Bidirectional technological spillover in the Chinese star-rated hotel sector: an empirical investigation*

Abstract

The star-rated hotel sector, recognized as the pillar sector of the tourism industry, has played a growing role in boosting economic growth in China. A particularly of the Chinese star-rated is the presence of technology heterogeneity amongst low- and high-end hotels. Also, policy implementations are generally more favourable for high-end hotels, and these hotels have several foreign partnerships in different forms. As a result high-end hotels are playing a leading role in that sector. Low-end hotels are, in general, more concerned with local specificities. An important followed-up economic question is therefore to verify whether there exists technological spillover in the Chinese star-rated hotel sector. In particular, spillover has to be bidirectional to benefit the entire hotel sector. On the one hand, high-end hotels have to act as the major spillover generators moving the star-rated hotel sector to better performances. On the other hand, low-end hotels have to integrate the technological knowledge of high-end hotels, but also share their experience with local contexts. Two particularities of our empirical study are to model hotels as multi-service decision-makers, and to rely on a nonparametric empirical strategy.

Keywords: Star-rated Hotels; China; Efficiency; Technology gap; Spillovers; Meta-technology.

JEL Classification: C6; C13; C14

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1 Introduction

In China, the star-rated hotel sector has grown rapidly in recent years, becoming a significant contributing factor to the development of tourism industry as well as to the high economic growth. For example, in 2016, the total income of the hotel sector reached 893.81 billion RMB (National Bureau of Statistics of China), while star-rated hotels account for nearly 60% of the total hotel revenue. In fact, the performance changes of the star-rated hotels accurately reflect those of the Chinese hotel industry, as well as those of the Chinese tourism industry. Moreover, the hotel sector has attracted the major part of investment in the Chinese tourism industry (Su and Sun, 2017). It can help improve local economic development through its contribution to output, job creation, and business opportunity. The value of this sector is well recognized by Chinese policy-makers and they have emphasized the importance of transforming and upgrading of tourism industry including hotel sector. This significance is also well recognized by scholars and is evident in the increasing attention given to studying that sector (Yang and Cai, 2016; Yang et al., 2017; see Law et al., 2014; and Walheer and Zhang, 2018 for a recent literature review).

However, previous researches also point out that the fast development of hotel sector in China are accompanied by structural and cyclical issues, such as insufficient new products, excess capacity, mismatched supply and demand, interference with institutional mechanisms, low occupancy rates, unsatisfied profit return, knowledge-management related issues, vicious price competition, slow technical progress, and weak technical spillovers (Wong et al., 2016; Yang and Cai, 2016; Mao and Yang, 2016; Yang et al. 2017; Walheer and Zhang, 2018). Data shows that the hotel sector is rather volatile in terms of performance in China. As an example, the total profit reached 61 billion RMB in 2007 and then fell dramatically to a negative level in 2009. It took four years to recover and reach a positive profit of 61.43 billion RMB in 2013. After 2013, the total profit again became negative until 2015 (Ministry of Culture and Tourism of China). This can be explained by high investments and relatively low occupancy rates during that period (Yang and Cai, 2016; Walheer and Zhang, 2018).

A particularity of the Chinese star-rated hotel sector is that hotels can be considered as facing different technology capacities or frontiers if they reward different stars. Clear differences exist between hotels with a different number of stars. For instance, there are important differences in terms of revenue and investment between high-end (four and five star) and low-end (below three stars) hotels. For example, during 2007-2016, the average revenue-total assets ratio was 41.92% for high-end hotels, while it was 50.17% for low-end hotels; meanwhile, the number of high-end hotels increased from 1,964 to 3,163 and the number of low-end hotels decreased from 11,619 to 6,698 during the same period. Also, high-end hotels have attracted the major part of foreign investment. For example, in 2015, there were 261 foreign investments in high-end hotels but only 122 in low-end hotels (China Star-Rated Hotel Report). Most foreign-funded hotels enter China by Management Contracts or Franchise Contracts (Gu et al., 2012). In other words, the number of stars is directly connected to the hotel investor profile and ownership status (Pranic et al., 2012; Mao and Yang, 2016). To summarize, high-end hotels are acting as leaders in the star-rated hotel sector, while low-end hotels are the followers.

As technological differences exist in the Chinese star-rated hotel sector, an important followed-up economic question is therefore to verify whether there exists technological spillover. In general, spillover effects are the technological achievements of firms' R&D that can be obtained and used by other firms, without cost due to externalities (Grossman and Helpman, 1991) and without involving market transactions (Crespo and Fontoura, 2007). In efficiency analysis, spillover can be understood as the influence of a group of firms on the efficiency of another group from different technology levels (Arzaghi and Henderson, 2008; Tsekouras et al., 2016; Walheer, 2018a; He and Walheer, 2019). In the context of the Chinese star-rated hotel sector, we want to study how high- and low-end hotels influence each others. To be more precise, we first want to establish that high-end hotels act as the main spillover generators pushing the technological frontier of the star-rated hotel sector forward. This may occur through several channels, such as employee mobility, enhanced competition, management system, corporate culture, or service consciousness (Crespo and Fontoura, 2007; Meyer and Sinani, 2009; Fernandes and Paunov, 2012; Yang and Mao, 2017). Next, we want to verify that low-end hotels benefit from the technological advancement of high-end hotels. In practice, this may occur trough learning from the management mode, or hiring skilled workers who previously worked for higher-star hotels. At this point, it is worth noticing that low-end hotels may also act as spillover generators sharing their experience of local culture with high-end hotels.

All in all, technological spillover has to be bi-directional to benefit the entire star-rated hotel sector. One, outgoing spillovers must be observed from high-end hotels to the star-rated hotel sector (and from low-end hotels to a lesser extent). Two, incoming spillovers must be observed from the star-rated hotel sector to low-end hotels (and to high-end hotels to a lesser extent). The presence of bi-directional technological spillover effects has important economic consequences for the Chinese star-rated hotel sector; such as cost reduction and demand improvement at the sector-level, product quality increase for low-end star hotels; better knowledge of the local specificities for high-end hotels

Besides tackling a new empirical question, our empirical exercise offers three additional distinguishing features. Firstly, hotels can be considered as multi-service provider. In Chinese hotel sector, there is increasing importance of supplement services. For example, in 2015, the accommodation service accounted for 47.23% of the total revenue, the catering and food service for 39.09%, and other services for 13.68% (China Star-Rated Hotel Report). Also, we observe a diversification process of hotel activities since the revenue share of their more traditional service (accommodation service) slowly decreases over time (50% in 2005 against 44% in 2015) in favour of new service (catering and food service) (36% in 2005 against 41% in 2015). Next, we make use of a tailored non-parametric efficiency approach taking the specificities of the Chinese hotel industry into consideration. In particular, our estimation method does not require making specific assumptions about any aspects of the hotel production process. Next, our estimation method allows us to easily take the economic objective of hotels into account. It also provides the option to consider a different production technology for each star-rated hotel and to consider each service individually. This has the added advantage of linking inputs to services. Finally, our estimation method is corrected for potential measurement errors, noises, or bias.

The remainder of this paper unfolds as follows. In Section 2, we provide a brief literature review to position our contribution, and in Section 3, we introduce our concept of the efficiency and technology gap ratio based on multi-service meta-technology. In Section 4, we present our empirical analysis of the Chinese star-rated hotel sector. Finally, in Section 5, we provide a summary, discuss the policy implications of our findings, and present our conclusions.

2 Literature Review

With the rapid development of the hospitality industry worldwide, growing attention has been given to evaluating hotel performance. Wassenaar and Stafford (1991) are among the pioneers in assessing hotel performance. They have made used of the 'lodging index,' which is defined as the revenue earned per room per night. However, such traditional methods are unable to reflect the multidimensional attributes of the hospitality sector. Therefore, subsequent studies have examined benchmark hotels by evaluating their input—output performance. Morey and Dittman (1995) were the first to use a (nonparametric) efficiency analysis to evaluate the performance of 54 hotels of a national chain in the US. They found these hotels were reasonably efficient, with an average efficiency score of 0.89. Inspired by these pioneers, efficiency analysis has been used extensively for the hotel industry. We refer to Assaf et al. (2012) and Zhang et al. (2016) for their literature reviews. In the following paragraphs, we focus our attention on an empirical analysis of the Chinese hotel industry.

Peng and Chen (2004) applied basic efficiency analysis model to star-rated hotels in three Chinese provinces for the period of 1999—2002. The authors found that hotels in Beijing and Guandong were relatively more efficient than hotels in Shanghai. Using various hotel groupings according to ownership, size, and star rating, Pine and Phillips (2005) made a statistical comparison of the performance of hotels. Their comparisons indicated that better performance occurs in hotels that have foreign ownership connections, are bigger, or have a higher star rating. Similarly, Tsai (2009) evaluated the cross-efficiency of the 31 Chinese provinces from 2002 to 2006 and demonstrated the interest of a multi-output productivity index compared with a single productivity indicator. Yang et al. (2017) investigated Chinese provinces for the year 2012, finding that efficiency depended on the regions and hotel segments. Meanwhile, Liu and Tsai (2018) studied the total factor productivity (TFP) of Chinese provinces with the Hicks-Moorsteen index approach for the period of 2001-2015. They found that TFP was mainly due to growth in operational efficiency. Finally, applying the profit Luenberger and Malmquist-Luenberger indexes from 2005 to 2015 on 30 Chinese provinces, Walheer and Zhang (2018) found that star-rated hotels performed better over time in China, but not for every activity they offered.

A common feature of these empirical studies is that they assumed a common production process for the hotels. Recent developments have suggested that this assumption is strong and that considering different production processes depending on the number of stars seems more reasonable. While no strong theoretical foundation has been suggested to support such modeling, it emerges rather from previous empirical investigations. We can nevertheless attribute the technology heterogeneity to different reasons: service quality (Mak, 2008), information on equipment, and other qualities measurable in advance (Núñez-Serrano, Turrión and Velázquez, 2014). In addition, a strong connection has been found between hotel performance and number of stars (Assaf and Agbola, 2011; Such and Mendieta, 2013); moreover, the number of stars is closely connected to hotel characteristics such as ownership, service quality, and size (Assaf and Agbola, 2011; Gu et al., 2012; Chen and Chen, 2013).

