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Group cross-efficiency evaluation in data envelopment analysis: An application to Taiwan hotels

Sheng Ang*, Menghan Chen, Feng Yang

School of Management, University of Science and Technology of China, 96 Jinzhai Road, Hefei, Anhui 230026, PR China

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ABSTRACT

Data envelopment analysis methodology has been applied to hotels performance evaluation in tourism industry. This study develops group efficiency and group cross-efficiency models to evaluate Taiwan hotel chains and subsidiary hotels with data from 2011 to 2015. We present group efficiency with two definitions and develop self-evaluation models for groups. The two definitions are the average performance which views the group efficiency as the average of its members' performance, and the weakest performance which uses the worst of members' efficiencies to indicate the group efficiency based on the cask principle, respectively. In the group cross-efficiency evolution, we develop corresponding models based on the average performance and the weakest performance as the group efficiency. Our developed models are extensions of classic cross-efficiency model, focusing on the performance of hotel chains in the perspective of the group instead of individual hotel. Empirical results show that Hotel Royal and Regent Hotel outperformed from 2011 to 2015 comparing with other hotel chains.

1. Introduction

With the development of world economy, travel becomes one popular leisure-time activity for increasing people, and the global demand for tourism continues to increase (Holden, 2016). For some countries and regions, tourist industry has even been a pillar industry and becomes a new engine of economic development (Fagertun, 2017). Taiwan, an island located at the pivot of Asia-Pacific region, is a great tourist destination due to its spectacular natural scenery, diverse culture, and highly developed technology (Hsieh and Lin, 2010). Since lifting of the martial law in 1985, the number of inbound tourists and the tourist revenue almost increase year by year. In 2016, 10,690,279 person-time travellers visited Taiwan, and US$ 13.374 billion foreign currencies were created by providing services for those travellers (Source from Tourism Statistics Database, Taiwan Tourism Bureau, http://stat.taiwan.net.tw). A report showed that 78% of tourists choose hotels for their accommodations, among which 20.81% choose international tourist hotels and lodge in 6.49 nights on average (Taiwan Tourism Bureau, 2016). Since tourists are a significant source of customers and create huge benefits for hotels, competition among these international tourist hotels for attracting and retaining guests is increasing (Tsai, Wu, & Sun, 2013). Under such a circumstance, operational efficiency evaluation has become one of major concerns for stakeholders in tourism industry.

Data envelopment analysis (DEA), a nonparametric approach initiated by Charnes, Cooper, and Rhodes (1978), has been frequently used in the evaluation of hotels (see e.g., Morey and Dittman, 1995, Tsai et al., 2013, Aissa and Goaied, 2016). Our literature review on hotels evaluation with DEA (in Section 2.2) shows that existing DEA models focus on the hotel evaluation mainly from individual perspective. In practice, hotel chain is the most common mode of ITHs management. A hotel chain usually set up subsidiary hotels in various districts so that more customers can be served and more benefits can be earned. All hotels affiliated to a hotel chain are uniformly managed by a central team. The central team controls and administrates resources for all affiliated hotels, as well as makes production decisions. Although under a unified management, each subsidiary hotel provides services to tourists independently without the help from peers belonging to the same chain. As a result, each affiliated hotel is treated as a decision making unit (DMU), and a hotel chain then can be regarded as a group consisting of several DMUs. Decision made by the central team for all affiliated hotels of a hotel chain, focuses on the performance of whole chain rather than that of an individual hotel. Due to the limitation of resources, the individual interests are not always consistent with the overall interest. Then, a rational evaluation tool in the perspective of group is desiderated by managers.

In this paper we will extend the concept of cross-efficiency in DEA to the group level, and propose a set of evaluation methods. Before

* Corresponding author.
E-mail address: shengang@ustc.edu.cn (S. Ang).

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carrying out the cross-efficiency evaluation, two types of definitions of the group efficiency and corresponding self-evaluation models are introduced. In addition to the definition of average performance of internal members in one group, the performance of a group can also be determined by its weakest member who performed worst, which is known "cask principle" in management. Hence, in this way we define the group efficiency as minimum of its members' efficiencies. Under the average definition, a composite DMU created by aggregating inputs and outputs of all members in a group is introduced to evaluate the group efficiency. Based on the weakest performance definition, a max-min model is built to find the maximum of members' efficiencies in a group under evaluation, and this model ensures that weights used are common across that group's members. In the stage of cross-efficiency evaluation, cross-efficiency of a particular group under evaluation is considered as the average of its self-evaluated efficiency and peer-evaluated efficiencies obtained with weight profiles provided by all other groups. As same as evaluation for individual DMUs, that optimal common weights for groups are also not unique, which result in the non-uniqueness problem of cross-efficiencies. Following previous study, aggressive secondary objective formulations are adopted into group cross-efficiency to address this issue. In empirical application, we apply our methodology to evaluate group efficiencies and group cross-efficiencies for seven hotel chains in Taiwan with the data from 2011 to 2015. Our contributions in the current study can be summarized as follows. First, we develop two types of definitions for group efficiency and models to measure the average performance and the weakest performance as the group efficiency, respectively. Second, we extend the classic cross-efficiency evaluation to the group cross-efficiency evaluation. Third, we apply the methodology to evaluate hotel chains in Taiwan. The study contributes not only to the DEA methodological extensions but also to the DEA application area, especially in hotels.

The rest of the paper is organized as follows. In Section 2, we review related works in literature. Section 3 develops the methodology of group efficiency and group cross-efficiency evaluation. In Section 4, we employ the methodology to evaluate the operation performance of hotel chains in Taiwan. Section 5 concludes the paper.

