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Behavioral changes following the collaborative development of an accounting information system

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A B S T R A C T

This research examines physician response to implementation of an activity-based costing (ABC) system developed and designed with physician input. We analyze changes in resource utilization for treatment of cataract patients and find changes in practice patterns, where physicians redeployed resources toward more severely ill patients and decreased average length of stay. We also find preliminary evidence of improvement in financial performance. We contribute to research investigating the influence of user participation on accounting system success, ABC system success, and hospital accounting information systems.

Introduction

This paper examines an aspect of activity-based costing (ABC) information systems that has been overlooked in prior accounting research literature: whether non-accountant participation in the development of the information system influences the participants' resource allocation decisions after system implementation. This participatory aspect of system development is crucial in professional settings because accounting information tends to be ignored by decision-makers as they allocate resources (i.e., Bergman, 1994).

Our study is a joint test of the effects of user participation in designing an ABC accounting information system and the consequent behavioral changes by the participants. We provide insights into the dynamics and success of system implementation. Our study provides a particularly useful setting in which to examine the impact of participation on system success because participation is a key element of ABC system design (i.e., Hunton & Gibson, 1999; Ives & Olson, 1984; Shields, 1995). Prior research suggests that systems are more likely to be accepted and considered successful if users are involved during system development; however, evidence of this is inconclusive (i.e., Lynch & Gregor, 2004).

The professionals we study are physicians from the ophthalmology department of a hospital who perform cataract surgery on both inpatients and outpatients. We investigate implementation of an accounting information system that developed standard costs by incorporating the physicians' knowledge about their activities and use of resources. We test whether implementation of this new accounting information system led to cost containment behavior by examining resource utilization changes.

The new system was the result of a collaborative effort between physicians and hospital accountants at a large government-owned hospital in Taiwan. Development of the standard cost system was a two-stage process. First, physicians were asked to use an activity-based costing approach to develop cost information. They then used this information to analyze current clinical pathways (standard treatment protocols) and to develop new, more cost-effective pathways, with corresponding standard costs for the department. Physician involvement in the process appears to have affected their behavior. They ignored information

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from the previous standard cost system, but appeared to use information from the new system to reduce resource usage and overall patient costs.[1] After the new system was in place, there is also evidence that physicians changed their behavior and decision-making as they redeployed resources and focused on sicker patients.

Our results have implications for healthcare and other professional organizations where professionals make decisions about resource use, and thereby, the financial performance of the organization. Typically, professionals are not involved in accounting information system development. Our results suggest that including professionals in system development may lead to changes in behavior and improve their resource allocation decisions.

We contribute to several streams of accounting research literature. Prior research on the benefits of user participation gauges system performance by measuring self-reported user satisfaction scores (i.e., Foster & Swenson, 1997; Shields, 1995; Swenson, 1995). We provide empirical results indicating that involvement in system design leads to actual changes in resource deployment and improved financial performance. This study is also one of the first to identify non-accountant participation as a crucial factor in the success of ABC information systems.

The remainder of the paper is organized as follows. Section 2 sets our study within a theoretical context and develops our hypotheses. Section 3 presents a description of the study setting and describes our data collection and research methodology. Section 4 describes results of our empirical tests and Section 5 concludes the paper.

Background and hypothesis development

Literature review

We draw from two streams of research: the influence of participation in accounting information system development and factors that influence the success of activity-based costing systems. When new accounting information systems are introduced, there are three stages: design, implementation, and use. Prior accounting research has typically only explored one of these stages at a time. For example, Datar and Gupta (1994) analyze the effects of design choices on measurement error and find that increasing the specificity of allocation bases and the number of cost pools can lead to increased measurement error. Several studies (e.g., Foster & Swenson, 1997; Hunton & Gibson, 1999; Shields, 1995 focus on factors that affect implementation of such systems. Shields (1995) finds that several factors are important in explaining the perceived success of activity-based costing implementations, such as top management support and linkage to performance evaluation and compensation. Relevant to our study is Shields' finding that perception of system ownership by non-accountants is highly correlated with the perceived success and financial benefits of these systems. In a field study of a state agency, Hunton and Gibson (1999) analyze whether individual or group participation in developing a new accounting information system provides more benefit (lower error rates). They find that when group discussion was included as part of the accounting system design and development, behavioral gains following system implementation persisted for 12 months.

In another related study, Bhimani (2003) investigates the interaction of organizational culture and system development and the effect of personal culture on the perceived success of the system. He finds that organizational culture has a large impact on system design. In addition, system users whose personal culture is more closely related to the organizational culture rate the system implementation as being more successful.

