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Pushing the Frontier of Sustainable Service Operations Management: Evidence from US hospitality industry

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Abstract

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Design/methodology/approach: This study applies exploratory factor analysis (EFA) to a six-year panel dataset of 984 US hotels to construct a two-factor standardized measure of environmental sustainability. The authors then conduct a stochastic frontier analysis (SFA) to investigate the relationship between the measured environmental sustainability and the operating performance frontier, considering the impact of operating structure.

Findings: Customer behavior and operational decisions are two key drivers of environmental sustainability. There is a positive link between environmental sustainability and operating performance. Operating structure has a significant impact on the operating performance. The performance frontier varies across market segment and location characteristics such as degree of urbanization and climate condition.

Practical implications: The findings indicate that service providers should actively involve customers, and manage both front-office and back-office operations in environmental sustainability initiatives. Operating structures that favor the alignment of multiple service supply chain partners' interests contribute positively to performance. The managers should be mindful of varying best-in-class performance due to operating unit characteristics such as market segment, and location characteristics.

Originality/value: This study is among the first attempts to develop a performance measurement system of environmental sustainability. The resulted standardized measure of environmental sustainability considers both the revenue and cost impacts in service operations.

This research is among the first generation of papers that bring the unique characteristics of service operations, particularly service co-production, into sustainability research.

Keywords
service co-production, resource efficiency, environmental sustainability, performance measurement system, United States of America, consumer behavior, performance measures

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Hospitality Administration and Management

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Introduction

The impact of the service sector on energy consumption, emissions, and wastes is substantial and growing (Rosenblumet al., 2000). For instance, a 10 percent reduction in energy consumption across the US hospitality industry alone is equivalent to taking 1,000,000 cars off the road for one year (AH&LA, 2011). Such impact will increase further as emerging economies join the advanced industrialized countries and become service economy (Metters and Marucheck, 2007). For service sector in general and for hospitality industry in particular, the design and implementation of sustainability practices pose key competitive and ethical challenges (Deloitte, 2010). How to reduce the environmental impact through sustainable initiatives while maintaining competitiveness has been a question of great importance to both practitioners and researchers. In spite of strong research interest, this question is still not well understood (Ambec and Lanoie, 2008). We attribute this lack of understanding to the knowledge gaps currently existing in three areas.

First, one key barrier in sustainable development arises from the lack of consistent environmental sustainability (ES) performance metrics (Schleich and Gruber, 2008). For example, researchers have operationalized the construct of environmental performance distinctively, ranging from the adoption of environmental management system or standard (Melnyk et al., 2003; Corbett et al., 2005) to the announcements of environmental awards or crises (Klassen and McLaughlin, 1996). Significant challenge arises when one tries to compare or generalize across these diverse indirect measures of environmental performance. Drawing on the service performance measurement literature (Fitzgerald et al., 1991; Johnston and Jones, 2004; Neely et al., 2005), we operationalize the measurement of ES in terms of resource efficiency – the total cost of resources (e.g. electricity, water, and materials) used to produce one unit of revenue. We then use a large-scale secondary data that conforms to industry standard to identify the common drivers of ES in service operation.

Second, prior sustainable operations management research has concentrated in manufacturing settings (Angell and Klassen, 1999; Kleindorfer et al., 2005; Corbett and Klassen, 2006). However, customer service co-production creates a situation that is uncommon in manufacturing settings, because customers are both consumers and suppliers (Bitner et al., 1997; Sampson, 2000; Bettencourt et al., 2002; Johnston and Jones, 2004). Further, the value underpinning and social dimension of sustainable development (Adams, 2006) points to an increasingly important role of customers in ES initiatives as value co-creation becomes the dominant logic (Grönroos and Ravald, 2011). To address the growing need for theories in sustainable service operations, we examine resource and revenue data at service operating units, which is equivalent to manufacturing plant level data commonly used to study operations practices and outcomes (Flynn and Sakakibara, 1995).

Third, knowledge gap exists in the relationship between environmental practices and economic performance. Researchers have directed substantial attention to this topic, but their empirical findings have been inconclusive (Dowell et al., 2000; King and Lenox, 2001a, b, 2002; Ambec and Lanoie, 2008). We address this issue by investigating the environmental and economic performance of the best-in-class performers and best practices (Schmenner and Swink, 1998; Angell and Klassen, 1999). Researchers have successfully applied such approach to areas ranging from new product development (NPD) (Swink et al., 2006) to manufacturing capability and proficiency (Lieberman and Dhawan, 2005). Because these research areas and ES share the same emphasis on innovation and continuous performance improvement, sustainability research can also benefit from investigating the operating characteristics of the best performers.

We aim to fill these three knowledge gaps through investigating the following research question:

RQ1: How does ES relate to the best-in-class operating performance in service settings?

The contributions from this research are:

1. We identify a standardized two-factor operational measure to assess ES in a service setting.
2. We offer a conceptual model to understand how ES and operating structures relate to the operating performance frontier.
3. We empirically test the framework and estimate the performance impact of ES in a service supply chain, using a panel dataset featuring 984 US hotels from 2001 to 2006.

The rest of the paper is organized as follows: in Section 2, we propose a standardized measure of ES, and develop two hypotheses to link this measure to best-in-class operating performance in a service supply chain setting. In Section 3, we describe the research design and the empirical methodologies and briefly discuss several robustness checks. In Section 4, we report empirical results. In Section 5, we discuss the managerial implications of our findings, limitations of this paper and future research directions. In Section 6, we provide conclusions.

Theory Development

A Conceptual Framework of ES and Operating Performance

We propose a systematic approach to measuring ES and linking it to firm performance. To this end, three hierarchical considerations demand attention (Neely et al., 2005). First, at individual measurements level, how to reduce the large number of measurements to fewer meaningful and managerially actionable dimensions is a key challenge (Neely et al., 2005). Take hotels as an example, fundamental resources consumed in operations include electricity, fuel, water, materials, etc. A large set of measures exist to track these resources in terms of raw consumption, utility costs, and allocation to various functional departments. Without a robust method to streamline the records, little actionable information can emerge from this ocean of data. Second, at the operating unit level, when integrating these individual measurements into the operational decision-making process, it is important to first identify the performance results and the determinants, and then understand the relationship between the two in order to influence action (Fitzgerald et al., 1991). Third, at the firm boundary, performance measurement systems need to interface with external forces such as competitors and stakeholders (Neely et al., 2005). Relative performance measures are therefore preferred (Globerson, 1985) because benchmarking against a firm's competitors is central to finding ways to continuously improve and inform stakeholders.