A well-established method to study the efficiency and technological advancement of firms is the concept of meta-technology. Introduced by Battese and Rao (2002), this concept has been suggested when firms are partitioned into different categories.[1] Meta-technology-based techniques have been widely used in the contexts of China and the hotel sector. Regarding China generally, refer, for example, to Chen et al. (2009), Wang et al. (2013) for Chinese regions; Fu et al. (2016) for the banking sector; Zhang and Choi (2013) for fossil fuel power plants; Hang et al. (2015) for Chinese cities; Fei and Lin (2017) for the agricultural sector; Lin and Zhao (2016) for the textile sector; Li et al. (2017) for the regional high-tech sector; Feng et al. (2017) for Chinese provinces; and He and Walheer (2019) for the Chinese manufacturing sector. For examples of application to the hotel sector, refer to Assaf et al. (2012), Assaf and Dwyer (2013), Huang et al. (2013), Yu and Chen (2016), and Cho and Wang (2017).

In the case of the Chinese hotel industry, the concept of meta-technology has also been used by several authors to capture hotel production process heterogeneity. Lin (2011) measured the efficiency behavior during 2002-2006 of 62 international tourist hotels in Taiwan and concluded that the cost—efficiency of domestic chain hotels was higher than that of independent hotels and international chain hotels. Assaf, Barros, and Josiassen (2012) investigated the influence of environmental variables on 78 key Taiwanese hotels' efficiency for the period 2004—2008. The authors divided the hotels into different groups based on size, ownership, and classification. They confirmed that different characteristics of a particular hotel would influence its efficiency. More precisely, chain hotels, larger hotels, and international hotels were found to perform

[1]See also O'Donnell et al. (2008) and Walheer (2018a) for more details about this methodology.

better. Lin, Chiu, and Huang (2012) evaluated technology gaps in productive and service processes of Taiwanese non-chain, franchised and company-owned hotels over the period of 2006—2008. They found that franchised type hotels performed better than the company-owned type for the study period. Huang et al. (2013) found that different groups (domestic chain, franchise membership, management contract and independent) performed very differently in practice. Huang et al. (2014) divided hotels into chain-operated and independently operated groups and found that the sample hotels were operating under heterogeneous technologies.

The performance of hotels may also vary according to each service they provide. Most the hotels provide not only accommodation but also other supplement services, such as catering and entertainment. In general, empirical studies have considered that hotels provide multi-services by considering several outputs in the efficiency analysis (Wang et al., 2006; Assaf and Agbola, 2011). Nevertheless, their exploration of the nature of multi-service hotels appears not to have progressed beyond this stage, since most previous works only provided an overall or aggregate vision of the hotel performance (in practice, only an overall efficiency measurement was provided). In contrast, we believe that providing complementary service-specific indicators of hotel performance is of great interest because it allows us to investigate the cause of the hotel (in)efficiency behavior better. To the best of our knowledge, only one recent study has considered this option (see Walheer and Zhang, 2018). Clearly, a similar argument holds true for technological advancement, which has never been considered before. In other words, when examining the multi-service nature of the hotels, technological advancement is a way to consider the presence of heterogeneity inside the hotel production process.

An advantage of taking the intra- and inter-heterogeneity aspects into account is that this method provides us with the option to search for the existence of technological spillovers between hotels at both the overall (i.e. when considering all services together) and service-specific (i.e. when looking at each service individually) levels. While the former has been partially studied in past works (see Mao and Yang, 2016; Park and Chen, 2017 for related studies), the latter has been neglected. In particular, we investigate whether high-end hotels have pushed the hotel sector performance forward and how low-end hotels have benefited from the technological progress of high-end hotels. Indeed, in general, high-end hotels are associated with higher service quality, a better reservation system, more valuable brand names, better managerial skills, a better location choice, and in most cases, more friendly policies. It is therefore essential for policy-makers to confirm that high-end hotels represent best practice and to quantify how low-end hotels have benefited from the technological transfer. Moreover, given the multi-service nature of hotels, nothing can guarantee that the performances of each activity are similar or that the spillover effects are the same for each service.

For our star-hotel context, the meta-technology approach is thus tailored to study the performance of the hotels when taking their number of stars into account, but it is not designed to take their multi-service nature into consideration.[2] Therefore, to match our empirical investigation, we extend the concept of meta-frontier in that direction. This option is introduced by a simple modification of the initial concept of meta-technology. We believe that this extension is particularly relevant for the hotel sector, and for the tourism industry in general. Indeed, as emphasized in Barros et al. (2011) and Zhang et al. (2016), it is not only important to measure the performance of the tourism industry, but also crucial to provide accurate performance indicators that may yield policy implications.

3 Methodology

We assume that hotels are partitioned into N groups. In each group $n \in \{1, \ldots, N\}$, hotels provide Q services using inputs. In general, some inputs are used to provide all services (e.g. infrastructure, managers), while others are used only to provide specific services (e.g. employees, resources). The former give rise to economies of scale (Panzar and Willig, 1977) and of scope (Panzar and Willig, 1981) in the production process, forming a prime economic motivation for hotels to provide multiple services. The latter constrain the hotel production process since these inputs must be allocated between the services. We make use of $\mathbf{x}_n^q$ to capture the inputs used to provide service $q \in \{1, \ldots, Q\}$. Finally, we denote the prices of the inputs used for service q by $\mathbf{w}_n^q$.

Moreover, we assume that the hotels are cost minimizers. We believe that it is more relevant to take the hotel economic objective into consideration when evaluating their performance. The alternative is to rely on a technical perspective, that is, when

[2]Recently, several authors have considered a multi-service or multi-output representation of the production process. Refer, for example, to Cherchye et al. (2015), Zhou et al. (2016), and Walheer (2018e, 2019) for US electricity plants, Cherchye et al. (2016) for a large European service company, Walheer (2016a, b , 2018f) for European sectors.

only the input—output combinations are of interest. We remark that our choice is also motivated by the data (see Section 3). That is, when the hotel's aim is to use the minimal level of inputs to provide the services. Using our previous notation, we define the cost for providing service q by $\mathbf{w}_n^{q'}\mathbf{x}_n^q$. By summing the service-specific costs, we obtain the total cost for the hotels: $\sum_{q=1}^{Q} \mathbf{w}_n^{q'}\mathbf{x}_n^q$.

Finally, we believe that both the quantity and the quality of the services should be taken into consideration when evaluating hotel performance (Mason and Nassivera, 2013; Yang and Cai, 2016; Walheer and Zhang, 2018). Indeed, higher quantity results in higher costs, but the same holds true for greater quality: greater quality is, in general, associated with higher prices and thus higher costs. We denote the outputs measuring the quality and quantity of service q by $\mathbf{y}_n^q$.

We start by defining the notions of (cost-based) efficiency and technology gap for each individual service. To do so, we rely on ratios since they are easy to interpret and compute in practice. Next, we show how to define similar ratios at the overall level, that is, when considering all services together. Finally, we explain how the different concepts can be computed by means of linear programs.

3.1 Service-specific ratios

Our aim is to define an efficiency and technology gap ratio for every service. As an initial step, we model each service separately by its own production process, captured by service-specific input requirement sets. This set is defined for service q and group n as follows:

$$I_n^q(\mathbf{y}_n^q) = \{\mathbf{x}^q \mid \mathbf{x}^q \text{ can produce } \mathbf{y}_n^q \text{ in group } n\}. \tag{1}$$

$I_n^q(\mathbf{y}_n^q)$ contains all combinations of the inputs that can be used to provide service q. In general, the service-specific input requirement sets are interconnected since some inputs are used to provide all services and others are allocated between services.

The starting point of the cost evaluation is the minimal cost for each service q:

$$C_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q) = \min_{\mathbf{x}^q \in I_n^q(\mathbf{y}_n^q)} \mathbf{w}_n^{q'}\mathbf{x}^q. \tag{2}$$

$C_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q)$ selects the minimal input quantity in the input requirement set $I_n^q(\mathbf{y}_n^q)$ that can be used to provide service q, given the input prices $\mathbf{w}_n^q$. Cost-efficiency for service q in group n is obtained as the ratio of the minimal and actual costs:

$$CE_n^q(\mathbf{y}_n^q, \mathbf{x}_n^q, \mathbf{w}_n^q) = \frac{C_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q)}{\mathbf{w}_n^{q'} \mathbf{x}_n^q}. \tag{3}$$

This ratio, which dates to Farrell (1957), is bounded from above by 1. Intuitively, for each service q, minimal cost is always lower than actual cost: $C_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q) \leq \mathbf{w}_n^{q'} \mathbf{x}_n^q$, making $CE_n^q(\mathbf{y}_n^q, \mathbf{x}_n^q, \mathbf{w}_n^q)$ smaller than 1. A value of 1 indicates that minimal and actual costs coincide, reflecting cost-efficiency. Lower values induce larger cost inefficiency behavior, and thus potential cost savings for service q.

To define our concept of technology gap ratio, we must first introduce the notion of service-specific meta-technology. The service-specific meta-technology set is obtained as an envelopment of the service-specific group technology sets. Formally, we define the meta-technology for service q as follows:

$$I^q = I_1^q \cup I_2^q \cup \cdots \cup I_N^q. \tag{4}$$

In a sense, I^q makes the hypothetical assumption that all hotels are comparable. That is, the number of stars does not matter anymore; or, to put it differently, hotels are homogeneous.

It is straightforward to extend our concept of minimal cost for service q when considering the meta-technology:

$$C^q(\mathbf{y}_n^q, \mathbf{w}_n^q) = \min_{\mathbf{x} \in I^q(\mathbf{y}_n^q)} \mathbf{w}_n^{q'} \mathbf{x}. \tag{5}$$

$C^q(\mathbf{y}_n^q, \mathbf{w}_n^q)$ has to be interpreted in an analogous way to $C_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q)$. That is, $C^q(\mathbf{y}_n^q, \mathbf{w}_n^q) = \mathbf{w}_n^{q'} \mathbf{x}_n^q$ means that service q is provided with minimal cost (with respect to the meta-technology), and $C^q(\mathbf{y}_n^q, \mathbf{w}_n^q) < \mathbf{w}_n^{q'} \mathbf{x}_n^q$ reflects potential cost savings (with respect to the meta-technology). Note that, by construction, $C^q(\mathbf{y}_n^q, \mathbf{w}_n^q) \leq C_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q)$; minimal cost with respect to the meta-technology is always smaller than minimal cost with respect to the group technologies. Intuitively, this reflects that the group technologies are included in the meta-technology, as stated in (4).