Other research examines the usefulness and financial impact of new accounting systems. For example, Ittner, Lanen, and Larcker (2002) find evidence of improvement in cycle time and first-pass quality for some firms using ABC, leading to reductions in manufacturing costs. However, they find no improvement in return on assets, on average, from these benefits. Their evidence suggests that plant characteristics affect the impact of ABC systems on profitability. Gordon and Silvester (1999) fail to find positive stock market returns associated with ABC adoption, while Kennedy and Affleck-Graves (2001) find that ABC firms have higher market returns relative to non-ABC firms. We extended this literature by examining the effect of user participation during the design stage on subsequent system success by examining changes in resource utilization. The research summarized above is primarily from a US context, we thus provide additional institutional background and discuss the progression of health care costs in the US and Taiwan in the next section.

Institutional background

The cost of health care has been rising worldwide. In an attempt to reduce costs, insurers (both public and private) have moved away from cost-based reimbursement so that hospitals and physicians become more sensitive to cost. In 1983, the US Government, through its Medicare program (which provides care for the elderly), became one of the first government insurers to change reimbursement systems away from a retrospective cost-based payment to a prospective flat-fee per diagnosis to emphasize cost-containment. Similar diagnosis-based payment systems have since been implemented in other countries worldwide, including Australia, Germany, The Netherlands and Taiwan.

When reimbursement is linked to costs, physician and hospital incentives are aligned, because both physicians and hospital managers are focused on the quality of physician treatment decisions rather than cost. However, after the change in payment method, hospitals sustain losses when physicians order treatment resources in excess of the flat fee. In the US, following the change in reimbursement methods, hospitals explored several methods to motivate physicians to contain costs. Accountants began to provide cost information for physicians, but were concerned about whether such information would affect practice patterns. Eldenburg (1994) found that when a subset

[1] Our discussions with the physicians indicated that prior to the ABC system, they did not think that the costs were meaningful.

of Washington State hospitals provided physicians with information about their own case costs and also included benchmark information, such as the average cost per diagnosis at the hospital or state-wide level, physicians reduced the amount of resources used.

Because physicians tended to ignore cost information, US hospitals began to use clinical practice guidelines (also called clinical pathways or clinical protocols). In 1989, a US government organization, the Agency for Health Care Policy and Research, developed 12 guidelines for a variety of diseases and disorders (Bergman, 1994). In 1995, the Healthcare Financial Management Association introduced a method to integrate financial analysis with development of standardized clinical practices, with the aim of decreasing cost and increasing quality of care. However, according to Bergman (1994, p. 74), in a discussion of a survey to which 1513 physicians responded, "...fee-for-service internists were more likely to view guidelines warily – as too rigid, slanted toward cost-control and unlikely to improve the quality of care."

Hospital reimbursement in Taiwan has followed a similar course. In 1995, the government implemented a National Health Insurance (NHI) program that extended health insurance coverage to those uninsured at the time – about 8.62 million, or 41% of the population (Cheng, 2003).[2] At first, NHI reimbursement was based on a fee-for-service scheme. However, total medical costs increased more rapidly than the government had expected. In October 1997, to control these escalating health care expenditures, the Bureau of National Health Insurance (BNHI) introduced a prospective, flat-fee system based on case diagnosis for 50 relatively uncomplicated diagnoses (Lang, Chi, & Liu, 2004). This system is similar to the diagnosis-related group (DRG) system in US, although without segmentation by age or insurer. A global budgeting system was introduced in 1998, but hospital care was not included in the global budget until July of 2002 (Cheng, 2003; Hsueh, Lee, & Huang, 2004).[3]

A difference between US and Taiwanese hospitals is that physicians in Taiwan are employed and compensated by the hospitals with which they are associated, whereas in the US, physicians are usually self-employed or belong to a practice group and receive their fees directly from patients or insurers. Hospitals in Taiwan had shifted physician compensation from fixed salaries to remuneration that is partially or completely based on the revenues they generate (Cheng, 2003). The hospital in our study provides salaries for its physicians, with bonuses based on total charges incurred by their patients.[4] This compensation scheme works well under a cost based system, but is not efficient under a flat-fee per diagnosis system as hospital and physician incentives are misaligned.

To help motivate cost containment behavior, the largest hospitals in Taiwan provide monthly department-level income statements or cost reports (primarily for cost centers) to department heads.[5] Taiwanese hospital managers use information developed for regulatory reports as a basis for their budgets and monitoring. All hospitals provide financial statements to the Taiwanese Department of Health. Physicians are not typically part of the accounting information system design process for financial information or for the reports. However, physicians have been involved in development of clinical pathways, which have been used extensively in Taiwanese hospitals as a response to the 1997 change (Chang, Cheng, & Luo, 2006). Although our sample hospital used a standard costing system, it appears that few other Taiwanese hospitals have adopted this practice.[6]

