Performance evaluation of multi-supplier supply chains

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Abstract
In Supply Chain Management (SCM), strengthening partnerships with suppliers is a significant factor for enhancing competitiveness. Hence, firms emphasize on performance evaluation of suppliers. This paper propose a model for measuring the efficiency of multi- supplier and one manufacturer chains (SMCs) using network DEA. This model, also yield a set of intermediate products for suppliers that improve the efficiency of SMCs. The approaches are demonstrated with a numerical example.

Keywords
Data Envelopment Analysis (DEA), Supply Chain Management (SCM), Performance evaluation, supplier.

1 introduction

Supply chain management (SCM) is the combination of art and science that goes into improving the way your company finds the raw components it needs to make a product or service and deliver it to customers. Companies need a strategy for managing all the resources that go toward me-eting customer demand for their product or service. A big piece of SCM planning is developing a set of metrics to monitor the supply chain so that it is efficient, costs less and delivers high quality and value to customers. By the same discussion, SCM a systems approach to viewing the supply chain as a whole, and to managing the total flow of goods inventory from the supplier to the ultimate customer. Note also that within our definition of supply chain, the final consumer is considered a member of the supply chain. This point is important because it recognizes that retailers such as Wal-Mart can be part of the upstream and downstream flows that constitute a supply chain. (Another definition notes a supply chain is the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer (Christopher 1992)).

Companies must choose suppliers to deliver the goods and services they need to create their product. Therefore, supply chain managers must develop a set of pricing, delivery and payment processes with suppliers and create metrics for monitoring and improving the relationships. And then, SCM managers can put together processes for managing their goods and services inventory, including receiving and verifying shipments, transferring them to the manufacturing facilities and authorizing supplier payments. Supply chain managers schedule the activities necessary for production, testing, packaging and preparation for delivery. This is the most metric-intensive portion of the supply chain one where companies are able to measure quality levels, production output and worker productivity.

Data envelopment analysis (DEA) has been used powerful method to measure efficiencies of decision making units (DMUs). The aim of DEA is to compare the operating performance of a set of units such as companies, university departments, hospitals, bank branch offices, production plants or transportation systems. In order for the comparison to be meaningful, the units being investigated must be homogeneous. A lot of DEA-based approaches can be used to estimate the performance of supply chains. In the DEA studies, many authors have tried to identify the true managerial efficiency afteraccounting for the operational environment effects. Also DEA has been applied to gauge the supply chain performance in several works such as, Golany et al.(2006), Ling et al.(2006) and Jahanshahloo et al.(2006), where evaluation of supply chain efficiency, using DEA, has its advantage.

Since, the effectivenss of relationships is considered to be essential for the success of SCM, without providing a successful collaboration with suppliers and manufacturers, the corporation success cannot be achieved. Also for both of local and global business area, evaluation of the suppliers that is based on their success on efficient firms has become crucial for long term success. Therefore, in this paper, we propose a network DEA approach for performance evaluation of multi supplier and one manufacturer chain (SMC). This model also determines a set of new intermediate products that improves the efficiency of SMCs. Evaluation in multi supplier and one manufacturer chain (SMC). Section 2, introduce our model and in section 3 we have provided a numerical example. Conclusions are given in section 4.

2 Formulation for performance evaluation of SMCs

Supplier Performance Management is a complete supplier management solution that helps companies achieve greater visibility and actionable insight across their supply base and allows them to implement proactive management strategies to maximize supplier collaboration and mitigate supplier risk. Supported by four key components, Supplier Monitoring, Supplier Self-Assessment, Supplier Development and Collaboration, Emptoris Supplier Performance Management delivers an extensive combination of products and services enabling companies to increase the performance and value of their suppliers. Also, the main aim of supply chain management is to integrate various suppliers to satisfy market demand. Measuring and proactively developing the performance of suppliers is crucial to ensuring a well-functioning supply chain. So that, supplier selection and evaluation plays an important role in establishing an effective supply chain. Therefore, in this section we describe multi supplier chain performance evaluation model using Network DEA that includes intermediate products between the subunits of DMUs. Each DMU refer to a supplier-manufacturer chain and suppliers and manufacture are the subunits of DMUs.