The concept of technology gap ratio was defined by O'Donnell et al. (2008) as the ratio of minimal costs with respect to meta-technology and minimal costs with respect to group technology. Adapting their definition to our service-specific context, we obtain for every service q:

$$TG_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q) = \frac{C^q(\mathbf{y}_n^q, \mathbf{w}_n^q)}{C_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q)}. \tag{6}$$

$TG_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q)$ provides a measure of the gap between the technology available to all hotels and the technology available to a group of hotels. This ratio is smaller than unity by construction (we established previously that $C^q(\mathbf{y}_n^q, \mathbf{w}_n^q) \leq C_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q)$). A value of 1 indicates that no technology gap is present, while a smaller value reflects greater technology gaps. In other words, this ratio measures the proximity of the group frontier (i.e. the boundary of the group technology) to the meta-frontier (i.e. the boundary of the meta-technology); the larger $TG_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q)$ is, the closer the group frontier is to the meta-frontier. It turns out that $TG_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q)$ gives us a measure of technological advancement for service q.

3.2 Multi-service ratios

Fortunately, as explained before, by summing the service-specific costs, we obtain the cost for the overall service level. This also holds true for the minimal total cost (see Walheer (2018b, c, e) for more discussion). Cost-efficiency for group n is obtained as follows:

$$CE_n(\mathbf{y}_n, \mathbf{x}_n, \mathbf{w}_n) = \frac{\sum_{q=1}^{Q} C_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q)}{\sum_{q=1}^{Q} \mathbf{w}_n^{q'} \mathbf{x}_n^q}. \tag{7}$$

When $\sum_{q=1}^{Q} C_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q) = \sum_{q=1}^{Q} \mathbf{w}_n^{q'} \mathbf{x}_n^q$, this means that all services are provided with minimal costs (for all q: $C_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q) = \mathbf{w}_n^{q'} \mathbf{x}_n^q$). A lower value implies that at least one service is provided inefficiently ($C_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q) < \mathbf{w}_n^{q'} \mathbf{x}_n^q$ for at least one q). Therefore, $CE_n(\mathbf{y}_n, \mathbf{x}_n, \mathbf{w}_n) = 1$ reveals cost-efficient behavior at the overall level; while a value smaller than one reflects potential cost savings. In that case, the service-specific efficiency ratios provide more detailed information about the potential cost savings for each service individually. Finally, we remark that $\mathbf{y}_n$, $\mathbf{x}_n$ and $\mathbf{w}_n$ are the outputs, inputs, and input prices at the overall level, respectively.

The technology gap ratio for the overall or multi-service level is defined as follows:

$$TG_n(\mathbf{y}_n, \mathbf{w}_n) = \frac{\sum_{q=1}^{Q} C^q(\mathbf{y}_n^q, \mathbf{w}_n^q)}{\sum_{q=1}^{Q} C_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q)}. \tag{8}$$

As for the service-specific technology gap ratio, $TG_n(\mathbf{y}_n, \mathbf{w}_n)$ is less than one. This is obtained by noticing that $\sum_{q=1}^{Q} C_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q) \leq \sum_{q=1}^{Q} C^q(\mathbf{y}_n^q, \mathbf{w}_n^q)$ since $C_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q) \leq C^q(\mathbf{y}_n^q, \mathbf{w}_n^q)$ for every service q. A value of 1 means that no technology gap is observed for the overall level. Lower values indicate the presence of a technology gap; the cause(s) can be investigated by using the service-specific indicators (i.e. the $TG_n^q(\mathbf{y}_n^q, \mathbf{w}_n^q)$'s).

3.3 Practical implementations

We assume that each group n contains K_n hotels. One attractive feature of our ratio is that it suffices to compute for every hotel $k \in \{1, \ldots, K_n\}$ in group $n \in \{1, \ldots, N\}$ only two minimal costs: $C_n^q(\mathbf{y}_{nk}^q, \mathbf{w}_{nk}^q)$ and $C^q(\mathbf{y}_{nk}^q, \mathbf{w}_{nk}^q)$. Different methods could be used at this stage. We prefer, given our context, to make use of a nonparametric estimation method. Indeed, there is no guideline to define the technology when hotels are partitioned into different categories and are multi-service decision-makers. Moreover, assuming a specific technology could bias the results of our study (Giannakas et al., 2003; Maha et al., 2018; Assaf and Tsionas, 2018). Therefore, we reconstruct the technology using a data envelopment analysis (DEA) —based methodology. DEA, introduced by Charnes et al. (1978), is a nonparametric technique used to compute efficiency of decision-making units without assuming a functional form for the technology.

In practice, minimal costs can be computed using linear programs. $C_n^q(\mathbf{y}_{nk}^q, \mathbf{w}_{nk}^q)$ for hotel $k \in (1, \ldots, K_n)$ in group $n \in (1, \ldots, N)$ is obtained as follows:

$$\begin{aligned} C_n^q(\mathbf{y}_{nk}^q, \mathbf{w}_{nk}^q) = \max_{C_n^q \in \mathbb{R}_+} & \; C_n^q \\ \text{s.t. } & C_n^q \leq \mathbf{w}_{nk}^{q'} \mathbf{x}_{ns}^q \text{ for all } s \in (1, \ldots, K_n) : \mathbf{y}_{ns}^q \geq \mathbf{y}_{nk}^q. \end{aligned} \tag{9}$$

In a similar vein, $C^q(\mathbf{y}_{nk}^q, \mathbf{w}_{nk}^q)$ for hotel $k \in (1, \ldots, K_n)$ in group $n \in (1, \ldots, N)$ is obtained as follows:

$$\begin{aligned} C^q(\mathbf{y}_{nk}^q, \mathbf{w}_{nk}^q) = \max_{C^q \in \mathbb{R}_+} & \; C^q \\ \text{s.t. } & C^q \leq \mathbf{w}_{nk}^{q'} \mathbf{x}_{ns}^q \text{ for all } s \in (1, \ldots, K_n) \text{ and } n \in (1, \ldots, N) : \mathbf{y}_{ns}^q \geq \mathbf{y}_{nk}^q. \end{aligned} \tag{10}$$

In other words, the constraint verifies that hotels providing greater service quantity/quality than the evaluated hotel k (i.e. $\mathbf{y}^q_{ns} \geq \mathbf{y}^q_{nk}$) have higher costs. When this is the case, the linear programs in (9) and (10) will conclude that minimal costs coincide with actual costs. Also, note that (9) and (10) are very similar, the only difference being that in (9), the comparison hotels are only those in group n, while in (10), the comparison is conducted using all the data (this follows from the hypothetical assumption of homogeneity between hotels; see (4)). Finally, we point out that these two linear programs require very weak assumptions about the technology ~~(Varian, 1984; Tulkens, 1993),~~ and they can easily be extended when data are not or are partially observed (Cherchye et al. 2016; Walheer, 2018b, c).[3]

While DEA has certain advantages (no functional form for the production process, easy use, fast computation), it is a deterministic methodology. It thus ignores measurement errors and statistical noises. Since we make use of regional data sets, aggregation issues may be present. Moreover, efficiency scores obtained by DEA are, by construction, biased. These two aspects have been taken into consideration by implementing a well-known robust bias-corrected DEA approach (see, e.g. Daraio and Simar, 2007).

4 Application

We apply our methodology to the star-rated hotel sector in China. As explained in the introduction, two distinguishing features of our empirical study are to take the number of stars of the hotels into account (notion of inter-heterogeneity) and to consider hotels as multi-service decision-making units (notion of intra-heterogeneity). Star-rated hotels have different characteristics in terms of economies of scale, market share, and access to advanced technologies, and they should thus not be treated as one homogeneous group. Also, the majority of hotels not only provide accommodation, but also other supplement services, such as catering and entertainment.

Below, we first discuss the specificities of our set-up in more detail. Subsequently, we present the results of our empirical analysis.

[3] In particular, no returns-to-scale assumption is specified. That is, the variable returns-to-scale is assumed; in practice, we can test the returns-to-scale assumption by means of linear programs (Walheer 2018d).

4.1 Data, variable selection, and descriptive statistics

As explained in the introduction, we discriminate hotels with respect to their number of stars and the services they provide. In our study, following Yang and Cai (2016), and Walheer and Zhang (2018), we consider that hotels provide two main services: the accommodation service and the catering service. Other services (such as entertainment, recreation, and business services) are pooled together. Note that this modelling is also consistent with the data since the accommodation and catering services account for 46.83% and 39.69% of the total revenue for the period, respectively (see Table A.2). To capture the quantity and quality of the services, we use the revenue generated by each activity. Indeed, greater quantity results in higher revenue, while greater quality implies higher price and thus higher revenue (Fukuyama and Weber, 2008; Sahoo et al., 2014; Cherchye et al., 2016; Walheer and Zhang, 2018).

For example, in 2015, the accommodation service accounted for 47.23% of total revenue, the catering and food service for 39.09%, and other services for 13.68% (China Star-Rated Hotel Report). Also, we observe a diversification process of the hotel activities since the revenue share of their more traditional service (accommodation service) slowly decreases over time (50% in 2005 against 44% in 2015) in favor of the new service (catering and food service) (36% in 2005 against 41% in 2015). All in all, to provide a fair and reliable performance analysis, both types of heterogeneity should be considered.

We select three inputs: the number of employees, the number of rooms, and total fixed assets (Barros et al., 2011; Assaf and Agbola 2011; Yang et al., 2017; and Walheer and Zhang, 2018). The number of employed persons is used as an indispensable part and core input which indicates the hotels'capacity to offer all services available; the number of rooms is used to represent the hotel variable capacity to support its daily operation; and total fixed assets is used to reflect the support the hotel gives to its development and future extension. While the number of employees and total fixed assets are used to provide all services, the number of rooms is only used for the room service. Table 1 presents a summary of the inputs and outputs used for each service.

To obtain the data for our three outputs and three inputs, we combine two databases: the Wind Database and the Supplement of China Tourism Statistic Year Books. This data set is popular for empirical research; see, for example, Yang and Cai (2016), Yang et al. (2017), and Walheer and Zhang (2018). We end with a sample

Table 1
Hotel production process

Service	Inputs	Outputs
Accommodation service	Number of employees Number of rooms Total fixed assets	Total Revenue
Catering service	Number of employees Total fixed asset	Total Revenue
Other services	Number of employees Total fixed assets	Total Revenue

of 31 provinces and a period spanning from 2005 to 2015. Note that Tibet has been removed from our empirical analysis given poor representation. The price data for the number of rooms are extracted from the Wind Database, and the wages from the China Statistic Bureau. The prices of total assets are not observed. We estimate these prices when computing the minimal costs. Roughly speaking, when some prices are not observed, they are considered as variables in the linear programs (see (9) and (10)). Note that the programs are still linear in that case, and that price intervals are usually specified to avoid trivial or unrealistic estimated prices. Please refer to Cherchye et al. (2016) and Walheer (2018b, c) for more detail.

