.

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