The conceptual model shown in Figure 1 addresses the above three questions and explores the relationship between ES measurement and operating performance. First, we operationalize the performance measure of ES in terms of the cost efficiency of resource consumption. This operationalization aligns with the resource productivity principle (Daly, 1990; Lovins and Lovins, 2001). The ES measure derived from exploratory factor analysis (EFA) is a standardized score that condenses the information contained in resource costs (normalized by revenue) into fewer managerially meaning dimensions.

Second, we explore how profitability, as a fundamental performance result, is related to ES. Prior research has offered diverging perspectives on the economic performance impact of ES. For example, Porter and van der Linde (1991, 1995) argued that improving environmental performance reduces waste and increases productivity, thus improving corporate performance. In comparison, Walley and Whitehead (1994) argued that environmental initiatives that systematically increase profitability are rare, therefore managers must acknowledge the trade-offs between economic competitiveness and environmental protection. This controversy has persisted as empirical researchers presented inconsistent findings (Dowell et al., 2000; King and Lenox, 2001a, b, 2002; Ambec and Lanoie, 2008). We argue that, in addition to understanding the correlation between environmental and economic performance in average cases, researchers can contribute further by investigating the factors that are responsible for an operating unit's underperformance from the best-in-class. The theory of performance frontiers (TPF) (Schmenner and Swink, 1998) offers the framework to understand this issue. The TPF maintains that inefficiencies are influenced by managerial decisions, operating characteristics, and external forces. Therefore, resolving these inefficiencies through rationalizing resource utilization will reduce the plant's distance from the performance frontier, i.e. best-in-class performance. Researchers have applied the TPF to a number of empirical research settings including the US airline industry (Lapre and Scudder, 2004) and NPD projects (Swink et al., 2006). The main focus of these empirical studies is to investigate how various operating characteristics contribute to performance shortfalls when measured against the best performers. Similarly, our study applies the TPF to analyzing the role of ES in performance deviation from the best-in-class.

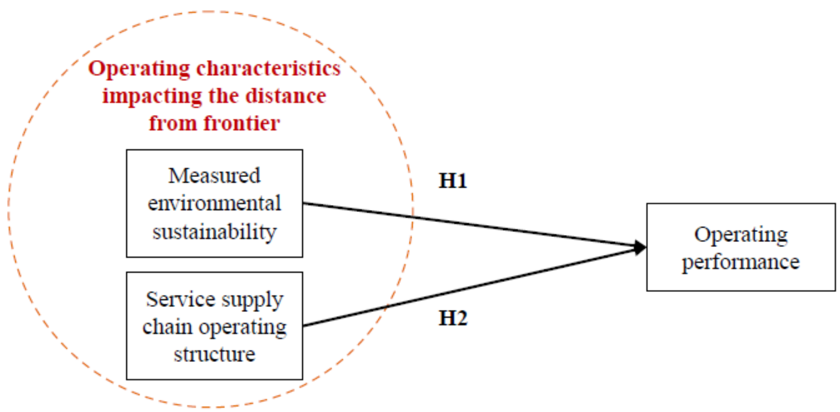

Figure 1. A conceptual model linking ES to operating performance

Third, the frontier framework enables benchmarking. By analyzing relative performance among operating units, and bringing the best-in-class operating units into the spotlight, this framework aligns with the continuous improvement mission of performance measurement systems, such as those championed by the Malcolm Baldrige National Quality Award in the USA and the European Quality Award. Our conceptual framework focuses on two operating characteristics – ES performance measure and the operating structure in service supply chain – that are central to the ES and performance link in service operations. We will develop two hypotheses regarding the relationship between these two operating characteristics and the operating performance in the next two sections.

ES Rooted in Service Co-Production

We argue that ES in service operations is contingent upon service co-production, because customer is both the consumer and supplier of the service (Bitner et al., 1997; Sampson, 2000; Bettencourt et al., 2002; Johnston and Jones, 2004). During a service encounter, customer inputs, in the form of the customers themselves, their tangible belongings, and the information they provide, are instrumental in shaping the service outcome (Sampson and Froehle, 2006), affecting both customer satisfaction and environmental outcomes. Sustainability research in service settings has presented empirical evidence supporting the notion that environmental practices are positively related to performance through the mediating effect of enhanced customer satisfaction and loyalty (Kassinis and Soteriou, 2003). In this paper, we hypothesize that ES is positively related to operating performance when customer and service provider co-produce for improved ES, resulting in reduced cost, enhanced revenue, or both.

The impact of environmental initiatives on cost saving is well known. The cost savings may accumulate through resource consumption reduction and waste prevention during production (Guide et al., 2000; King and Lenox, 2002). In service settings, customer's central role in co-producing the service means that customer buy-in is crucial to realizing the performance gain from energy conservation or waste prevention. Case evidence showed that customer involvement in conservation and recycling makes both environmental and economic sense (Enz and Siguaw, 1999). Research also found that environmental initiatives such as linen, towel reuse programs save substantial operating costs through customer participation (Stipanuk, 2001).

Revenue enhancement through improving sustainability of service operations is relative new but gaining traction. In our society, environmental sensibility continues to grow (GfK, 2011). A recent survey showed that 65 percent of corporate travel executives responsible for over $10MM in annual travel budgets are in various stages of implementing green business travel guidelines (HSPI, 2011). Individual customers also voiced their support for various energy-conservation technologies (Susskind and Verma, 2011). Therefore, early movers in sustainable service operations are poised to capture the growing market interested in green service offerings. To summarize, we hypothesize that there is a positive link between the measured ES and operating performance (link 1 in Figure 1):

H1: ES, when normalized with respect to revenue, is positively associated with gross operating profit.