As an initial step, we present key descriptive statistics to contextualize our analysis (all Tables are available in Appendix A). We start by providing in Table A.1 the total number of star-rated hotels in China from 2005—2015 along with the proportion of hotels per number of stars. Two main lessons arise from Table A.1. One, we observe that the total number of hotels has not significantly changed for the period. Two, the proportion of one- and two-star hotels has significantly reduced. More precisely, one-star hotels became irrelevant for the whole industry because they represented less than 1% of the total hotels in 2015, while the share of two-star hotels was reduced from 46.47% in 2005 to 20.82% in 2015. This is also why we decide to remove one-star hotels from our empirical analysis. In contrast, the proportions of three- and four-star hotels have increased by 12 and 13 percentage points in the past 10 years, respectively. Three-star hotels represented almost 50% of all hotels in 2018. Finally, the share of five-star hotels has also increased by five percentage points over the same period. This shows that both the rationalization of low-end hotels and the rapid development of high-end hotels have become new trends in the development of China's star-rated hotel sector.

Next, we present in Table A.2 the revenue proportions per service and number of stars over time. Two main lessons can be learned from Table A.2. First, it is clear that hotels are multi-service decision-makers since the three activities present a significant revenue share (even if the revenue share for the other services is weaker). For the period 2005—2015, the accommodation service constitutes 46.83% of hotel total revenue, the catering service accounts for 39.69%, and other services generate 13.48%. Second, we also note that the share of the room service in the total revenue slowly decreases over time, while the share of the catering service increases. This phenomenon is clearer for high-end hotels with a steady growth pace every year. For two-star hotels, the relative importance of the accommodation and catering services has not changed significantly. This reveals not only the existence of heterogeneity between different star-rated hotels, but also that there is an intra-heterogeneity aspect for the Chinese hotel sector in terms of specializing in different services.

Finally, in Tables A.3 and A.4, we present the proportion of inputs and outputs by discriminating hotels with respect to their number of stars. An initial observation is that hotels have faced different changes in their revenue, input, and output shares depending on their number of stars. In particular, we find that four- and five-star hotels have increased their revenue share for all services, while their shares of inputs, that is, rooms, fixed assets, and labor, have increased by 10.28, 16.27 and 21.69 percentage points, respectively. Therefore, high-end hotels were the most important hotels in terms of both inputs and outputs in 2015. Note that the relative shares of rooms and total assets are equivalent for four-star hotels, but two times larger for total assets in the case of five-star hotels. This reveals a significant difference in terms of infrastructure between high-end hotels. In contrast, three-star hotels, which were the most important hotels in 2005, have lost their leading place over time. This holds true for both inputs and outputs. Actually, their revenue shares have decreased by around 10 percentage points for all services, and for the number of employees and total fixed assets. We note that the number of rooms is stable for the period; this may indicate a potential issue of low occupancy rates. Finally, two-star hotels account for less than 5% of the revenue for all services, while the number of rooms still represents a bit less than 10%. Again, this may highlight low occupancy rate issues. These findings once more reveal the existence of heterogeneity between different star-rated hotels, in particular, the presence of inter-heterogeneity in terms of inputs and outputs.

All in all, these key descriptive statistics highlight that we should pay attention to the heterogeneity problem arising from different star-hotel groups and different services provided when evaluating the performance of the star-rated hotel sector in China.

4.2 Results

We compute, using (9) and (10), the (cost-based) efficiency and technology gap ratios for the star-rated hotels for the period 2005—2015. We start by presenting the results for these ratios. Next, we investigate the presence of spillovers between hotel groups.

Efficiency and technology gap ratios. As an initial step, we present in Figure 1 the average of the efficiency and technology gap ratios per number of stars when pooling all years together. In Figure 1, we also present the percentage of efficient hotels and of hotels with no technology gap. The first observation is that the Chinese hotel sector is relatively efficient and technically advanced for the period, with averages of around 0.75 and 0.80, respectively. This demonstrates the important support from local and national governments. Indeed, the hotel (and tourism) sector is a pillar sector for supporting high economic growth in China. In fact, this sector has received much attention from Chinese policy-makers. Nevertheless, our results suggest that efforts are still possible and that potential costs can be saved without affecting the quantity or the quality of the services.

Next, we find a positive connection between the number of efficient hotels and the number of stars. Two possible explanations are suggested. First, high-end hotels have attracted the major part of domestic and international investments. Usually, hotels with foreign partnerships are thought to be more efficient (Mao and Yang, 2016). Second, high-end hotels have benefited from many policy implementations that have a direct effect on their efficiency behavior (Santos et al., 2016). Interestingly, we find that two-star hotels present relatively good performance in terms of technological advancement. Indeed, these hotels have the highest share of hotels with no technology gap for the period. One possible explanation for this is the rationalization observed for two-star hotels (see Table A.1). In a sense, only the best hotels in terms of technology have been retained in that category. Also, as pointed out by Yang et al. (2017), high-end hotels have been disappointed in terms of profits and returns on investment, while contrasting findings have been found for low-end hotels (Inntie, 2017; Tsang and Hsu,2011). In fact, there is still a high demand for low-end hotels in China (Subramanian et al., 2015). Our results may be interpreted as proof that important efforts have been made to upgrade low-end hotels to attract more consumers and satisfy investors. In other words, these hotels have a comparative advantage compared with other hotel groups in the Chinese hotel industry.

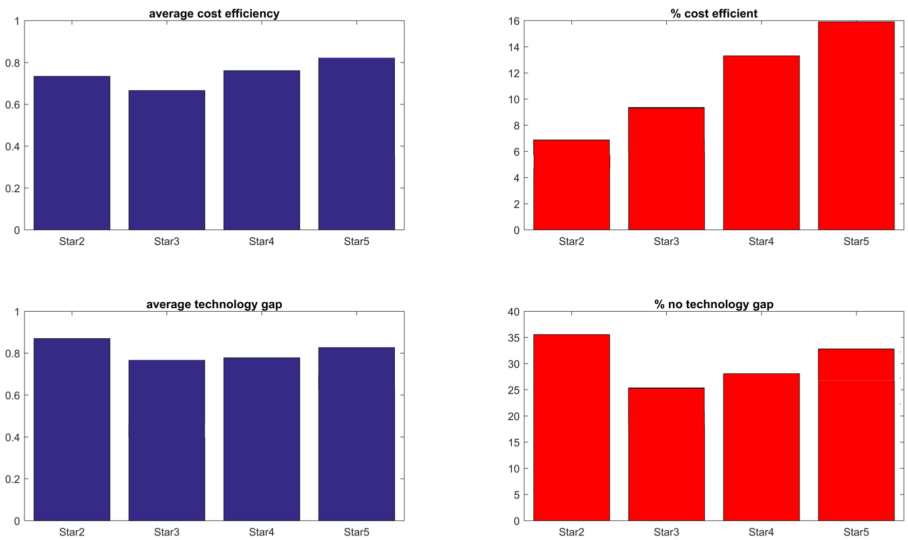

Fig. 1. Multi-service performances

Next, we propose similar results for each service: see Fig.2 for the accommodation service, Figure 3 for the catering service, and Figure 4 for other services. Our first observation is that five-star hotels perform particularly well regarding the accommodation service and other services in terms of efficiency, while for the catering service, it is four-star hotels that perform the best. In other words, high-end hotels are the best performers. Also, we find higher levels of efficiency for all hotels for the provision of a more traditional accommodation service. In general, the catering service presents better efficiency performance than other services. Next, in terms of the technology gap ratio, we again acknowledge the superiority of high-end hotels, but also find that two-star hotels demonstrate high performance. This is particularly true for other services. The accommodation service also presents better performances for that dimension, but the performance difference with the two other services is much smaller than for the efficiency dimension. This reveals greater consistency in terms of technological advancement than in terms of efficiency for the Chinese star-hotel sector.