A number of researchers have studied hospital response to Taiwan's regulatory changes in medical reimbursement. Several researchers examine changes in hospital efficiency in response to the 1997 reimbursement change. Lin, Xirasagar, and Tang (2004) examined cost per discharge and found that costs were significantly lower in for-profit hospitals compared to government and nonprofits after the reimbursement change, whereas they had been significantly higher than other hospitals under the cost-based payment scheme. Some researchers (e.g., Chang et al., 2004; Hsu & Hu, 2007; Wei, 2007) have employed Data Envelopment Analysis (DEA) analysis to determine the effects of regulatory change in Taiwan on overall hospital efficiency, or efficiency by ownership type. For example Chang et al. (2004) examined district hospital operations from 1994 through 1997 and found a decrease in efficiency after the 1995 change to NHI. Wei (2007) collected data from 110 large hospitals in Taiwan from 2000 to 2004 and provides evidence that while there was little or no change in private hospitals, operating efficiency of public and proprietary hospitals was lower after implementation of the global budgeting system. Hsu and Hu (2007) integrate DEA and simple additive weighting to compare efficiency performance across hospital ownership types during 2003 (after the global budget was implemented in 2002). The operating efficiency scores of hospitals by ownership ranked in the following order: corporate, private, municipal, department of health, veteran's, and armed forces hospitals. The Taiwan-based study that is most closely related to our research is Chu, Liu, Romeis, and Yaung (2003). This study investigates a large teaching hospital and finds that efficiency increased after physicians were offered revenue-growth based bonuses of up to 10% of their salaries, conditional on no operating losses during the fiscal year. In our setting, physician compensation remained constant before and after system implementation, so our results are driven by the accounting system change and not compensation incentives.

[2] By the end of 2001, 97% of the total eligible population had enrolled (Lu & Hsiao, 2003).

[3] The global budget sets an annual cap on total medical expenditures whereby as the volume of services increase, average payment per service decreases. This regulation reduces incentives to increase treatment under the flat-fee per service reimbursement system (Chang, Chang, Das, & Li, 2004).

[4] Compensation based on salary with a variable portion is consistent with paying a reservation wage, and encouraging physicians to exert effort. In this setting, utilization of resources requires physician effort.

[5] The information about Taiwanese hospitals' use of accounting information was gathered from our survey of the 11 largest hospitals in Taiwan.

[6] None of the hospitals surveyed use standard costs.

Theoretical framework

The theoretical framework for our study is the intersection of research examining the success of activity-based accounting information system implementation and research examining the effect of participation in information system development on its success. A hallmark feature of ABC is the collaboration between accountants and system users to identify the activities that are used to develop cost pools and cost drivers. System designers invite participation from department managers and employees to identify the activities involved in the manufacturing or service delivery processes (Kaplan & Atkinson, 1998). In our setting, development of the ABC system relied heavily on physician participation to identify cost pools and cost drivers, and then to apply this accounting information to their clinical pathways, resulting in new, more cost effective clinical pathways that were used as the basis for the hospital's standard cost system. The aim was to encourage physicians to become more aware of the cost consequences of their activities. Hospital managers wanted physicians to continue to focus on patient treatment, but also to consider costs as they made treatment decisions.

A rich literature exists on the benefits of user participation in information system design and development as well as on user acceptance factors. Hartwick and Barki (1994) find that overall responsibility (project leadership and responsibility for system choices) positively affects user involvement, attitude, and system use. Hunton and Price (1994) formulate the stages in developing an accounting information system as planning, analysis, design, implementation and post-implementation. Ives and Olson (1984) define six degrees of user involvement and suggest that the stronger the degree of involvement, the greater the payoffs in terms of user attitudes and performance. These involvement levels include: (1) no involvement; (2) symbolic involvement; (3) involvement by advice; (4) involvement by weak control; (5) involvement by doing; and (6) involvement by strong control (p. 591). In our setting, physicians were involved by doing, i.e., they were members of the design team, helping to choose cost pools and cost drivers. In this role, they were also involved in Hunton and Price's stages of analysis, design, and implementation. Theoretically, users involved in these activities should be more positive about the systems and use system information in decision making to a greater extent; thus, behavioral changes could occur. Venkatesh, Morris, Davis, and Davis (2003) review and evaluate eight competing models related to user acceptance. They develop a unified model which may assist managers in assessing the success of new information systems. They examine determinants of user acceptance which include underlying constructs such as perceived system usefulness, system complexity, usage expectations of others, and organizational support. We extend this literature by examining the outcomes following user participation and acceptance.