Service Operating Structure

In services, multiple business entities often come together to provide the service. Franchise arrangement serves as an example. The performance of an establishment depends on the franchisor that focuses on the brand development, and the franchisee who owns the outlet and either self-manage the day-to-day operations or outsource it. The operating structure therefore formalizes the relationship between the owner and operator and ties together the owner's entrepreneurial investments and the operator's management expertise and sometimes brand equity. We hypothesize that operating structures that are inherently favorable for the multiple partners' interests to be aligned contribute positively to performance. This hypothesis is built on the following two considerations.

First, the number of self-interested partners can negatively impact the service supply chain performance. When the operating structure involves more partners, the setup and coordination costs are higher: not only the initial contracting process becomes more complex; and the ongoing decision-making processes must harmonize their diverse conflicting interests. For example, energy efficiency improvement opportunities are often identified by the hotel operator but must be approved and funded by the hotel owner. Because the operator is compensated on revenue (short term) and the owner is interested in ROI and asset appreciation (long term), the difference in performance time framework and diverging interests often result in a split-incentive problem (Schleich and Gruber, 2008). Evidence from the commercial real estate market (Fisher and Rothkopf, 1989; Jaffe and Stavins, 1994) suggests that such split-incentive problem is the root cause for lackluster investment in energy efficiency. Conversely, it is conceivable that better performance may arise from simpler operating structure where fewer self-interested partners collaborate to provide service.

Second, if the operating structure involves outsourcing, the asset specificity is lower, and the danger of opportunism is higher (Williamson, 1975).Evidence from the hotel industry suggests that site specificity and brand capital are the most pertinent dimensions of asset specificity and high asset specificity results in insourcing (Lamminmaki, 2005). In other words, when all partners commit tangible and/or intangible assets, it is in their best interest to collaborate and maximize the combined payoff. It is therefore logical to expect less negative impact from opportunism when the operating structure only involves insourcing. To summarize, we hypothesize that the operating structure affects the operating performance (link 2 in Figure 1):

H2: Operating structures that are simpler (fewer partners) and only use insourcing are associated with higher gross operating profit, when one assesses ES on the basis of resource efficiency.

Empirical Study

In this section, we describe the empirical research design for testing the conceptual framework and associated hypotheses shown in Figure 1. First, we discuss the research context and unit of analysis. We then explain the empirical methods:

- The EFA method for constructing the ES measure in terms of resource efficiency.
- The stochastic frontier analysis (SFA) method for estimating the relationship between the ES measure and the best-in-class operating performance.

Finally, we discuss what we may expect from the SFA and briefly discuss several robustness checks.

The hospitality industry renders a unique opportunity to observe sustainability within a service context. First, the hospitality industry is characterized both as a real estate investment for the property owners and as a service opportunity between the hotel operators and guests. ES is a central issue in the service operations for all parties involved (CHR, 2009). Second, the operating structure is a fundamental decision in the industry. Often, a hotel owner chooses to franchise and hire a chain to operate it (branded management), or franchise and hire a professional management company to operate it (franchise plus nonbranded management). There are fewer parties involved in the branded management operating structure, where the management is not outsourced to parties without asset commitment. Therefore, the operating structures in the hospitality industry have the variability necessary for studying the issue at hand. Third, the extensive reporting system required by the operating structure yields high quality data on performance as well as operating details. Finally, the managerial insights and policy implications generated from this research are applicable to similarly structured service industries such as retail and commercial real estate supply chains.

The unit of analysis is the operating unit – individual hotel property – rather than the industry or firm (for example, a hotel chain). A hotel site is equivalent to a manufacturing plant and plant level data are commonly used in operations management research (Flynn and Sakakibara, 1995). It is at individual hotel sites that lodging services are produced and consumed, and that the cost and revenue data are compiled for reporting.

We use a six-year panel dataset of 984 US hotel properties' operating statements from 2001 to 2006. This panel dataset is a representative subset of over 6,000 hotels annually surveyed by the PKF Hospitality Research (PKF-HR).

ES Assessment in US Hotels

We apply EFA (Hair et al., 1995) to the resource consumption data of the hotels in the sample to develop a measure of ES. Resources consumed include five expense items in the operating statement – electricity, water, and sewer expenses, as well as various material supplies consumed in Rooms Department, Food and Beverage (F&B) Department, and Maintenance and Engineering Department, all normalized by revenue per available room (RevPAR). To reduce the influence of extreme values, we winsorized the five expense items at 99.5 percent (h = 0.25 percent) level (Cox, 1998). Using principal factor extraction method and oblique promax rotation in EFA (Table I), we obtain two-factors shown in Table I.

Table I. Rotated factor loadings from EFA

Variables	Customer Behavior Cost Factor (CBCF)	Operating Cost Factor (OCF)
Electricity expense (% of RevPAR)	0.18	*0.53*
Water and sewer expense (% of RevPAR)	−0.15	*0.51*
Maintenance other expense (% of RevPAR)	*0.45*	0.34
Rooms laundry linen supplies (LLS) expense (% of RevPAR)	*0.65*	0.00
F&B laundry linen supplies (LLS) expense (% of RevPAR)	*0.67*	−0.15

Notes: Due to missing variable, the number of observations is 5,897, principal factor extraction method, oblique promax rotation Kaiser on; the RevPAR normalized expense variables were treated with Winsor, a STATA routine for winsorization Version 1.3.0 (Cox, 1998); we set $h = 0.25$ percent in this analysis; EFA extracts two-factors from five expense items in hotel operations, 2001-2006

The loadings in Table I meet the guidelines for item-to-factor loadings suggested by Comrey and Lee (1992) – the loadings for electricity and water and sewer are close to 0.55 (good), the loading for maintenance other expense is 0.45 (fair), and the loadings for Rooms linen, laundry, and supplies (LLS) and F&B LLS are above 0.63 (very good). We observe that the Rooms and F&B LLS expenses load heavily on Factor 1, but very slightly on Factor 2. AH&LA's 2010 Lodging Survey found that nearly 90 percent of the hotels surveyed reported to have a linen and towel reuse program. It follows that the customer behavior determines the usage of linens, towels, and supplies. We posit that Factor 1 captures the influence of customer behavior on resource consumption and name it the "Customer Behavior Cost Factor" (CBCF). The roughly equal coefficients for Rooms LLS and F&B LLS further supports this characterization, since the same set of hotel customers are likely to drive the similar varying pattern in LLS consumption.