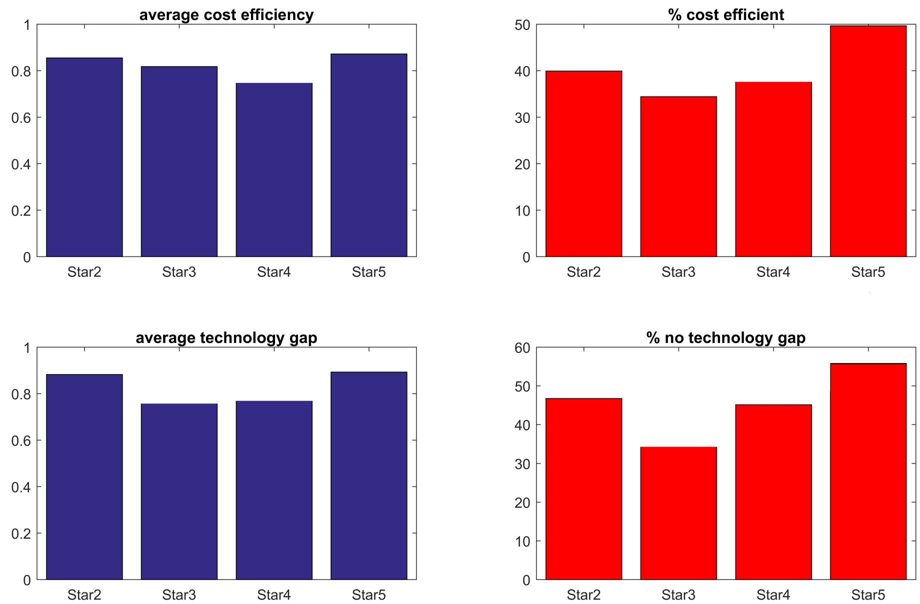

Fig. 2. Accommodation service performance

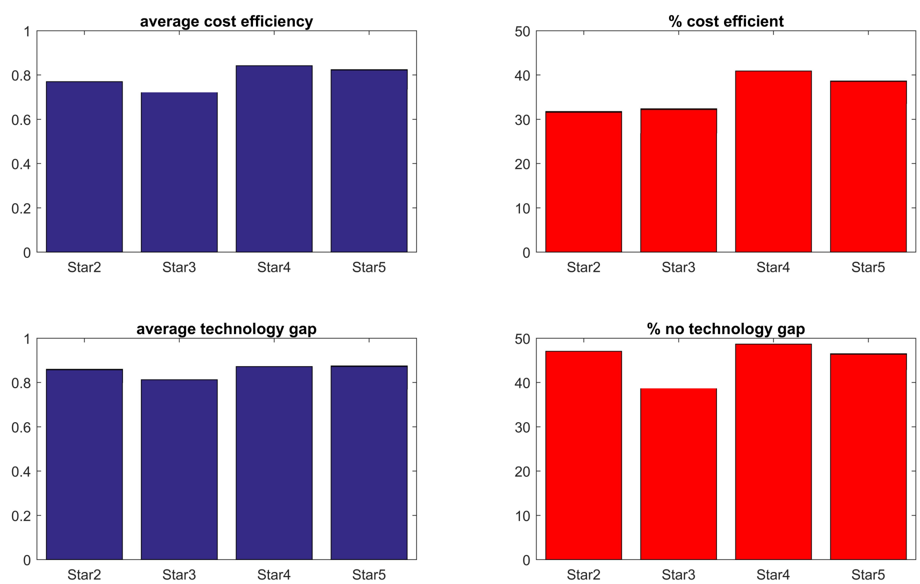

Fig. 3. Catering service performance

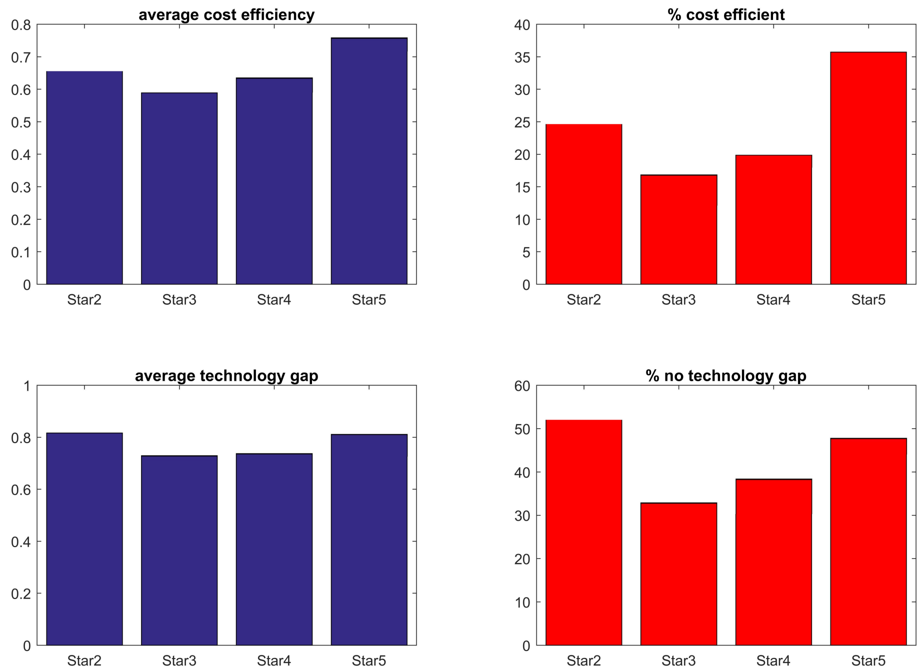

Fig. 4. Other service performance

While the previous results have set the stage, they do not reveal how the performance changes over time. We present several Tables in Appendix B to capture these changes. In particular, Table B.1 provides the averages of the efficiency and technology gap ratios, as well as the percentages of efficient hotels and of hotels with no gap over time for the multi-service level. Tables B.2 and B.3 provide similar information for every service individually.

An initial observation is that, for all the three services, the efficiency ratios are relatively stable over the period and reach their highest level between 2010 and 2012. A possible explanation for this is the financial crisis in 2008—2009. Indeed, the Chinese star-rated hotel sector profit level reached the bottom in 2009 and then recovered during the following three years. We find that the efficiency ratio for the catering service has slowly increased over time, except in 2008 when the financial crisis occurred. This demonstrates not only that compared with the more traditional services, new services, such as the catering service, are becoming increasingly important for the Chinese star-rated hotel sector, but also that these new services are more susceptible to factors such as economic fluctuations and decline in consumer spending power.

Further, the catering service is as efficient as the accommodation service, and both are much more efficient than other services, which only achieved around 65% of potential best performance. Next, a larger proportion of hotels are efficient at providing accommodation and catering services, while only 25% of the hotels are efficient at providing other services. This shows that while the Chinese star-rated hotel sector is undergoing transformation and gradually enriching the types of products and services provided, the performance of new emerging services is still not satisfactory for the majority of hotels. In addition, three-star hotels perform the poorest regarding other services. Finally, we find that the technology gap ratios slowly decrease for the accommodation service, while the technology gap ratios for the catering service slowly increase for the period. Other services present the worst performance for that dimension. This also reveals that the technological advancement of the Chinese hotel industry is mostly driven by traditional services, but we also observe a slow change in favor of new services.

Next, when discriminating between hotels with respect to their number of stars we find that, before 2010, the higher the star rating, the more efficient the hotel. After 2001, this is no longer the case since two-star hotels are becoming the most efficient, while five-star hotels lose their best practice status. This is also confirmed by the percentage of efficient hotels. Indeed, the percentage of efficient hotels for the two-star group is increasing, while it decreases for five-star hotels. Again, these results reveal the willingness of policy-makers to rationalize the number of low-end hotels and to retain only the best performing ones. Also, they show that important investments have been made in high-end hotels and that this has negatively affected the performances of high-end hotels. Similar conclusions hold true for the technology gap ratios. Before 2011, five-star hotels were the technology leaders with the highest average technology gap ratios. After 2001, two-star hotels showed the best performance. In addition, the percentage of low-end hotels with no technology gap increased during the period, while for high-end hotels the reverse is true. More precisely, for two- and three-star hotels, the percentage of hotels with no technology gaps increased from 5% to 50% and from 21.43% to 35.71%, respectively, while for four- and five-star hotels, the percentage reduced from 32.14% to 28.57% and from 42.86% 21.43%, respectively.

Finally, the results by service also provide interesting findings. An initial observation is that two-star hotels performed poorly in 2005, but they improved their efficiency level over time for all services. In particular, two-star hotels achieved a higher efficiency level for the accommodation service initially but performed better in the catering service in 2015. This once more reveals the increasing importance of the catering service for the Chinese star-rated hotel sector. A similar pattern is observed for three-star hotels: they were initially better at providing the accommodation service, but the catering service becomes the most important service over time. Note that other services present the poorest performance for these two groups of hotels. Regarding four-star hotels, the catering service nearly always presents the best performance; however, for five-star hotels, it is the accommodation service that always performs the best.

Another important observation is that before 2010 high-end hotels performed better regarding accommodation and catering services, while after 2011 low-end hotels performed better. Further, for other services, we find that five-star hotels were operating at a lower level than for the accommodation and catering services; however, they were operating at a higher level for other services than were two-star hotels. The main reason for the decline in the economic performance of five-star hotels after 2010 is due to the decline in the efficiency of their accommodation and catering services. For the technology gap ratio, we find that, at the beginning of the period, five-star hotels were the technology leader for all three services. Over time, the technology level of two-star hotels gradually improved in all services, thus revealing that the significant improvement for these hotels was not limited to just efficiency but also held true for technological advancement. For three- and four-star hotels, the technology level of their accommodation service lies between the other two groups and there were no excessive fluctuations during the study period. However, the technological level of the catering service gradually improved for these two hotel groups. Regarding other services, three-star hotels performed better than four-star hotels but still lagged behind other hotel categories for the period.

Spillovers. A reason for supporting the development of high-end star-rated hotels is that the hotel sector may benefit from the efficiency and technological advancement of these hotels. In general, spillovers are essentially endogenous outcomes of interactions between firms with superior performance as generators and those with inferior performances as receivers. Within the context of the Chinese hotel sector, we regard high-end star-rated hotels to be spillover generators and lower star hotels to be spillover recipients. Clearly, this assumption cannot be taken for granted and should be tested. Moreover, our previous results concerning the efficiency and technological advancement of hotels reveal not only the dominance of high-end hotels but also the huge progress of low-end hotels; and they reveal a different pattern for each service.

A natural requirement is to verify the role of the high-end hotel in the positive change of the low-end hotel performance. To do this, we must distinguish between two directions for spillovers: outgoing and incoming spillovers.[4] Outgoing spillovers represent spillovers from group technologies to the hotel sector technology (i.e. the meta-technology). In other words, outgoing spillovers allow us to verify which group of hotels defines the hotel sector technology. We expect that outgoing spillovers will be larger for high-end hotels. In practice, the presence of outgoing spillovers is tested by verifying whether best performers (i.e. firms with greater efficiency ratios) define the meta-technology over time. Next, incoming spillovers represent spillovers from the hotel sector technology to the group technologies. In other words, incoming spillovers allow us to verify how the group of hotels have benefited from the technological knowledge available in the hotel sector. We expect that low-end hotels have benefited from this technological knowledge. Moreover, there is no reason why all types of hotels should not benefit from the knowledge available at the hotel sector level. In fact, we expect that technological transfer should increase with the number of stars. Therefore, for incoming spillovers, a high enough connection is expected for low-end hotels. In practice, the presence of incoming spillovers is tested by investigating whether those hotels that define the meta-technology become highly efficient over time.

Further, as pointed out earlier in Section 3.1, not only is the presence of heterogeneity between hotels important but also the presence of intra-heterogeneity. Therefore, following our multi-service approach, we also test for the presence of outgoing and incoming spillovers for each service individually. We believe this provides valuable information for policy-makers to ascertain whether and how spillover effects are present between hotels for each service separately. In light of our previous findings based on the efficiency and technology gap ratios, we expect higher spillover effects for the catering service. If this is the case, it would reveal that the progress made by high-end hotels for that service has benefited the entire star-rated hotel sector. In other words, high-end hotels would be the main group responsible for the activity

[4] See also Tsekouras et al. (2016), Walheer (2018a), and He and Walheer (2019) for more detail about these two types of spillovers.

diversification process observed at the hotel sector level.