The intermediate products between these subunits are the outputs of suppliers that used by manufacturer to produce final outputs of chain. We propose a formulation under the assumption that all supplier-manufacturer chains have exactly the same internal structure.

Suppliers in a chain consume different inputs and produce different outputs.

In this model we consider intermediate products as variables in order to improve the overall efficiency of SMCs, i.e., provide the complete information on how to project inefficient SMCs on to the DEA frontier and improve inefficient SMCs.

2.1 Method

Suppose SMC_j , (j=1,...,n), are n homogeneous SMCs that includes m-1 suppliers.

The following notation is introduced, Fig (1):

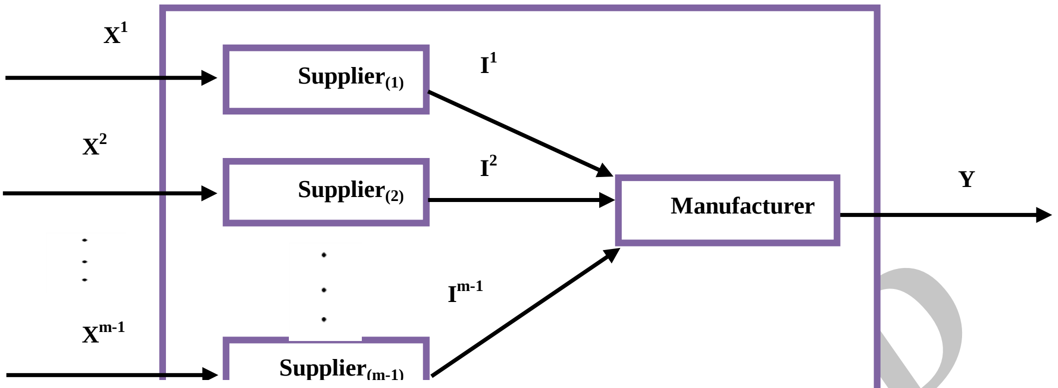

Fig 1. supplier-manufacturer chain

- $z^t_{u_t j}$ is the amount of u-th output of supplier t of SMC_j and y_{qj} is the q-th output of manufacturer of SMC_j . (u_t=1,...,U_t).

For SCM_o belonging to a set of n homogeneous and independent SMCs with m-1 suppliers and one manufacturer, input-oriented version of the envelopment and constant return to scale, the model can be written as follows:

- w_t are the weights that can be evaluated in the model or given by the manager.

Here we compute the weights in the model.

- λ^t_j is the multiplier of supplier t belonging to SMC_j and μ_j is the multiplier of manufacturer of SMC_j .
- $x^t_{i_t j}$ is the amount of i-th input of supplier t of SMC_j, (i_t=1,...,l_t).

$$\theta_o = min \sum_{t=1}^{m-1} w_t \theta^t$$

s.t. $\sum_{j=1}^{n} \lambda_j^t x_{i_t j}^t \leq \theta^t x_{i_t o}^t \quad t = 1, \dots, m-1, \quad i_t = 1, \dots, I_t$ (1)

$\sum_{j=1}^{n} \lambda_j^t z_{u_t j}^t \geq z_{u_t o}^t \quad t = 1, \dots, m-1, \quad u_t = 1, \dots, U_t$ (2)

$\sum_{j=1}^{n} \mu_j z_{u_t j}^t \leq z_{u_t o}^t \quad t = 1, \dots, m-1, \quad u_t = 1, \dots, U_t$ (3)

$\sum_{j=1}^{n} \mu_j y_{qj} \geq y_{qo} \quad q = 1, \dots, Q$ (4)