Electricity and water expenses load heavily on Factor 2, but less on Factor 1. Research of historic data (Mandelbaum, 2004) revealed that utility costs consistently ranged from 3.5 to 4.5 percent of total revenue. Because revenue expands and contracts during business cycles, this historic trend suggests that hotel managers can influence Factor 2 through operating procedure or facility management, so we name Factor 2 the "Operating Cost Factor" (OCF). Both wear and tear resulted from hotel customer' activities and hotel operators' maintenance operations contribute to maintenance other expense, as indicated by the similar loadings (0.45 and 0.34) on CBCF and OCF in Table I.

The EFA results suggest that both the customer-facing front-office and operating-focused back-office operations (Silvestro et al., 1992) are crucial drivers of sustainable service operations.

Stochastic Frontier Analysis

Frontier analysis provides a relative ranking of the operating units. This methodology has been applied to health care (Jacobs, 2001; Greene, 2004; Theokary and Ren, 2011), NPD (Swink et al., 2006), financial markets (Habib and Ljungqvist, 2005), and manufacturing (Lieberman and Dhawan, 2005), to study performance differentials and identify contributing operating characteristics. We choose SFA (Aigner et al., 1977; Meeusen and van den Broeck, 1977) for this paper because ES in the service setting is a complex phenomenon fraught with uncertainty, and open to a variety of random shocks from the natural environment, regulatory change, and social movements. By modeling heterogeneous operating unit characteristics as well as stochastic noises and measurement errors, SFA is uniquely suitable for analyzing the performance differentials across operating units.

Figure 2 shows how the conceptual model shown in Figure 1 is formalized in the US hospitality industry. An operating unit's performance is jointly determined by:

- the frontier output, which is the best-in-class performance in value creation from the factor inputs (e.g. capital, labor, and material costs);
- the efficiency of production, which is related to the heterogeneous operating unit and supply chain characteristics including environment sustainability load factors and operating structures; and
- controlling for a number of market, geographic, and economic conditions.

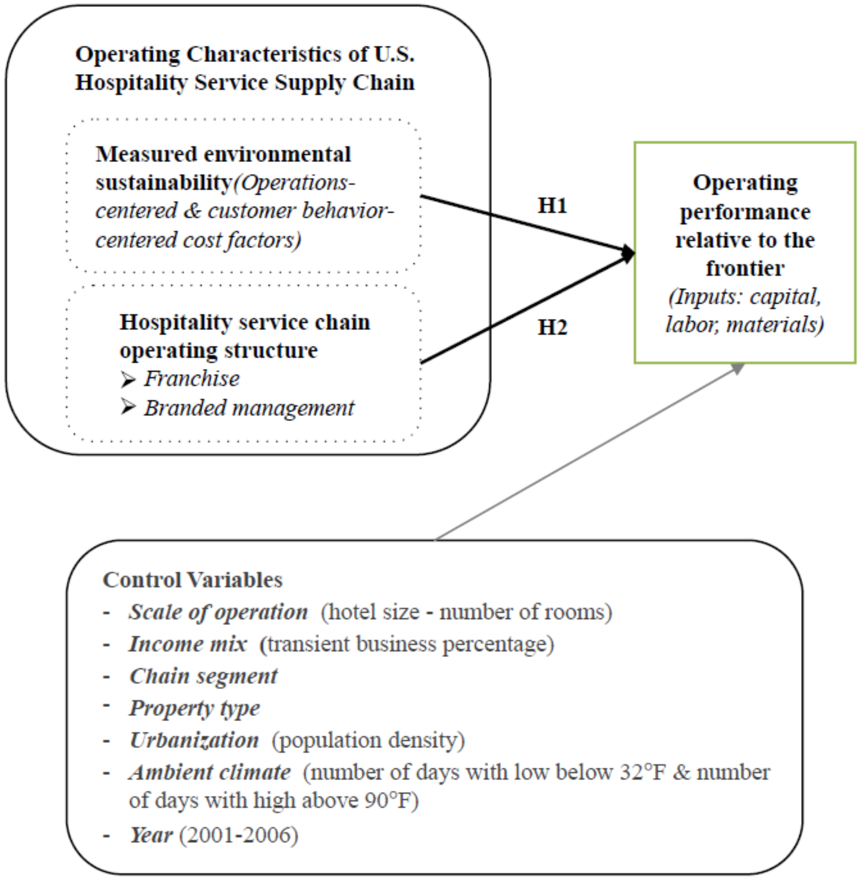

Figure 2. Testing the conceptual model and hypotheses in hospitality service supply chain

The basic function form of SFA for panel data is specified in equation (1)

(1)

$$Y_{it} = \alpha + \beta X_{it} + (V_{it} - U_{it})$$

$$\text{where } i = 1, 2, \ldots, N; \; t = 1, 2, \ldots T, \; V_{it} \sim N(0, \sigma_v^2), U_{it} \sim N^+(0, \sigma_u^2)$$

Equation (1) specifies the stochastic frontier production function in terms of the fundamental production inputs, given certain economic and technological standing, expressed in a log transformed Cobb-Douglas production function (Cobb and Douglas, 1928). The Cobb-Douglas production function is not only the simplest mathematical formula that relates multiple inputs and outputs, but is also widely used in the economics and management literature on economic performance (Meeusen and van den Broeck, 1977; Battese and Coelli, 1995; Lieberman and Dhawan, 2005). The dependent variable, Yit, reflects the output of hotel property *i* at time period t, which is operationalized as the log of gross operating profit per room per night. This is the value-added generated by each room per night. The value is converted to 2008 dollar using the CPI inflation adjustor published by the Bureau of Labor