Quantifying the spillover effects is complex in our case given our modeling of the hotel production process and the two levels of heterogeneity we consider for the hotels. Moreover, we allow for spillovers in two directions. Given the nonparametric spirit of our methodology used to compute the efficiency and technology gap ratios, we decided to rely on a nonparametric technique to quantify the spillover effects. In particular, we make use of Spearman's correlation coefficient. Spearman's correlation coefficient is a nonparametric statistic since it is based on ranks. In particular, we compute Spearman's correlation coefficient between current efficiency and technology gap ratios and past values using a one-year window; this window captures the time needed for efficiency and technology advancement to dissipate in the Chinese star-hotel sector. We present the Spearman's correlation coefficients and their $p-$values when pooling all years together in Table 2. Note that higher Spearman's correlation coefficients (i.e. smaller $p-$values) reveal greater spillover effects.

Table 2
Spillovers

Service	**Test statistics**				**$p-$values**			
	two-star	three-star	four-star	five-star	two-star	three-star	four-star	five-star
	Outgoing spillovers							
Multi	0.34	0.45	0.56	0.66	0.17	0.07	0.01	0.00
Accommodation	0.34	0.49	0.53	0.33	0.13	0.04	0.03	0.18
Catering	0.37	0.50	0.36	0.64	0.16	0.07	0.08	0.00
Others	0.41	0.33	0.52	0.47	0.07	0.19	0.04	0.06
	Incoming spillovers							
Multi	0.36	0.48	0.56	0.61	0.13	0.04	0.01	0.00
Accommodation	0.32	0.50	0.49	0.34	0.16	0.04	0.06	0.22
Catering	0.30	0.48	0.40	0.66	0.22	0.08	0.11	0.00
Others	0.41	0.38	0.49	0.46	0.19	0.14	0.02	0.06

The results in Table 2 provide strong evidence for the presence of spillovers in two directions in the Chinese star-rated hotel sector. Most of the $p-$values are small, indicating that in general the Spearman's correlation coefficients are significant. The only exceptions are two-star hotels and three-star hotels for other services. Also, incoming and outgoing spillover effects present similar Spearman's correlation coefficients for all services and groups of hotels, indicating that both phenomena are important in that sector. Next, it is confirmed that high-end hotels are the main generators of spillovers to the hotel sector. In fact, the Spearman's correlation coefficients increase with the number of stars for the outgoing spillover effects. Interestingly, the results show that five-star hotels are the main generators for the catering service and for other services, while four- (and three-) star hotels are the main generators for the accommodation service. This is in line with our previous discussion about the inputs and outputs in Section 3.1. Subsequently, we find that all hotels have benefited from the technological transfer. Again, the amplitude of this phenomenon increases with the number of stars. Finally, the presence of spillovers is confirmed for all services, while there is no obvious ranking between services in terms of outgoing and incoming spillovers. The number of stars seems to be the most important variable to explain the spillover amplitudes.

As for the efficiency and technology gap ratios, we discriminate hotels per number of stars and per service. The results for the Spearman's correlation coefficients and their $p-$values are available in Appendix C; Table C.1 refers to the multi-service level, Table C.2 to the accommodation service, Table C.3 to the catering service, and Table C.4 to other services. Again, we can see from these tables that the presence of spillovers is confirmed since most of the Spearman's correlation coefficients are highly significant. The main role of high-end hotels is also confirmed for both spillover directions. These Tables reveal other interesting features. Two-star hotels have an increasing Spearman's correlation coefficient over time for the outgoing spillover effect. Hence, these hotels have generated an increasing amount of spillovers to the hotel sector. This is mainly due to the catering service (the spillover effect is decreasing for the other services) and is consistent with our previous finding that only the best two-star hotels have been retained in the Chinese star-rated hotel sector. In contrast, the level of incoming spillovers for five-star hotels has decreased with time, while the amplitude has slowly increased for four-star hotels. This demonstrates not only that high-end hotels are the main generators of incoming spillovers, but also that five-star hotels are losing their dominant place (this has been found previously with the efficiency and technology gap ratios). Note that this is mainly due to the accommodation service.

5 Discussion and policy implications

We summarize our main findings in four points:

- We find evidence of an economic transformation of the Chinese star-rated hotel sector from the most traditional accommodation service in favor of catering and other services. Nevertheless, the performance of traditional services(accommodation service) is higher than that of new services(catering and other services).
- In general, high-end hotels are the best performers for all services for the period. More precisely, five-star hotels are the best performers for the accommodation service and other services, and four-star hotels are the best performers for the catering service. Nevertheless, our results show that the performances started to slowly decrease after 2010 for these hotel categories. This is probably due to the economic crisis in 2008—2009 and to high new investments.
- Our findings demonstrate that there is a huge performance progression for two-star hotels, which is even more evident after 2010. This reveals that the rationalization of this type of hotel has been effective.
- There is strong evidence for the presence of both incoming and outgoing spillover effects. High-end hotels are the main generators, and all types of hotel have benefited from the technological transfer. The spillover effects are more important for the accommodation and catering services.

Our findings have rich policy implications.At the overall level, our results support recent policy implementations designed to develop vigorously the tourism industry in China. In particular, the Chinese star-rated hotel sector is in line with the concept of 'all-for-one tourism'. Indeed, we find that the star-hotel sector has achieved high performances that have continually improved over the years. Similar results have been found in other recent empirical studies about this sector (Yang and Chen, 2017; Walheer and Zhang, 2018). Nevertheless, we also find that improvements are possible. We summarize our policy recommendations in three main points:

- Although high-end hotels are the most important hotels for the star-rated hotel sector in China, our results suggest that low-end hotels deserve more attention. In some situations, policy-makers could be tempted to focus their policy implementations on high-end hotels only (Santos et al., 2016). However, we find that low-end hotels present important performance improvement, while high-end hotels present a slow performance regression. Thus, policy implementations should be designed for the sector in general, while taking the specificities of each hotel category into consideration.

- While the service diversification of the Chinese star-rated hotel sector is clearly observed, the new services have not reached a satisfactory level for the performances. Nevertheless, we acknowledge the important changes that have been made to promote the new services. Therefore, developing the new services further is a key element to promote and upgrade the Chinese star-rated hotel sector.

- Technology transfer between high- and low-end hotels is an observed phenomenon for the Chinese star-rated hotel sector. This once more highlights the need for overall policy implementations. New services do not generate enough spillover effects; when this is the case, we do not observe important benefits for the sector. This aspect is of great importance to promote and upgrade the Chinese star-rated hotel sector and should thus be one of the first elements present in the new policy implementations. Potential solutions include promoting foreign investment, cooperation with foreign advanced brands, and learning advanced management experience and technology (Pine and Phillips, 2005; Mak, 2008; Mao and Yang, 2016).

6 Conclusion

In China, the tourism industry has gained in importance in terms of both economic growth and attention given by policy-makers. Recently, Chinese policy-makers have emphasized the importance of transforming and upgrading the tourism industry, while focusing on the improvement of quality and efficiency tourism components. To reach that aim, they have introduced the concept of 'all-for-one tourism', which refers both to promoting China as a tourism destination and to tourism as an advantageous industry to develop economic growth in China. The star-rated hotel sector is regarded as a pillar sector of the tourism industry. However, the fast development of that sector also comes with structural and cyclical issues.

Low- and high-end hotels are, generally, recognize as using different technologies.

Policy implementations are also more favourable for high-end hotels, and these hotels have several foreign partnerships in different forms. As a result high-end hotels are playing a leading role in that sector. Low-end hotels are the followers that are more concerned with local specificities. An important followed-up economic question is thus to verify whether there exists technological spillover in the Chinese star-rated hotel sector. In particular, spillover has to be bidirectional to benefit the entire hotel sector. One, high-end hotels have to act as the major spillover generators moving the star-rated hotel sector to better performances. Two, low-end hotels have to integrate the technological knowledge of high-end hotels, but also share their experience with local contexts.

Two particularities of our empirical study are to discriminate between hotels with respect to their number of stars (notion of inter-heterogeneity) and to recognize that hotels are multi-service decision-makers (notion of intra-heterogeneity). Moreover, we extend the concept of meta-technology specially designed to evaluate performance in the presence of heterogeneity to match our empirical investigation, and we rely on a robust non-parametric estimation method. Our findings reveal important patterns useful for both hotel managers and Chinese policy-makers.

As a final remark, we point out a natural next step of our research question. As done recently by Kounetas and Napolitano (2018) for Italy, external or environmental variables can be used to better understand technological differences between Chinese hotels. We may wish to use abundance of tourism resources (an indicator to reflect the richness of tourism resources and the attractiveness of tourism resources to consumers), openness degree (a measurement of trade openness), or location (i.e. geographical aspects). Recent studies using these variables include Deng (2018), Liu and Tai (2018) , and Hai et al. (2019). Unfortunately, data are not available for the period considered in this paper for China.

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Appendix A

Table A.1
Proportion of hotels per number of stars

Year	Total	One-star	Two-star	Three-star	Four-star	Five-star
2005	11,828	5.18	46.47	36.28	9.69	2.38
2006	12,751	4.73	44.69	37.48	10.74	2.37
2007	13,583	4.37	42.10	39.07	11.74	2.72
2008	14,099	3.67	39.83	40.51	12.92	3.06
2009	14,237	3.20	37.75	41.56	13.94	3.55
2010	11,779	1.80	30.87	45.71	17.00	4.63
2011	11,676	1.40	28.06	46.87	18.40	5.27
2012	11,367	1.25	26.57	47.32	19.23	5.63
2013	11,687	1.07	24.22	48.18	20.20	6.32
2014	11,180	0.89	22.87	48.35	21.23	6.66
2015	10,550	0.86	20.82	48.32	22.51	7.48

Table A.2
Revenue proportion by service and number of stars (%)

	Accommodation service	Catering service	Others services	Accommodation service	Catering service	Other services
Year	**two-star**			**three-star**		
2005	47.90	37.95	14.15	48.56	38.31	13.13
2006	50.34	38.56	11.10	47.24	39.40	13.37
2007	48.63	38.65	12.72	48.24	38.41	13.35
2008	47.28	39.84	12.88	44.06	40.84	15.10
2009	47.30	41.50	11.20	44.85	41.55	13.60
2010	45.33	43.07	11.60	41.76	44.99	13.25
2011	45.25	47.21	7.54	40.57	44.92	14.51
2012	45.14	43.51	11.35	38.67	46.04	15.30
2013	43.65	42.21	14.13	40.84	43.71	15.45
2014	47.45	39.47	13.08	42.55	43.72	13.73
2015	47.95	37.41	14.64	41.99	43.16	14.85
Year	**four-star**			**five-star**		
2005	50.25	35.46	14.29	53.41	32.16	14.43
2006	46.81	33.69	19.49	51.29	33.22	15.48
2007	49.77	36.34	13.89	51.99	33.54	14.47
2008	44.88	39.91	15.22	49.40	35.22	15.37
2009	45.08	41.16	13.76	47.33	39.25	13.42
2010	40.44	41.39	18.17	45.15	41.80	13.05
2011	41.23	44.06	14.71	44.41	39.22	16.37
2012	40.61	45.91	13.48	43.99	43.02	13.00
2013	42.74	43.10	14.17	45.39	40.70	13.91
2014	42.44	40.85	16.71	44.17	40.07	15.76
2015	43.08	40.92	16.00	46.32	41.19	12.49