We use a hospital setting to examine our research questions. Researchers, as well as hospital management, have increased attention on hospital accounting information systems due to the rising healthcare costs. Using survey data from 277 financial managers from US hospitals, Pizzini (2006) finds that hospital accounting information systems that supply greater cost detail are considered more useful and states that the reduction of healthcare expenditures stems from cost containment of patient care as well as administrative efficiency. Abernethy and Vagnoni (2004) study how physician power impacts the use of accounting information systems by surveying physician managers in two large hospitals. They find that when authority is delegated to physician managers, the use of accounting information as well as their cost consciousness is increased. Our study extends this literature by focusing on user participation of non-accountants in the design of an ABC system and subsequent behavioral changes.

In our setting, hospital physicians in an ophthalmology department were involved in developing the ABC system from the time it was identified as a potential cost containment strategy. The Medical Director and Department Head met with hospital accountants to understand the nature of an ABC cost system and to make the implementation decision. Both the Medical Director and Department Head voiced strong commitment to the implementation because they felt the need for cost information that better reflected the use of resources. The Department Head was involved in designing the information collection method that was used to identify activities and track the use of resources. The method involved all of the department physicians, who were asked to provide information about their patient treatment, teaching, and research activities. The physicians filled out time sheets to determine time spent on a variety of activities. Nurse and technician time was also tracked. Next, physicians provided information about their use of resources other than labor. Examples of the department's patient care activities include time spent diagnosing, making bedside visits, prescribing medicine, and using a surgical laser. Cost drivers for patient care include number of bed days, operating minutes, procedure time, and machine time. The physician assigned to the accounting system development team defined the treatment that should be used, on average, at each level of severity.[7] Then the accountants provided cost data using the new pools and cost drivers. Department physicians analyzed their clinical pathways and altered them to be more cost effective without incurring any efficiency or quality losses. This level of involvement is part of the system analysis and design process, the fifth degree of involvement under Ives and Olson (1984) theoretical framework, and includes two activities listed by Hunton and Price (1994) that should result in a change in physician behavior after system implementation.

The Department Head and hospital accountants also redesigned the monthly reports to reflect the broad scope of activities in which physicians participated. Prior to the system change, physicians received a monthly department-level income statement that aggregated costs of teaching, research, and patient treatment into total

[7] The physician based his input on a "clinical pathways" analysis that the department's physicians had produced in 1998. Clinical pathways (protocols) provide an indication of how to treat patients with specific illnesses, but do not include any cost information.

expenses. This report was discussed each month in a meeting with all of the physicians and the department head. The hospital accountants hoped that physicians would use this information to monitor their costs. After the system change, physicians received an additional report that provided information about their three product lines: patient care, teaching, and research. While no revenues or reimbursements were received for teaching and research, the costs for physician time (salary allocations based on ABC information), support staff, and other resources were reported. This additional report enabled physicians to monitor the cost effects of their treatment decisions on department financial performance, teaching, and research activities. In addition, they could monitor the amount of revenues from patient treatment. With these new reports, physicians could consider the effects of any practice pattern changes on hospital surplus and on their compensation. Because of this high degree of involvement in all phases of developing the ABC system, we hypothesize:

> H1: When accountants and users collaborate in developing information systems such as ABC systems, users will change their behavior in accordance with system foci.

It has been difficult for researchers to identify objective measures to determine use of information from systems that users have helped to develop. Accordingly, user satisfaction has often been emphasized as a proxy for effectiveness (Cushing, 1990; Kim, 1989). Few researchers have undertaken empirical studies of changes in outcomes in response to participation in system development and implementation. Hunton and Gibson (1999), however, present a theoretical model that links participation strategies to cognitive and motivational factors that influence desired outcomes. They test the effects of individual versus group settings on the strength of the links in their model and also analyze the influence of participation in a new information system on error rates in sales orders and customer billing. Their results suggest that the group process strengthens the links and leads to lower error rates than does the individual process.

In contrast, the effectiveness of ABC system implementations has been assessed using a number of different performance measures and approaches. Early research measured user satisfaction or self-reported implementation success (Foster & Swenson, 1997; Shields, 1995; Swenson, 1995), and later research included measures of direct impact either internally using measures such as cycle time, first pass quality, and ROA (Ittner et al., 2002) or externally using stock market prices (Gordon & Silvester, 1999; Kennedy & Affleck-Graves, 2001). Most recently, Banker, Bardhan, and Chen (2008) analyze plant level data and find that World Class Manufacturing practices act as a mediating force that allows firms to leverage their use of ABC information to improve operations measured by change in cost, quality, and cycle and lead time.

A unique feature of our setting is that we investigate specific changes in practice patterns. If physicians feel the system is important and personally relevant, they are likely to use it more extensively and their practice patterns should change.[8] Overall, consideration of cost should result in a decrease in resource utilization.

> H1a: After implementation of the new accounting system, physicians will use fewer resources per patient for treatment.