Statistics (BLS). The Xs, a vector of production inputs, refer to the capital, labor, and various materials committed to the service production process. Other characteristics of hotel property such as the type of property (property type dummy variable), the chain segment, and the year dummies are also included in the X variables as controls. The composite term (V-U) reflects the combined effect of random noises (V) and the technical inefficiency (U). Following Battese and Coelli (1995), the Vs are assumed to be i.i.d. N (0, σ_v^2) random errors. The Us are assumed to be independently distributed, such that U is obtained by truncation (at zero) of the normal distribution:

(2)

$$U_{it} = \delta_0 + \delta Z_{it} + \omega_{it} \quad \text{where } i = 1, \ldots, N; \; t = 1, \ldots T, \; \omega_{it} \sim N^+(0, \sigma_\omega^2)$$

Equation (2) specifies the technical inefficiency effects, which is assumed to be a function of a set of explanatory variables, the Zs, an unknown vector of coefficients, d, and a disturbance term v. The explanatory variables Zs capture heterogeneous operating characteristics, including the ES factor scores (i.e. OCF and CBCF), the operating structure (franchise vs branded management operating structure), and several control variables according to relevant literature and the hospitality industry operating characteristics. We control for the effects of hotel scale, income mix, market, geographic, and economic conditions on resource consumption patterns and operating performance.

Scale of operation: Economies of scale is an important factor in the study of efficiency (Christensen and Greene, 1976). We include the number of guest rooms in a hotel property as the control for the scale of operation.

Income mix: Income mix refers to the percentages of revenue from different income sources. Hotel income sources generally fall into three categories: transient (individual business or leisure travelers), group (trade meetings or conferences), and contract (block rooms at discounted rate) (STR, 2011).

Chain segment: Facing heterogeneous customer demand, a service organization finds it crucial to deliver the right experience and auxiliary goods to the target customers (Roth and Menor, 2003). Hotels typically position themselves at different chain segments to attract the target customers. We distinguish between five chain segments – upscale, upscale without Food and Beverage (F&B), midscale with F&B, midscale without F&B, and economy, which correspond to the price/quality bands widely accepted in the hospitality industry.

Property type: The hospitality industry distinguishes between seven types of hotel properties: conference center, convention hotel, extended stay hotel, full-service hotel, limited-service hotel, resort hotel and suite hotel, with each type emphasizing unique range of services provided.

Urbanization: The level of urbanization is associated with varying infrastructure condition (such as transportation) that affects resource efficiency (Camagni et al., 2002) and resource scarcity and price (Brown and Field, 1978).

Ambient climate: According to EPA statistics, heating, ventilating, and air-conditioning (HVAC) systems collectively account for approximately 40 percent of the electricity used in commercial buildings in the USA. The ambient temperature not only affects the weather conditioning need but also affects the energy efficiency practices.

Year: The US hospitality industry is known for its cyclical nature (Choi et al., 1999). We control such temporal change by including the Year variable.

Equation (3) is the full model accompanying the framework in Figure 2:

(3)

$$
\begin{aligned}
&ln(\text{Gross Operating Profit} \\
&\quad \text{per Room Night})_{it} = \alpha + \beta_1 ln(\text{Capital}_{it}) \\
&\qquad + \beta_2 ln(\text{Labor})_{it} + \beta_3 ln(\text{MaterialCost})_{it} \\
&\qquad + \beta_{4\text{-}9}(\text{Property Type Dummies})_{it} \\
&\qquad + \beta_{10\text{-}13}(\text{Chain Segment Dummies}) + \beta_{14\text{-}18}(\text{Year Dummies})_{it} \\
&\qquad + V_{it} - [\delta_0 + \delta_1(\text{CBCF Load Score})_{it} + \delta_2(\text{OCF Load Score})_{it} \\
&\qquad + \delta_3(\text{Operating Structure})_{it} + \delta_4 ln(\text{Number of Rooms})_{it} \\
&\qquad + \delta_5 ln(\text{Transient Income Pct})_{it} + \delta_6 ln(\text{Population Density})_{it} \\
&\qquad + \delta_7 ln(\text{Days High})_{it} + \delta_8 ln(\text{Days Low})_{it} + \omega_{it}]
\end{aligned}
$$

Table II summarizes the variables and their definition as specified in equation (3). Table III presents the descriptive statistics of the key variables.

We estimate equation (3) by applying the SFA model for panel data proposed by Battese and Coelli (1995), in which the non-negative technical inefficiency effects are assumed to be independently distributed as truncations of normal distributions with constant variance, but with means which are a linear function of observable variables (Zs). H1 predicts positive estimates of the coefficients, d1 and d2 for the customer behavior and operating cost load scores, respectively. H2 predicts a negative coefficient d3 (branded management operating structure).

Table II Variables included in the SFA

Variable name	Description
lnY	Log of gross operating profit per room night (the production output). This is the value-added per room night which equals the firm's sales during the fiscal year, minus cost of goods sold, then divided by the total number of rooms available per year. This is equivalent to the sum of all payments to labor and capital, plus indirect taxes. The value is converted to 2008 dollar using the CPI inflation adjustor published by the BLS
lnK	Log of the sum of property tax and insurance, proxy for the capital input
lnL	Log of total labor cost per room night (labor input). The value is converted to 2008 dollar using the CPI inflation adjustor published by the BLS
lnC	Log of the costs for linen and supplies, food, beverage, gifts, and utilities
Property type dummies	Seven categories: conference center, convention hotel, extended stay hotel, full-service hotel, limited-service hotel, resort hotel and suite hotel. The conference center is the reference group
Chain segment dummies	Five categories: economy, budget, or lower-tier; mid-tier without food and beverage; mid-tier with food and beverage; upper-tier without food and beverage; upper-tier with food and beverage, upscale, or luxury. The upper-tier with food and beverage is the reference group
Year dummies	Year indicator, 2001-2006. Year 2006 is the reference group
CBCF	CBCF load score of the ES measure, Bartlett method
OCF	OCF load score of the ES measure, Bartlett method
mgmtcon	Dichotomous variable 1 if the hotel is managed by branded manager
Lnsize	Log of number of rooms per hotel property, proxy for the capital inputs
Lnmixtrst	Log of the percentage points of transient business income in total revenue
lnpopden	Log of population density in the zip code where the hotel property is located (in persons/square kilometer)
lnDaysLow	Log of number of days in a year with low temperature below 32°F
lnDaysHigh	Log of number of days in a year with high temperature above 90°F