Table A.3
Proportion of inputs and outputs by number of stars (%)

	Rooms	Total assets	Labor	Accommodation service	Catering service	Other services
Year	**two-star**					
2005	31.40	13.99	23.13	13.67	15.11	14.55
2006	29.48	11.24	22.28	15.15	15.60	10.54
2007	27.07	10.60	17.71	12.51	13.50	11.86
2008	24.86	9.70	15.81	11.93	11.91	10.03
2009	23.09	8.36	15.01	11.75	11.55	9.56
2010	16.69	6.54	11.10	7.67	7.27	5.66
2011	14.49	4.56	9.64	6.15	6.32	2.93
2012	13.12	4.60	8.59	6.05	5.38	4.59
2013	12.20	3.83	7.45	5.31	5.23	5.14
2014	11.26	3.62	6.96	5.30	4.63	4.10
2015	9.99	3.62	6.84	4.88	4.06	4.59
Year	**three-star**					
2005	41.70	31.50	41.28	32.26	35.49	31.41
2006	41.90	31.99	41.68	30.70	34.43	27.41
2007	41.91	30.40	41.07	30.67	33.15	30.76
2008	41.21	28.77	39.85	29.51	32.41	31.19
2009	41.56	27.59	39.91	31.47	32.68	32.78
2010	41.64	26.15	37.82	28.11	30.21	25.72
2011	41.42	25.37	36.87	27.16	29.62	27.80
2012	40.28	24.01	37.88	26.50	29.10	31.63
2013	40.35	23.44	35.30	25.96	28.27	29.37
2014	39.62	22.20	35.50	24.81	26.79	22.46
2015	39.19	25.60	35.87	23.47	25.77	25.57

Table A.4
Proportion of inputs and outputs by number of stars (%)

	Rooms	Total assets	Labor	Accommodation service	Catering service	Other services
Year				**four-star**		
2005	18.57	28.52	23.87	27.63	27.19	28.31
2006	20.42	30.30	25.02	28.98	28.05	38.07
2007	21.97	31.34	28.42	30.93	30.66	31.26
2008	23.72	32.17	29.48	29.72	31.31	31.09
2009	24.13	32.08	29.12	31.76	32.50	33.29
2010	27.75	33.83	32.71	32.57	33.27	42.22
2011	28.96	34.00	32.96	33.14	34.88	33.86
2012	29.32	34.08	33.07	33.41	34.82	33.45
2013	30.07	34.77	34.69	33.39	34.26	33.10
2014	31.25	35.81	34.26	33.21	33.60	36.71
2015	31.93	33.46	33.97	33.04	33.51	37.79
Year				**five-star**		
2005	8.33	25.99	11.72	26.44	22.20	25.73
2006	8.20	26.47	11.02	25.17	21.93	23.97
2007	9.05	27.67	12.80	25.90	22.69	26.12
2008	10.21	29.36	14.87	28.84	24.37	27.69
2009	11.21	31.97	15.96	25.02	23.26	24.37
2010	13.92	33.47	18.37	31.66	29.25	26.40
2011	15.13	36.07	20.54	33.55	29.18	35.40
2012	17.27	37.31	20.47	34.04	30.70	30.34
2013	17.38	37.96	22.56	35.34	32.25	32.39
2014	17.87	38.38	23.28	36.69	34.98	36.74
2015	18.89	37.32	23.31	38.61	36.66	32.06

Appendix B

Table B.1
Efficiency and technology gap for multi-service: number of stars

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Efficiency: two-star											
Average	0.72	0.73	0.76	0.70	0.71	0.78	0.76	0.86	0.82	0.86	0.81
% efficient	3.54	7.15	7.60	7.69	8.57	9.14	11.51	14.18	13.59	14.28	17.15
Efficiency: three-star											
Average	0.72	0.68	0.62	0.65	0.64	0.78	0.81	0.79	0.78	0.76	0.73
% efficient	7.04	3.59	5.21	7.16	10.69	7.16	7.07	10.66	10.71	14.26	11.04
Efficiency: four-star											
Average	0.75	0.62	0.70	0.72	0.77	0.80	0.79	0.83	0.77	0.79	0.76
% efficient	21.46	10.74	17.86	14.31	17.88	3.57	7.15	17.87	3.58	17.84	14.28
Efficiency: five-star											
Average	0.86	0.75	0.79	0.82	0.77	0.79	0.81	0.84	0.84	0.79	0.75
% efficient	24.97	10.73	21.41	17.84	14.29	14.31	14.32	7.16	21.42	17.84	10.68
Technology gap: two-star											
Average	0.82	0.80	0.86	0.85	0.84	0.92	0.89	0.92	0.90	0.92	0.88
% no gap	25.02	25.01	46.43	42.89	32.17	46.41	24.98	42.86	42.85	42.88	49.98
Technology gap: three-star											
Average	0.82	0.75	0.74	0.76	0.79	0.82	0.87	0.85	0.79	0.83	0.84
% no gap	21.41	17.88	14.27	35.70	21.42	21.44	35.70	32.14	21.41	24.98	35.72
Technology gap: four-star											
Average	0.85	0.72	0.79	0.77	0.87	0.84	0.84	0.85	0.84	0.82	0.85
% no gap	32.13	32.12	39.27	32.14	32.12	21.43	28.58	28.54	32.15	32.14	28.58
Technology gap: five-star											
Average	0.91	0.82	0.86	0.86	0.82	0.87	0.85	0.88	0.85	0.82	0.86
% no gap	42.88	35.71	46.46	42.83	35.69	28.60	35.71	28.56	28.54	28.56	21.42

Table B.2
Efficiency: number of stars

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Accommodation service: two-star											
Average	0.83	0.83	0.81	0.82	0.81	0.89	0.92	0.90	0.90	0.82	0.83
% efficient	35.70	35.69	35.70	46.43	28.55	46.45	42.88	57.14	46.43	35.71	28.59
Accommodation service: three-star											
Average	0.80	0.81	0.73	0.82	0.84	0.89	0.90	0.83	0.76	0.83	0.80
% efficient	35.70	32.16	24.99	28.56	35.71	39.27	35.72	39.28	32.16	46.42	28.55
Accommodation service: four-star											
Average	0.82	0.70	0.73	0.79	0.87	0.83	0.89	0.88	0.85	0.84	0.79
% efficient	49.99	35.70	49.98	42.85	39.30	28.59	42.88	50.00	35.73	35.72	35.72
Accommodation service: five-star											
Average	0.95	0.86	0.84	0.89	0.89	0.91	0.91	0.87	0.87	0.80	0.82
% efficient	57.16	49.99	53.55	60.69	50.01	39.29	42.84	39.27	57.13	46.44	50.01
Catering service: two-star											
Average	0.77	0.66	0.72	0.65	0.63	0.84	0.81	0.85	0.82	0.85	0.87
% efficient	21.44	25.00	14.29	7.15	21.43	50.00	28.56	42.87	35.71	35.71	39.30
Catering service: three-star											
Average	0.79	0.68	0.74	0.60	0.64	0.82	0.85	0.85	0.84	0.78	0.82
% efficient	32.15	17.86	21.43	14.30	17.85	35.70	28.58	39.30	39.30	39.30	39.29
Catering service: four-star											
Average	0.81	0.76	0.82	0.78	0.85	0.90	0.83	0.88	0.89	0.89	0.87
% efficient	42.86	39.28	39.30	35.72	32.12	39.28	32.13	46.41	53.55	46.42	42.86
Catering service: five-star											
Average	0.84	0.73	0.82	0.70	0.71	0.86	0.83	0.84	0.86	0.83	0.82
% efficient	39.29	32.14	46.41	28.58	28.58	46.41	42.88	42.85	35.70	35.69	28.58
Other services: two-star											
Average	0.64	0.65	0.66	0.69	0.63	0.66	0.70	0.84	0.74	0.73	0.70
% efficient	10.70	14.29	32.13	28.56	17.85	25.00	28.57	39.31	21.43	39.29	28.57
Other services: three-star											
Average	0.61	0.55	0.44	0.48	0.53	0.54	0.61	0.72	0.62	0.67	0.68
% efficient	14.30	14.30	-0.01	10.72	10.72	17.85	10.72	25.00	24.99	17.87	21.43
Other services: four-star											
Average	0.64	0.50	0.64	0.56	0.61	0.58	0.68	0.69	0.61	0.63	0.59
% efficient	28.57	14.29	25.00	17.86	21.45	10.70	17.87	28.58	17.87	21.42	17.87
Other services: five-star											
Average	0.77	0.70	0.70	0.81	0.71	0.72	0.67	0.80	0.77	0.75	0.73
% efficient	42.86	32.13	32.14	42.85	42.85	35.71	35.70	32.13	35.72	28.56	32.12