As physicians examine their practice patterns and consider ways to reduce the use of resources, they may treat less complex cases as outpatients instead of inpatients. This could increase resource use in the outpatient setting, but decrease "room and board" resources for inpatients. If less complex cases are treated as outpatients, length of stay could increase for the remaining more complex inpatients. However, if physicians are attempting to contain costs, length of stay could be managed, even for more complex patients. Thus, another way physicians could respond to the system is to reduce average length of stay. We hypothesize:

> H1b: Length of stay will decrease after system implementation.

Because both revenues and costs affect performance and our study focuses primarily on costs, we make no predictions about the effects of the new system implementation on overall performance. We were unable to get detailed financial data for the department we studied. However, we were able to access selected summary financial metrics. We report these as descriptive evidence about changes in financial performance surrounding implementation.

Research setting, data collection, and method

Research setting

The hospital we study is a teaching and research hospital.[9] Physicians are therefore involved in three activities: treating patients, teaching student physician candidates, and conducting research. Of these activities, the hospital receives reimbursement only for patient care. Prior to 1997 reimbursement was cost-based and the hospital had incentives to increase costs so that revenues would also increase. To encourage physicians to spend more time treating patients, a compensation scheme was employed whereby physicians received salary plus a bonus based on gross revenues (each physician's total patient charges). However, when the government began reimbursing hospitals based on a flat-fee per diagnosis (i.e., a diagnostic-related group (DRG) reimbursement system) and reimbursement became patient

[8] See Hartwick and Barki (1994) for a summary of the literature describing user participation and user involvement.

[9] The authors were in the unique position to meet with hospital accountants as they adopted a new accounting information system in response to increased cost containment pressure stemming from the government-driven change in reimbursement scheme. Identifying this as a natural experiment, we requested data to study cost information before and after the implementation and were graciously provided a great deal of help by the accounting department.

volume-based rather than cost-based, the hospital became more cost sensitive and needed to encourage physicians to use treatment resources more cost-effectively. This produced tension between the physicians and hospital managers. Physicians could increase their bonuses by increasing the treatment provided, thus increasing gross charges per patient, but at some point, the hospital would begin to lose money as physicians over-used resources.

Data collection

Sample selection

The study hospital is one of the largest in Taiwan, with approximately 2900 staffed beds. The hospital is government-owned and revenues during the time period of the study were based on a DRG reimbursement system. The government is the primary insurance provider in Taiwan, although there are a very small number of private pay patients. Because the government provides universal insurance, there is little or no charity care.

We examine patient information from the Ophthalmology Department, for which a new accounting system was implemented in January 2001. While the system adoption decision was made much earlier, the system was not fully implemented until January 2001, when the first reports were released in the new format, using the new ABC information. Physician participation in the system occurred prior to this time, which could work against finding results for the actual implementation.

Our dataset includes patient-level data for inpatients and outpatients treated for cataracts from July 1, 2000 through August 30, 2001. These data include information on severity of illness, gender, age, procedures employed, disease codes, charges, and hospital reimbursement.[10] The hospital tracks quality measures for each department, so we include monthly metrics on frequency of complications, infection, and readmission rates as control variables in our analyses.

Table 1 summarizes the sample selection process. We omitted patients treated in January and February 2001 from the sample to allow a transition period as physicians adjusted to the new system. Coding errors were minimal and occurred primarily in the inpatient data. Twenty inpatients were coded with invalid procedure codes and four had either invalid physician codes or invalid charges. These data errors represent less than one percent of the original sample. Coding errors in the outpatient sample were due to invalid physician codes.[11]

Patient charges and use of resources

For patient billing, hospital accountants assign a specific charge for each resource used by individual patients based on guidelines provided by the Federal government. The hospital's charge system is highly complex because for many years reimbursement was based on charges. Charges are assigned for items such as supplies, nursing time over and above that included in room and board charges, procedures such as X-rays, and any other services used by patients. These charges are accumulated for each patient and represent all of the resources used to treat that particular patient. However, because the government and most other insurers reimburse based on a flat fee per DRG, charges do not reflect reimbursement or revenues for the hospital. Charges only provide a measure of resources used while the patient was treated in the hospital.

The use of gross patient charges as a measure of output volume is consistent with use of revenues in Foster and Gupta (1990) and Anderson, Banker, and Janakiraman (2003). Gross patient charges proxy for the actual resources used to treat each patient. For many years, health care and accounting researchers have used charges to measure resource usage, because few hospitals track the cost of care for individual patients.[12] Charges reflect volume levels and complexity of care, and increase as resource usage increases. The variation in charges reflects variation in patient treatment. There were no changes to the charge system information during the period of the study. The fact that all of the charges are related to cataract treatment increases their homogeneity as well.