$\sum_{t=1}^{m-1} w_t = 1$ (5)

$z_{u_t o}^t \geq 0 \quad t = 1, \dots, m-1, \quad u_t = 1, \dots, U_t$ (6)

$\lambda_j^t \geq 0, \mu_j \geq 0 \quad j = 1, \dots, n$ (7)

This model evaluate the efficiency of SCM_o and compares SCM_o with all other SMCs. Constraints 1 is input constraints for suppliers and constraints 2 and 3 are the intermediate product constraints. $z^t_{u_t o}$ considered as variables in order to improve the efficiency scores of SMCs. SCM_o is: (1) weakly efficient if and only if there exists at least one of its suppliers and manufacturer which is weakly efficient relative to the corresponding suppliers and manufacturer of other SMCs. (2) efficient if and only if each of its suppliers and manufacturer is efficient relative to the corresponding suppliers and manufacturer of other SMCs. If the weights were given by the manager, constraint(5) will be eliminated and the problem turns to linner form.

Due to the existence of intermegiate products, the usual procedure of adjusting the inputs or outputs by the efficiency scores, as in the standard DEA approach, does not necessarily yield a frontier projection. Therefore, this approach for determining the frontier points for inefficient supply chains within the framework of SMCs. Namely, for each SMC_o we introduce $z^t_{u_t o} \geq 0, t = 1, \dots, m-1,$ that representing a set of new intermediate products to provid the complete information on how to project inefficient supply chains on to the DEA frontier. Therefore, cooperation starts with joint planning and ends with joint control activities to evaluate performance of the supply chain members, as well as the supply chain as a whole.

3 Application

Now we represent a numerical example with 17 SMCs. Table 1 indicates a set of 17 SMCs with internal structure of 2 suppliers and 1 manufacturer that supplier(1) consume one input and produce one output. supplier (2), consume two inputs and produce one output. Outputs of suppliers are inputs for manufacturer which by using those inputs, produce two final outputs. x^1_1 is the input amount of supplier(1) and x^2_1 and x^2_2 are the input amounts of supplier 2. i^1_1 is the intermediate product that produced by supplier 1 and i^2_1 is produced by supplier 2.y_1 and y_2 are the outputs of manufacturer. Table 2 reports the overall efficiency of SMCs and optimal intermediate measures obtained from the model. For example for SMC1 if the amount of i^1_1 and i^2_1 turn to 220.21 and 6.41, the efficiency of SMC1 will improve.

Table 1. Data for 17 multi supplier and one manufacturer chain (SMC).

NO.	x_1^1	x_1^2	x_2^2	i_1^1	i_1^2	y_1	y_2
SMC1	1.0168	1.221	1.2215	166.9755	8.3098	122.1954	3.7569
SMC2	0.5915	0.611	0.4758	50.1164	1.7634	19.4829	0.6600
SMC3	0.7237	0.645	0.6061	48.2831	3.4098	34.4120	0.7713
SMC4	0.5150	0.486	0.3763	35.0704	2.3480	15.2804	0.3203
SMC5	0.4775	0.526	0.3848	49.9174	5.4613	34.9897	0.8430
SMC6	0.6125	0.407	0.3407	23.1052	1.2413	32.5778	0.4616
SMC7	0.7911	0.708	0.4407	39.4590	1.1485	30.2331	0.6732
SMC8	1.2363	0.713	0.5547	37.4954	4.0825	20.6013	0.4864
SMC9	0.4460	0.443	0.3419	20.9846	0.6897	8.6332	0.1288
SMC10	1.2481	0.638	0.4574	45.0508	1.7237	9.2354	0.3019
SMC11	0.7050	0.575	0.4036	38.1625	2.2492	12.0171	0.3138
SMC12	0.6446	0.432	0.4012	30.1676	2.3354	13.8130	0.3772
SMC13	0.7239	0.510	0.3709	26.5391	1.3416	5.0961	0.1453
SMC14	0.5538	0.442	0.3555	22.2093	0.9886	13.6085	0.3614
SMC15	0.3363	0.322	0.2334	16.1235	0.4889	5.9803	0.0928
SMC16	0.6678	0.423	0.3471	22.1848	1.1767	9.2348	0.2002
SMC17	0.3418	0.256	0.1594	13.4364	0.4064	2.5326	0.0057