2. Literature review

2.1. DEA and cross-efficiency evaluation

Data envelopment analysis, initiated by Charnes et al. (1978), is an approach based upon mathematic programming for measuring relative efficiencies of a cluster of homogeneous decision making units (DMUs) with multiple inputs and outputs. In DEA, the efficiency of a DMU is assessed by calculating the ratio of its weighted sum of inputs and weighted sum of outputs through a set of weights (Pedraja-Chaparro, Salinas-Jimenez, & Smith, 1997). General DEA models such as the CCR model (Charnes et al., 1978) and the BCC model (Banker, Charnes, & Cooper, 1984), allow each DMU under evaluation to choose weights for inputs and outputs by itself such that it obtains its optimally maximized efficiency score. However, this flexibility in selecting optimal weights for inputs and outputs may lead to the appearance of unrealistic weights and too many DMUs defined as efficient among which no further distinctions can be made (Yang, Ang, Xia, & Yang, 2012).

To avoid the presence of unrealistic weights and improve the discrimination power of the DEA technique, cross-efficiency evaluation was proposed by Sexton, Silkman, and Hogan (1986) and Doyle and Green (1994). In addition to self-evaluation in original DEA, the cross-efficiency evaluation method provides peer evaluation to evaluate DMUs. Specifically, a DMU gets peer-evaluated efficiencies with the weight profiles provided by all other DMUs, then, the average of its self-evaluated efficiency and peer-evaluated efficiencies is considered as the cross-efficiency. There are two of main advantages of cross-efficiency evaluation: it offers a unique ordering of DMUs, and it eliminates unrealistic weight vectors without requiring elicitation of weight restrictions from application area experts (Anderson, Hollingsworth, & Inman, 2002). Hence, the cross-efficiency evaluation has been widely applied in various industries, e.g., evaluating nations performance in Olympics by Wu, Liang, and Chen (2009), selecting a portfolio in the stock market by Lim, Oh, and Zhu (2014), and selecting technology by Wu, Chu, Sun, Zhu and Liang (2016), Wu, Chu, Zhu, Li, and Liang (2016). More applications in other areas can be found in Shang and Sueyoshi (1995), Sun (2002), Ertay and Ruan (2005), Cui and Li (2015), etc.

Besides, theoretical researches of cross-efficiency evaluation mainly focus on issues of the cross-efficiency's non-uniqueness. To get a unique cross-efficiency value, secondary objectives were suggested by Sexton et al. (1986). The original secondary objectives are aggressive and benevolent formulations given by Doyle and Green (1994). The aggressive formulation maximizes own efficiency and minimize efficiencies of all others. On the contrary, the benevolent formulation optimizes efficiencies of peers in the premise of maximizing own efficiency. Since then, a series of secondary goals are designed for different situations and purposes. Liang, Wu, Cook, and Zhu (2008) analysed varied conditions and extended secondary functions of Doyle and Green (1994). Wang and Chin (2010) thought that preference of peer DMUs need be concerned and proposed corresponding secondary models to get unique efficiencies. Jahanshahloo, Lotfi, Jafari, and Maddahi (2011) acquired a unique cross-efficiency for each DMU by selecting symmetric weights. Wu, Sun, Zha, and Liang (2011) suggested that optimization of rankings could be a preferable secondary goal for DMUs which focus on their rankings rather than efficiencies. Wu, Chu, Sun et al. (2016), Wu, Chu, Zhu et al. (2016) set desirable and undesirable efficiency values for each DMU, then considered close to the desirable value as a secondary goal in the evaluation of cross-efficiency. In addition, diverse approaches for searching a unique cross-efficiency can also be found in other studies, such as Cook and Zhu (2014) and Contreras (2012).

In both self-evaluation by CCR or BCC models and traditional cross-efficiency evaluation, previous studies focus on individual DMUs but ignore the groups that possess and manage a number of independent DMUs. There is not a generally accepted methodology for evaluation of groups. Some scholars noted characteristics of grouped DMUs, but still devoted themselves to assessing individual DMUs, such as within-group common weights evaluation and benchmarking in Cook and Zhu (2007) and Cook, Ruiz, Sirvent, and Zhu (2017), and individual DMUs evaluation considering team performance indexes in Xia, Chen, and Zeng (2017).

2.2. Hotels evaluation with data envelopment analysis

Original DEA models, including CCR model (Charnes et al., 1978) and BCC model (Banker et al., 1984), and their extensions have been widely used to classify efficient and inefficient hotels. Morey and Dittman (1995) first applied the CCR model to evaluate efficiencies of 54 hotels opened by an American hotel chain in 1993. Hwang and Chang (2003) used the CCR model to assess 45 Taiwanese hotels in 1994 and 1998. Barros (2005) utilized the BCC model to calculate 43 Pousada hotels' efficiencies. Barros and Mascarenhas (2005) focused on the 43 Pousada hotels as well, and computed their technical, allocative, and economic efficiencies, respectively. Barros and Dieke (2008) employed both CCR and BCC models to analyse performance of 12 hotels during the period of 2000–2006 in Luanda, Angola, and found that members of international hotel chains perform better. Cross-efficiency method, an extension of original DEA models, is also used in hotels evaluation. For instance, Tsai (2009) extended BCC model to cross-efficiency evaluation and measured starred hotels in various Chinese provinces from 2001 to 2006. Tsai et al. (2013) focused on 12 hotels from 4 hotel chains in Taiwan and calculated cross-efficiencies for each hotel with the consideration of the cooperation within a chain and the competitions among chains.