Table B.3
Technology gap: number of stars

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Accommodation service: two-star											
Average	0.87	0.90	0.82	0.85	0.83	0.92	0.92	0.94	0.92	0.89	0.91
% no gap	39.31	39.29	46.41	46.42	35.71	53.56	50.00	60.70	50.02	49.99	42.86
Accommodation service: three-star											
Average	0.83	0.83	0.76	0.83	0.85	0.91	0.89	0.82	0.79	0.83	0.82
% no gap	39.31	32.13	28.56	35.72	39.31	39.30	35.70	42.86	32.15	46.43	35.70
Accommodation service: four-star											
Average	0.87	0.73	0.77	0.83	0.86	0.87	0.87	0.89	0.84	0.87	0.82
% no gap	53.56	42.86	53.58	50.02	39.30	35.70	42.87	53.57	46.43	39.31	39.29
Accommodation service: five-star											
Average	0.98	0.88	0.86	0.90	0.92	0.92	0.93	0.88	0.87	0.83	0.85
% no gap	60.73	53.58	57.15	60.70	60.69	46.44	46.42	42.87	57.14	46.44	53.57
Catering service: two-star											
Average	0.80	0.71	0.78	0.75	0.73	0.89	0.82	0.91	0.88	0.96	0.91
% no gap	32.13	35.71	35.71	46.44	42.88	57.16	32.15	60.73	46.42	71.42	57.14
Catering service: three-star											
Average	0.85	0.80	0.77	0.71	0.74	0.82	0.89	0.86	0.85	0.83	0.88
% no gap	60.72	42.87	28.57	25.01	35.69	39.28	39.31	49.99	46.41	42.85	42.86
Catering service: four-star											
Average	0.84	0.77	0.83	0.82	0.93	0.90	0.86	0.90	0.90	0.89	0.92
% no gap	42.86	46.45	50.00	46.42	46.45	42.84	35.69	57.15	64.31	53.58	49.99
Catering service: five-star											
Average	0.88	0.76	0.88	0.79	0.78	0.86	0.88	0.87	0.85	0.82	0.82
% no gap	53.56	42.84	60.73	42.87	35.70	50.02	46.44	50.01	42.86	35.72	35.71
Other services: two-star											
Average	0.77	0.78	0.84	0.82	0.80	0.79	0.81	0.86	0.86	0.83	0.85
% no gap	39.31	46.45	60.72	53.59	57.12	60.71	46.41	57.12	50.00	57.15	67.85
Other services: three-star											
Average	0.73	0.61	0.63	0.71	0.73	0.67	0.78	0.82	0.74	0.79	0.79
% no gap	24.99	17.87	14.30	32.14	24.98	32.13	39.30	42.87	35.69	42.86	42.85
Other services: four-star											
Average	0.70	0.60	0.61	0.75	0.72	0.72	0.73	0.75	0.68	0.72	0.70
% no gap	42.85	28.57	35.71	35.72	35.69	32.13	46.45	32.14	25.00	39.29	32.13
Other services: five-star											
Average	0.81	0.76	0.74	0.89	0.77	0.69	0.75	0.82	0.85	0.80	0.75
% no gap	53.59	46.43	49.99	57.13	49.99	35.70	49.99	46.44	46.42	35.72	39.30

Appendix C

Table C.1
Spillovers: multi-service

Year	Test statistics				$p-$values			
	two-star	three-star	four-star	five-star	two-star	three-star	four-star	five-star
	Outgoing spillover							
2006—2005	0.34	0.55	0.68	0.51	0.07	0.00	0.01	0.00
2007—2006	0.31	0.31	0.46	0.48	0.12	0.13	0.02	0.01
2008—2007	0.29	0.14	0.70	0.61	0.14	0.45	0.00	0.01
2009—2008	0.26	0.45	0.60	0.62	0.00	0.01	0.01	0.00
2010—2009	0.13	0.32	0.36	0.55	0.50	0.11	0.05	0.02
2011—2010	0.42	0.50	0.56	0.47	0.03	0.00	0.01	0.01
2012—2011	0.53	0.66	0.59	0.64	0.00	0.00	0.01	0.00
2013—2012	0.44	0.53	0.37	0.80	0.01	0.01	0.05	0.01
2014—2013	0.36	0.67	0.54	0.72	0.06	0.00	0.00	0.00
2015—2014	0.12	0.44	0.62	0.65	0.57	0.02	0.01	0.00
	Incoming spillover							
2006—2005	0.33	0.43	0.66	0.51	0.10	0.02	0.00	0.00
2007—2006	0.40	0.36	0.56	0.53	0.02	0.06	0.01	0.00
2008—2007	0.15	0.29	0.55	0.38	0.44	0.11	0.00	0.04
2009—2008	0.55	0.48	0.70	0.59	0.00	0.01	0.01	0.00
2010—2009	0.17	0.53	0.36	0.42	0.40	0.00	0.04	0.02
2011—2010	0.64	0.72	0.48	0.51	0.00	0.00	0.01	0.00
2012—2011	0.43	0.45	0.49	0.53	0.02	0.02	0.01	0.01
2013—2012	0.37	0.56	0.42	0.70	0.06	0.00	0.03	0.00
2014—2013	0.47	0.75	0.41	0.77	0.02	0.00	0.02	0.01
2015—2014	0.38	0.64	0.60	0.80	0.06	0.00	0.00	0.01

Table C.2
Spillovers: accommodation service

Year	Test statistics				$p-$**values**			
	two-star	three-star	four-star	five-star	two-star	three-star	four-star	five-star
	Outgoing spillover							
2006—2005	0.34	0.48	0.69	0.08	0.07	0.01	0.00	0.65
2007—2006	0.30	0.30	0.43	0.25	0.12	0.10	0.02	0.17
2008—2007	0.36	0.36	0.58	0.47	0.06	0.05	0.00	0.03
2009—2008	0.67	0.37	0.67	0.35	0.00	0.04	0.00	0.05
2010—2009	0.48	0.26	0.51	0.04	0.00	0.16	0.01	0.86
2011—2010	0.29	0.80	0.56	0.23	0.12	0.00	0.00	0.23
2012—2011	0.44	0.63	0.19	0.23	0.01	0.00	0.33	0.19
2013—2012	0.27	0.56	0.53	0.51	0.18	0.01	0.01	0.00
2014—2013	0.20	0.57	0.47	0.41	0.36	0.00	0.00	0.03
2015—2014	0.43	0.50	0.69	0.29	0.02	0.01	0.00	0.15
	Incoming spillover							
2006—2005	0.32	0.54	0.63	0.39	0.09	0.00	0.00	0.05
2007—2006	0.27	0.44	0.22	0.12	0.18	0.01	0.24	0.56
2008—2007	0.13	0.30	0.46	0.33	0.52	0.12	0.01	0.11
2009—2008	0.56	0.47	0.59	0.47	0.00	0.01	0.01	0.01
2010—2009	0.45	0.30	0.54	0.11	0.01	0.11	0.00	0.69
2011—2010	0.20	0.88	0.47	0.25	0.28	0.00	0.01	0.25
2012—2011	0.40	0.61	0.15	0.11	0.04	0.00	0.40	0.53
2013—2012	0.22	0.55	0.43	0.50	0.24	0.01	0.03	0.01
2014—2013	0.24	0.72	0.34	0.56	0.20	0.00	0.05	0.00
2015—2014	0.29	0.50	0.64	0.49	0.10	0.00	0.02	0.00

Table C.3
Spillovers: catering service

Year	Test statistics				$p-$values			
	two-star	three-star	four-star	five-star	two-star	three-star	four-star	five-star
	Outgoing spillover							
2006—2005	0.58	0.46	0.55	0.66	0.00	0.02	0.00	0.01
2007—2006	0.31	0.44	0.52	0.56	0.11	0.02	0.01	0.00
2008—2007	0.46	0.08	0.51	0.50	0.01	0.59	0.00	0.01
2009—2008	0.79	0.59	0.53	0.61	0.00	0.01	0.01	0.00
2010—2009	0.36	0.43	0.42	0.46	0.06	0.04	0.02	0.01
2011—2010	0.13	0.60	0.41	0.74	0.57	0.00	0.03	0.00
2012—2011	0.20	0.75	0.11	0.58	0.33	0.01	0.57	0.00
2013—2012	0.33	0.44	0.29	0.50	0.11	0.01	0.13	0.00
2014—2013	0.27	0.53	0.48	0.55	0.16	0.00	0.01	0.00
2015—2014	0.56	0.55	0.55	0.69	0.00	0.01	0.00	0.01
	Incoming spillover							
2006—2005	0.51	0.33	0.66	0.63	0.01	0.09	0.00	0.00
2007—2006	0.28	0.40	0.53	0.65	0.13	0.04	0.01	0.01
2008—2007	0.41	0.14	0.46	0.66	0.04	0.47	0.01	0.00
2009—2008	0.73	0.42	0.47	0.67	0.00	0.02	0.01	0.00
2010—2009	0.29	0.70	0.17	0.40	0.18	0.00	0.39	0.04
2011—2010	0.13	0.67	0.38	0.61	0.62	0.00	0.06	0.00
2012—2011	0.26	0.54	0.14	0.48	0.25	0.01	0.49	0.01
2013—2012	0.28	0.55	0.46	0.58	0.23	0.00	0.02	0.00
2014—2013	0.24	0.50	0.57	0.57	0.27	0.02	0.00	0.00
2015—2014	0.19	0.69	0.49	0.79	0.38	0.01	0.00	0.01

Table C.4
Spillovers: other services

Year	Test statistics				$p-$**values**			
	two-star	three-star	four-star	five-star	two-star	three-star	four-star	five-star
	Outgoing spillover							
2006—2005	0.39	0.48	0.30	0.39	0.05	0.02	0.10	0.05
2007—2006	0.28	0.13	0.42	0.62	0.14	0.48	0.03	0.00
2008—2007	0.37	0.16	0.76	0.15	0.06	0.39	0.00	0.48
2009—2008	0.25	0.46	0.55	0.46	0.19	0.02	0.02	0.01
2010—2009	0.51	0.40	0.55	0.54	0.01	0.04	0.00	0.00
2011—2010	0.74	0.22	0.63	0.33	0.00	0.28	0.01	0.07
2012—2011	0.57	0.11	0.65	0.32	0.00	0.59	0.00	0.08
2013—2012	0.36	0.35	0.30	0.55	0.06	0.05	0.14	0.00
2014—2013	0.49	0.52	0.38	0.72	0.01	0.01	0.04	0.00
2015—2014	0.42	0.36	0.22	0.69	0.02	0.04	0.22	0.00
	Incoming spillover							
2006—2005	0.13	0.26	0.47	0.40	0.53	0.17	0.02	0.04
2007—2006	0.39	0.22	0.33	0.33	0.05	0.25	0.07	0.07
2008—2007	0.13	0.50	0.55	0.32	0.58	0.01	0.01	0.09
2009—2008	0.29	0.49	0.61	0.17	0.11	0.03	0.00	0.37
2010—2009	0.23	0.33	0.42	0.55	0.30	0.09	0.03	0.00
2011—2010	0.56	0.34	0.59	0.36	0.00	0.08	0.01	0.05
2012—2011	0.69	0.13	0.58	0.46	0.00	0.49	0.00	0.03
2013—2012	0.73	0.29	0.35	0.40	0.00	0.14	0.05	0.04
2014—2013	0.56	0.65	0.39	0.50	0.00	0.00	0.04	0.02
2015—2014	0.65	0.61	0.33	0.66	0.00	0.01	0.09	0.00