Note: Variable names and definitions

Table III Descriptive statistics of the variables

Variable	Number of obs	Mean	SD	Min.	Max.
lnY	5,886	3.14	0.65	−1.18	5.33
lnK	5,903	1.14	0.61	−1.54	4.37
lnL	5,904	2.77	0.79	1.33	5.83
lnC	5,904	1.80	0.84	0.06	4.50
CBCF	5,897	0.00	1.28	−2.25	5.94
OCF	5,897	0.00	1.45	−3.79	8.65
Mgmtcon	5,904	0.29	0.45	0.00	1.00
Lnsize	5,904	5.21	0.59	3.81	7.96
Lnmixtrst	5,872	4.37	0.32	2.48	4.61
Lnpopden	5,904	6.68	1.30	0.46	10.51
LnDaysLow	5,904	3.98	0.90	0.00	5.34
LnDaysHigh	5,904	3.66	0.80	1.10	4.72

Robustness Checks

In this section, we address some potential concerns about our empirical methodology.

First, to examine the representativeness of the sample, we compared the sample hotels and the 2009 national lodging industry profile compiled by American Hotel and Lodging Association (AH&LA) in terms of customer characteristics (purpose of travel), geographic distribution, property size, RevPAR, and occupancy rate (Table IV).

Our sample appears to be representative in terms of the geographic distribution and income mix. The hotels include in our sample operate at a larger scale, with higher RevPAR, and higher occupancy rate. This does not weaken our findings for the following reasons: first, SFA focuses on the best-in-class performance, which is represented in the sample. Second, we are interested in the operating structure effect, and hotels of larger scales offer the variability in operating structures (franchise vs branded management).

Table IV Sample hotel characteristics compared with the AH&LA national profile in 2009

	Sample characteristics (2008)	AH&LA lodging industry 2009 profile (year-end 2008 figures)
Total number of properties	984	49,505
Income mix		
Leisure (%)	59	57
Business (%)	41	43
Top five markets	CA, TX, FL, NY, GA	TX, CA, FL, GA, AZ
By size		
Under 75 rooms (%)	1	56
75-149 rooms (%)	53	32
150-299 rooms (%)	26	9
300-500 rooms (%)	14	2
Over 500 rooms (%)	6	1
RevPAR ($)	77.14	64.37
Occupancy rate (%)	68	60.4

Second, endogeneity becomes a concern when one or more of the explanatory variables correlate with the error term. We did not find any evidence of correlation between the explanatory variables and the error term by estimating equation (3) with the ES measures lagged by one year, an ad hoc test suggested by Shepherd (2009).

An alternative frontier analysis technique, Data Envelopment Analysis (DEA) (Charnes et al., 1978), takes a non-parametric (deterministic) approach that makes minimal assumptions about the production frontier but assumes away the possibility of random shocks. We tested the robustness of the SFA results against DEA by comparing the rankings of the predicted efficiency (Greene, 2007). The results from these two approaches are comparable: 35 percent of the efficiency rankings are in the same quartile between the two methods; 75 percent of the efficiency rankings are in the same and immediate neighboring quartiles.

Results

In this section, we describe the SFA results and interpret the estimated coefficients. We rely on the coefficient estimates and the model fit statistics to draw conclusions regarding the two hypotheses. Table V summarizes the SFA results from four model specifications.

From left to right, the first column contains the estimates from the base model, which has all the variables except for the variables in the hypotheses. Building on the base model, the second model “H1 only” tests H1 by including the two ES load scores. The third model “H2 only” tests H2 by adding to the base model just the branded management indicator in the efficiency function. The rightmost model tests the two hypotheses simultaneously, which is the full model specified in equation (3). Positive signs for the parameter estimates in the efficiency function indicate increasing distance from the performance frontier as the variable increases, therefore suggesting a negative relationship with the efficiency and the dependent variable.

In the “H1 only” column, the parameter estimates for CBCF and OCF factor scores are positive and significant, suggesting that higher load scores (lower ES), are associated with high inefficiency. In other words, higher ES is associated with higher efficiency. These results provide strong support to the positive performance impact of increasing ES (i.e. reducing the CBCF and OCF). H1 is supported.

In the “H2 only” column, the coefficient for the branded management operating structure is negative and statistically significant, indicating that, everything else equal, hotels managed by professional management companies are more efficient. Therefore, H2 is supported.

In the “H1 and H2” column, both ES load scores and the operating structure (branded management indicator variable) are included. This is the full model specified in equation (3). The results remain consistent in magnitude and the sign with the previous two models, which lends further support to the two hypotheses.

Consistent with industry observations, the operating frontier output varies with the property type, the chain segment, and the business cycle. The implication is that the hotel owners and operators should be mindful of the contextual details and ensure comparability during ES benchmarking in order to understand the variation in efficiency and operating performance across the hotels in their property portfolio. Further, the statistical significance of the control variables (economies of scale, urbanization as measured by population density, income mix, and ambient climate) suggests that the hotel management should tease out the variation due to these operating and local characteristics to ensure fair comparison.