Throughout the test period, the hospital assigned costs according to a standard costing system based on severity of illness. There are four levels of severity for patients in our sample and each level of severity is assigned a different standard cost. There are thus four standard costs. All outpatients have a severity score of 1, with a corresponding (pre-implementation) standard cost of $NT 12,259. Inpatients have severity scores ranging from 2 to 4, with corresponding (pre-implementation) standard costs of $NT 16,184 for severity level 2, $NT 17,746 for level 3, and $NT 22,075 for level 4.

Table 1
Sample development – cataract inpatient admissions and outpatient visits.

	Inpatient visits	Outpatient visits	Total
Beginning sample			
July 2000–August 2001	3274	361	3635
Minus			
Coding errors	24	2	26
Treatment during transition period	305	62	367
Outliers	22	0	22
Remaining observations	2923	297	3220

Notes: Patients treated during January and February 2001 were omitted from the analysis to allow for a period of transition to the new system.

Research method

To test H1a, whether resource usage per patient decreases after the system implementation, we focus on

[10] Government reimbursement rates change periodically, for example, they changed in June, 2001. Our analyses take this change into consideration.

[11] Visual inspection of the data indicated observations with obvious data misalignment. Physician codes in the patient data that did not correspond to entries in the physician file were verified with hospital personnel. These physicians were not part of the normal departmental staff, so their patients were excluded from the analysis.

[12] For example, Eldenburg (1994) uses average charge by DRG per hospital to compare resource usage across hospitals. The use of charges as costs is common in healthcare research literature. See Finkler (1982) for a complete discussion of this topic.

hospital charges and perform separate analyses for inpatients and outpatients. Costs associated with treating patients on an inpatient basis tend to be higher, so treating more patients on an outpatient basis potentially reduces overall cost. However, patients who are moved from an inpatient setting to an outpatient setting are likely to need increased resources relative to other outpatients. This strategy could result in an increase in the average use of resources for outpatients.

We conduct an initial analysis for inpatients. Because the dataset for inpatients includes detailed information about patient severity of illness, we can conduct additional analyses on that population. We first investigate whether there is a shift in the mean charge after the accounting system changes (i.e., an intercept shift). We estimate the following model:

$$Charges = \beta_0 + \beta_1 Post + \beta_2 Severity + \beta_3 Age + \beta_4 Gender + \beta_5 NewReimb + \beta_6 Infect + \beta_7 OperComplic + \beta_8 Readmit + \varepsilon \quad (1)$$

where *Charges* = total hospital charges accumulated for resources used during the patient's treatment; *Post* = 1 if the patient was treated after system implementation, 0 otherwise; *Severity* = severity of illness metric; *Age* = Patient age; *Gender* = 1 if the patient is male, 0 otherwise; *NewReimb* = 1 if the admission date is after June 1, 2001, when reimbursement levels changed, 0 otherwise; *Infect* = infection rate during the month of treatment; *OperComplic* = frequency of complications during the month of treatment; *Readmit* = monthly rate of readmission within 14 days of surgery; and ε = error term.

For the inpatient analysis, H1a predicts that mean charges per inpatient will be lower after the hospital implements the new system. We thus predict that β_1, the coefficient on Post, will be negative.

The initial inpatient analysis employs severity of illness score as the severity of illness metric. Models employing standard cost as the severity of illness metric result in similar inferences.[13] We expect the coefficient on *Severity* (β_2) to be positive, since physicians should use more resources as the patient's condition becomes more critical.

Our model includes the variables *Age* and *Gender*, which control for patient characteristics that could impact resource usage.[14] We do not make sign predictions for these variables. We also include controls for quality (infection rate, complication rate, and readmission rate) because these factors are likely related to treatment decisions and therefore affect patient charges. The direction of the relation between quality and charges is unclear, however. Charges may increase as physicians use more resources to lower infection, complication and readmission rates. The relation may go the opposite direction if physicians cut back on quality, with resulting increases in resources required to combat the consequences of poorer quality of care.

A final control, *NewReimb*, takes into consideration the reimbursement environment. Government reimbursements for cataract treatment increased on June 1, 2001. While outpatient reimbursement increased by 0.04%, inpatient reimbursement increased by an average of 1.1% (weighted by frequency of patients with different levels of severity of illness). Although charges did not change at this time, it is possible that the increase in reimbursement somewhat eased the need to control costs, which would result in more resources used per patient and thus, higher charges. Thus, we predict a positive coefficient on *NewReimb* (β_5).