We can conclude from the results that:

- Compare the performance of supply chain and related operations against other companies
- Determine what processes to improve and by how much to improve them either eliminating waste, or by improving process reliability

- Guide the consolidation of internal supply chains
- Create standard processes and common information systems across business units (which generates major cost savings, cycle-time and quality improvements).

Table 2. Overall efficiency scores of SCMs and improved intermediate products.

NO.	θ_j^*	x_1^1	x_1^2	x_2^2	i_1^1	i_1^2	y_1	y_2
SCM1	0.5056	0.5141	0.6173	0.6176	220.21	6.41	122.1954	3.7569
SCM2	0.1775	0.1050	0.1085	0.0845	38.69	1.13	19.4829	0.6600
SCM3	0.1965	0.1422	0.1267	0.1191	45.21	1.32	34.4120	0.7713
SCM4	0.1150	0.0592	0.0559	0.0433	19.94	0.58	15.2804	0.3203
SCM5	0.2633	0.1257	0.1385	0.1013	49.41	1.44	34.9897	0.8430
SCM6	0.2929	0.1794	0.1192	0.0998	42.52	1.24	32.5778	0.4616
SCM7	0.1836	0.1452	0.1300	0.0809	39.46	1.15	30.2331	0.6732
SCM8	0.1121	0.1386	0.0799	0.0622	28.51	0.83	20.6013	0.4864
SCM9	0.0713	0.0318	0.0316	0.0244	11.27	0.33	8.6332	0.1288
SCM10	0.0793	0.0990	0.0506	0.0363	17.70	0.52	9.2354	0.3019
SCM11	0.0935	0.0659	0.0538	0.0377	18.39	0.54	12.0171	0.3138
SCM12	0.1435	0.0925	0.0620	0.0576	22.11	0.64	13.8130	0.3772
SCM13	0.0471	0.0341	0.0240	0.0175	8.52	0.25	5.0961	0.1453
SCM14	0.1344	0.0744	0.0594	0.0478	21.18	0.62	13.6085	0.3614
SCM15	0.0686	0.0231	0.0221	0.0160	7.81	0.23	5.9803	0.0928
SCM16	0.0799	0.0534	0.0338	0.0277	12.05	0.35	9.2348	0.2002
SCM17	0.0425	0.0145	0.0109	0.0068	3.31	0.10	2.5326	0.0057

4 conclusions

In this paper, we proposed a model for evaluating the efficiencies of SMCs (Suppliers-Manufacture Chains) using network DEA where in the overall efficiency is expressed as a weighted sum of the efficiencies of individual suppliers. This problem can applied for firms with some factories or supermarkets that provide goods from different plants.The weights are calculated in model. The model also yield a set of intermediate products for suppliers that improve the efficiency of SMCs.The model also calculate improved intermediate products.

The presented model has important applications in areas such as performance evaluation of complex network supply chain. The approach has the advantage of providing a clear indication of where the strengths and weaknesses exist in such series multi-supplier setting.

Also, according to the method mentioned for further research will: how to develop powerful performance measures for supplier evaluation, providing, how to articulate the criticality of supplier performance, how to select suppliers for a supplier evaluation program, how to involve internal stakeholders in the supplier evaluation process , how to decide between supplier evaluation methods such as supplier scorecards and system metrics, how to decide if Supply Chain Event Management software will work for your organization , how to reward suppliers, how to correct poor supplier performance.

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