Table V Maximum likelihood estimates of SFA parameters in equation (3)

log(Y)		Base model	*H1* only	*H2* only	*H1* and *H2*
Number of observations		5,904	5,904	5,904	5,904
Log likelihood function		−2,805	−1,909	−2,783	−1,942
Info. criterion: AIC		0.959	0.656	0.952	0.668
Info. criterion: BIC		0.990	0.689	0.984	0.702
Info. criterion: HQIC		0.970	0.668	0.963	0.680
Frontier function					
Constant	β_0	2.879	2.540	2.876	2.578
Log capital	β_1	− *0.119 (0.009)*	− *0.024* (0.008)	− *0.118* (0.009)	− *0.030* (0.007)
Log labor	β_2	0.582 (0.018)	*0.199 (0.016)*	*0.578 (0.019)*	*0.213 (0.015)*
Log material costs	β_3	*0.077* (0.014)	*0.598 (0.014)*	*0.081 (0.015)*	*0.568 (0.014)*
Efficiency function					
Constant	δ_0	−0.082	−0.248	−0.081	−0.228
CBCF – customer behavior cost factor score	δ_1	–	*0.038 (0.002)*	–	*0.031 (0.032)*
OPF – operating cost factor score	δ_2	–	*0.016 (0.001)*	–	*0.017 (0.001)*
Operating structure – branded management	δ_3	–	–	− *0.035 (0.013)*	− *0.197 (0.011)*
Control variables					
Number of rooms	δ_4	− *0.320 (0.011)*	− *0.324 (0.013)*	− 0.323 (0.011)	− *0.314 (0.013)*
Transient income mix pct	δ_5	*0.037 (0.007)*	− *0.063 (0.007)*	*0.037 (0.007)*	− *0.067 (0.007)*
Log population density	δ_6	− *0.054 (0.003)*	− *0.021 (0.003)*	− *0.052 (0.003)*	− *0.018 (0.003)*
Log # days with high above 90°F	δ_7	− *0.186 (0.008)*	− *0.196 (0.006)*	− *0.194 (0.011)*	− *0.211 (0.008)*
Log # days with low below 32°F	δ_8	− *0.137 (0.004)*	− *0.111 (0.004)*	− *0.140 (0.004)*	− *0.110 (0.005)*
PTYPE2	β_4	*0.569 (0.048)*	*0.426 (0.030)*	*0.568 (0.049)*	*0.436 (0.032)*
PTYPE3	β_5	*0.608 (0.104)*	*0.208 (0.086)*	*0.608 (0.104)*	*0.239 (0.100)*
PTYPE4	β_6	*0.608 (0.044)*	*0.935 (0.028)*	*0.605 (0.044)*	*0.905 (0.029)*
PTYPE5	β_7	*0.627 (0.084)*	*0.500 (0.082)*	*0.628 (0.085)*	*0.529 (0.090)*
PTYPE6	β_8	*0.203 (0.049)*	*0.218 (0.033)*	*0.203 (0.050)*	*0.212 (0.034)*
PTYPE7	β_9	*0.528 (0.049)*	*0.530 (0.030)*	*0.528 (0.072)*	*0.534 (0.031)*
LOWER	β_{10}	*0.536 (0.072)*	*0.318 (0.077)*	*0.536 (0.072)*	*0.348 (0.085)*
MIDNOFB	β_{11}	−0.127 (0.072)	− *0.334 (0.077)*	−0.127 (0.072)	− *0.308 (0.085)*
MIDFB	β_{12}	− *0.109 (0.013)*	0.005 (0.009)	− *0.111 (0.013)*	−0.012 (0.009)
UPNOFB	β_{13}	−0.023 (0.179)	−0.145 (0.176)	−0.023 (0.185)	−0.139 (0.223)
2001	β_{14}	0.007 (0.010)	0.001 (0.009)	0.007 (0.010)	−0.004 (0.009)
2002	β_{15}	− *0.025 (0.009)*	− *0.050 (0.008)*	− *0.025 (0.010)*	− *0.040 (0.008)*
2003	β_{16}	0.002	0.012 (0.009)	0.002 (0.009)	*0.028 (0.008)*
2004	β_{17}	− *0.027 (0.010)*	− *0.032 (0.009)*	− *0.027 (0.010)*	− *0.030 (0.009)*
2005	β_{18}	0.007 (0.010)	−0.001 (0.009)	0.007 (0.010)	− *0.027 (0.009)*
Variance parameters					
σ_s^2		0.056	0.045	0.057	0.046
Γ		0.999	0.999	0.999	0.999

Notes: The dependent variable is log value-added per room night; numbers in parentheses are estimated standard errors; coefficients in italics are significant the 0.05 level; we use the econometrics package LIMDEP version 9.0 (Greene, 2007) to estimate the parameters of equation (3); LIMDEP 9.0 has built-in support for maximum-likelihood estimate of the Battese and Coelli (1995) panel data model which concurrently estimates the parameters of the stochastic frontier model and the coefficients in the technical inefficiency function

Discussion

In this study, we apply EFA and SFA to a panel dataset and show that the measured ES factors (CBCF and OCF) and a key operating choice, operating structure, contribute to the variation of operating performance. In this section, we first discuss the managerial implications of our findings, then offer our thoughts on the limitations.

Managerial Implications

Our study builds the common ground for communication and collaboration among supply chain constituents by proposing a two-factor measure for benchmarking, and demonstrating how to use this measure to assess performance and potentially identify an improvement path within a frontier framework.

Assess ES in Terms of Resource Efficiency

Our study illustrates how to develop ES measures from actual resource consumption pattern using EFA, which examines the common variance in the raw data and condenses the information into fewer dimensions (Kim and Mueller, 1978). Two key dimensions – operating and customer behavior – of ES are identified. The significant effect of the CBCF shows that customers are highly influential in sustainable service operations. This is both an opportunity and a challenge in improving sustainability in service settings.

In addition to helping the hotel operators measure and track their sustainability performance, and thereby make informed decisions about necessary adjustment to their sustainable actions, this two-factor have broader implications for the industry and public policy in general. For example, industry baselines can be established for hotels in various chain segments as well as across geographic locations. Over time, such information may be utilized in the valuation process of the hotels, thus rewarding property owners for their sustainable efforts and reducing the split-incentive barrier. From public policy perspective, these measures complement certification programs such as LEED by providing outcome-based performance measurement.