Eq. (1) tests for a simple mean shift in charges. However, patients with a greater severity of illness require more resource-intensive treatments and more procedures. Thus, there are potentially more opportunities to reduce resource utilization if the patient is more severely ill. We test for this by interacting the severity of illness metric with the dummy variable for change in accounting system:

$$Charges = \beta_0 + \beta_1 Post + \beta_2 Severity + \beta_3 Severity * Post + \beta_4 Age + \beta_5 Gender + \beta_6 NewReimb + \beta_7 Infect + \beta_8 OperComplic + \beta_9 Readmit + \varepsilon \quad (2)$$

In Eq. (2), physicians' use of fewer resources for more severely ill inpatients after system implementation (H1a) would result in a negative coefficient on *Severity* * *Post* (β_3). Because the prediction for *Post* in Eq. (1) represents an average effect, adding an interaction term *Severity* * *Post* in Eq. (2) renders a sign prediction for the coefficient on *Post* in Eq. (2) problematic – the predicted negative shift in slope may impact the intercept for *Post*. We therefore do not make a prediction for *Post* (β_1) in Eq. (2); we examine the combined effect of slope and intercept shifts.

The dataset for inpatients includes detailed information about patient severity of illness, which includes aspects of both the nature of the patient's illness and procedures used to treat the illness. We conduct further analyses using both number of disease codes (*DiseaseCt*) and number of procedures (*ICDct*) as proxies for severity of illness. This decomposition allows us to examine impact of system change in more detail:

$$Charges = \beta_0 + \beta_1 Post + \beta_2 DiseaseCt + \beta_3 DiseaseCt * Post + \beta_4 ICDct + \beta_5 ICDct * Post + \beta_6 Age + \beta_7 Gender + \beta_8 Newreimb + \beta_9 Infect + \beta_{10} OperComplic + \beta_{11} Readmit + \varepsilon \quad (3)$$

where *DiseaseCt* = number of disease codes assigned to the patient; *ICDct* = number of ICD-9 (procedure) codes associated with the patient's treatment. The other variables were defined earlier.

Since physicians are likely to use more resources on patients that have more ailments, we expect the coefficients on *DiseaseCt* and *ICDct* to be positive. However, we predict that if incremental resources are less after system implementation, the coefficients on the interaction terms *DiseaseCt* * *Post* and *ICDct* * *Post* will be significantly negative. Similar to Eq. (2), we do not make a prediction on *Post* (β_1) once we include the interaction terms.

We examine outpatient treatment patterns using variations of Eqs. (1) and (2). For the outpatient analysis, the

[13] The primary difference between the two metrics is that severity of illness is a ratio score, since the values can only be integers 1–4. Standard cost reflects the non-linear relation between severity of illness and cost.

[14] Both disease processes and physician treatment patterns can differ by age and gender (see for example, Kaplan, Fitzpatrick, Cox, Shammas, & Marder 2002).

severity of illness metric, *Severity*, is number of procedures. Except for patient age and gender, this is the only severity of illness metric available in our outpatient data that has variation across observations. Consistent with the inpatient analysis, if physicians are using fewer resources after system implementation, we would expect the coefficient on *Post* to negative. However, if physicians are treating more severely ill patients on an outpatient basis, we expect that more resources will be used to treat outpatients, resulting in an increase in charges and a positive coefficient on *Post*. We therefore do not make any sign prediction in the outpatient analysis for β_1 (*Post*).

Our test of H1b examines inpatient length of stay, controlling for patient characteristics and severity of illness. Hospitals manage length of stay to increase capacity and efficiency. This hospital essentially operates at capacity, so reducing length of stay not only reduces resource utilization with respect to the basic costs associated with care of a patient (e.g., food, laundry expense, and nursing care), but also potentially increases the number of inpatients that could be treated. The models are similar to Eq. (3), replacing the dependent variable *Charges* with length of stay, *LOS*:

$$\begin{aligned} Length\ of\ Stay = {} & \beta_0 + \beta_1 Post + \beta_2 DiseaseCt \\ & + \beta_3 DiseaseCt * Post + \beta_4 ICDct \\ & + \beta_5 ICDct * Post + \beta_6 Age \\ & + \beta_7 Gender + \beta_8 NewReimb \\ & + \beta_9 Infect + \beta_{10} OperComplic \\ & + \beta_{11} Readmit + \varepsilon \end{aligned} \tag{4}$$

where *Length of Stay* = number days the patient was in the hospital.

The other variables were defined earlier. We expect the coefficients on $DiseaseCt * Post$ (β_3) and $ICDct * Post$ (β_5) to be negative if the length of stay decreases after system implementation.

Results

Descriptive statistics

Table 2 presents patient-level descriptive statistics. Panel A includes statistics for inpatients and Panel B reports statistics for outpatients. In Panel A, the patient populations before and after system implementation appear to be quite similar. The proportion of male versus female patients does not change. Average patient age differs by less than a month. In both periods, the inpatient population includes children. While cataract surgery is usually performed on older patients, some children have a congenital disposition for cataracts and require early surgery. The number of disease codes, the number of procedure codes, and charges do not differ significantly after the system change.