Identify Laggards and Diffuse Best Practices

One of the findings of this paper is that the best-in-class performance varies. The influences come from the overall economic cycle as well as the local conditions such as the extent of urbanization in the surroundings and the ambient climate. This finding is particularly important for hotel corporations with broad geographic coverage. Understanding the varying patterns in the performance frontier helps assess operating units in the comparable sets and identify those where the sustainability investment may yield the biggest performance improvement. Hotel owners and chains may use this benchmarking approach to quickly identify leaders and laggards in terms of ES among the hotels in their portfolio.

The next step is to combine this knowledge with the increasingly popular process evaluation programs adopted by hotel chains. For instance, Hilton's LightStay system measures indicators across 200 operational practices including housekeeping, paper product use, food waste, chemical storage, air quality, and transportation (Hilton, 2011). These process evaluation programs generate detailed process information. Effective practices adopted by the sustainability leaders may serve as the basis for sustainability actions for the laggards.

Manage the Tension Between Operating Structure and Investment in Improvements

The ES initiatives being actively pursued by hoteliers are diverse. However, the fundamental issue of split-incentive persists, as the significant effect of the operating structure uncovered by our study. The uncertainty beneath the split-incentive comes from two dimensions: the upfront investment cost and the length of the payback period (Table VI).

The lower left cell in Table VI lists initiatives which are often known as the low-hanging fruits. Due to the low upfront cost and quick payback, these initiatives are also quickly becoming the industry standard, gradually losing their status as points of differentiation or competitive advantage. Over time, differentiation is more likely to be associated with the initiatives requiring significant investment. However, the tension between property owners and operators may also grow due to heightened uncertainty resulting from higher upfront investment and longer payback period. In the lower right cell, technological uncertainty constitutes the main source of risk. In the upper right cell, however, the split-incentive problem between the owner and operator becomes dominant. Managing this tension requires innovative institutional changes, in addition to the metrics and communication platform offered by our paper.

Limitations

We recognize several limitations in this study. One limitation is associated with using cost data to construct the ES factors. Converting resource consumption into dollars allows standardization and cross-sectional analysis. However, significant geographic variations in unit costs for labor, energy, water, and capital (e.g. insurance costs) may raise methodological concerns. We performed SFA tests with state dummy variables included, and the results are robust. Yet, the state level control addresses majority but not all the regional variations. For instance, water rates are set at the municipality level with varying sewer rates. We considered instrumental variables such as living expense or quality of life type of measures (at the county-level), but these variables do not adequately address the multi-level regional variations. Due to data limitations, several key contributors to resource consumption are not included in this model, such as architectural parameters which include building age, footage, insulation, and equipment, etc. Data sources such as LEED application records or Energy Star ratings may provide information on architectural parameters. As smart room technology advances, sensor data may become available and supply real time feedback on environmental practices.

Another limitation arises from the lack of data support for fine granular characterization of the operating structure. H2 (operating structure and performance) is supported in this study, but there is a slight reduction in model fit statistics. The complexity in owner-operator interface in the hospitality industry may be responsible for the change in model fit statistics. First, the branded management vs franchise dichotomy used in this study can be further refined. There are a number of combinations when hotel owners and brands form partnership. For example, a hotel owner may enter franchise agreement with one national chain but contract another national chain to operate it. Second, the operating structure is highly fluid. Every time the ownership of a hotel property changes hands, the operating structure is re-evaluated. Such dynamic owner-operator interface may not be fully captured in current study.

Table VI. A categorization of environmental initiatives based on upfront investment and length of payback period

	Upfront investment	
Payback period	Low	High
Long	N/A	LEED certificate for new buildings Retrofitting existing buildings to be LEED certified Implement environmental management system (EMS) Energy efficient equipment Environmental friendly fixture Real time sensor technology
Short	Energy audit Process evaluation system Best practice checklist Train associates Educate customers	Break-through innovations such as the living machine, natural design

<u>Future Research Directions</u>

We have identified three future research directions. First, how to advance sustainable practices beyond low-hanging fruits by designing investment incentives for self-interested collaborating partners is a fundamental challenge (Jaffe et al., 2005), as evidenced by the intriguing finding on the performance impact of hospitality supply chain operating structure. This indicates important and interesting agency issues in ES investment and implementation. A contract modeling approach to examining the owner-operator dynamics may advance the understanding of the decision-making process and offer insights on effective incentive mechanisms.

Second, operational trade-offs during sustainable development is extremely important to practice but little researched. The operations-centered and customer behavior-centered dimensions of ES suggests potential trade-offs in balancing operational objectives and customer needs (Johnston and Jones, 2004). The performance consequences of these trade-off decisions point to a very promising empirical research area.

Third, abundant research topics exist at the interface of green marketing and green practices. The persisted concerns about green washing (Harrison and Freeman, 1999; Lyon and Maxwell, 2011) suggest that ES must be a consistent and concerted effort of the entire organization. Consistency is especially important in services because customer expectation and experience determines the level of satisfaction (Parasuraman et al., 1994) and ultimately business success. Future research taking an information economics and signaling perspective may shine light on this area.

Conclusions

In this study, we set out to address the knowledge gaps identified in sustainable operations management by proposing a standardized measure of ES and rigorously analyzing the performance link of ES using a large panel dataset. Our approach is not only integrative but also multi-disciplinary: incorporating operating performance frontier theory, supply chain perspective (owner-operator interface), and service co-production and co-creation (operator-customers interface).

Looking ahead, the trajectory of the ES movement is largely driven by technological and behavioral changes that affect both the OCF and CBCF. For example, the smart room solutions may generate real time resource consumption data at the room level, which calls for new benchmarking tools and theory, which in turn may lead to changes in staffing and operating procedures. Additionally, when provided with real time feedback, the hotel customers are likely to change their behavior more quickly. New theories can result from controlled experiments that investigate such behavioral change. Furthermore, internet technologies have given agencies such as expedia.com and travelocity.com increasing influence over customer behavior by posting customer reviews and eco-labels. Theories need to extend and update accordingly to match the emergence of these new stakeholders and their new roles in the service supply chain. In short, constantly evolving technology and behavioral changes in ES are poised to bring exciting theory and methodology opportunities.

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