The descriptive statistics reported in Panel B for outpatients indicate that these patient populations before and after system implementation are quite similar with respect to age and gender. In contrast to inpatients, the mean count of procedure codes for outpatients increases from 1.42 to 2.47 after the change. This provides preliminary evidence that physicians performed relatively more procedures on an outpatient basis after the hospital

Table 2
Descriptive statistics.

Variable	Pre-implementation					Post-implementation				
	N	Mean	Std. Dev.	Min.	Max.	*N*	Mean	Std .Dev.	Min.	Max.
Panel A: Patient-level descriptive statistics for inpatients										
Patient age	1445	71.53	10.08	13	88	1478	71.61	10.20	6	89
Patient gender	1445	0.68	0.47	0	1	1478	0.68	0.47	0	1
Severity of illness	1445	2.38	0.54	2	4	1478	2.405	0.543	2	4
Disease count	1445	2.04	0.19	2	3	1478	2.04	0.20	2	3
ICD-9 count	1445	2.16	0.79	1	3	1478	2.14	0.80	1	3
Length of stay	1438	1.39	0.54	1	4	1477	1.38	0.55	0	4
Charges ($NT 000's)	1445	24.99	0.84	24.06	32.41	1478	25.02	0.84	24.14	33.07
Panel B: Patient-level descriptive statistics for outpatients										
Patient age	154	69.27	11.34	10	88	143	70.08	10.51	37	88
Patient gender	154	0.55	0.50	0	1	143	0.54	0.50	0	1
Count of procedure codes	154	1.42	0.73	1	3	143	2.47	0.64	1	3
Charges ($NT 000's)	154	23.31	0.22	21.08	23.81	143	23.39	0.42	21.05	24.65

Panel C: Department-level descriptive statistics, monthly averages

	Pre-implementation Mean	Post-implementation Mean	Percent change	*P*-Value for *t*-test of difference
Operating income ($NT 000's)	9647	11,567	19.91	0.002
Revenue per patient ($NT)	1422	1494	5.07	0.01
Operating expense per patient ($NT)	795	742	−6.74	0.03
Material expense per patient ($NT)	157	126	−19.5%	0.06
Salary expense ($NT 000's)	9676	9572	−1.07	0.52

Notes: Gender is coded as 0 for females and 1 for males. Severity of illness is an integer score from 1 to 4. All outpatients have a score of 1 and inpatients can have a score from 2 to 4. Disease count is the number of disease codes assigned to each patient, and ICD-9 count is the number of procedure codes associated with the patient's treatment. Monthly averages are calculated over six months preceding and six months following system implementation. Amounts are adjusted to take into consideration governmental increases to reimbursements and changes in standard costs due to the system implementation. *T*-tests are two-tailed tests of differences in mean.

implemented the new system. We report statistical tests of this difference below. Similar to the inpatient descriptive statistics, charges for outpatients do not differ significantly after system implementation.

Table 2, Panel C presents selected financial data for the ophthalmology clinic as a whole; we were unable to obtain financial metrics associated with cataract patients alone. Cataract patients represent approximately 63% of the inpatients for the clinic, but less than 1% of the outpatients. Although no other initiatives were undertaken by the clinic during the sample period, changes in financial metrics pre- and post-implementation are likely to be only partially affected by the system implementation.

Average monthly operating income increased almost 20% pre- and post-implementation. This increase was due to both an increase in revenue per patient (5.07%) and a decrease in operating expense per patient (6.74%). The final column in Panel C provides *p*-values for a two-tailed *t*-test of difference in means pre- and post-implementation. All three differences in mean are significantly different from zero at conventional levels. Within operating expense, material expense per patient decreased 19.5%. This change is significantly different from zero at the 0.06 level. This reduction in resources used per patient provides preliminary evidence that physicians changed their practice patterns following system implementation.

The final metric in Panel C is Salary Expense. The salary information includes both nursing and physician compensation. Physicians are the only employees with variable components in their compensation, thus any fluctuation is due to changes in their compensation. While the data indicate a slight decrease in overall compensation pre- and post-implementation, the change is not significantly different from zero. Physician bonuses are based on gross charges. If physicians reduce the amount of resources used per patient, their compensation will decrease. Prior research finds that physicians are joint quantity-price optimizers and constraining them on one margin simply leads to compensating adjustments on the other margin to maintain their incomes (e.g., Hadley, 1979; Shwartz et al., 1981). Further, Shields and Young (1994) study the determinants of cost consciousness in an R&D setting and find that cost-based compensation was not a significant determinant. This suggests that in our setting, physicians may be treating more patients to compensate for using less resource-intensive treatments per patient.

Analysis of resource utilization

Table 3 reports results of OLS regression for Eqs. (1) and (2) for inpatient visits. The basic specification is similar across both models; the only difference is whether we

Table 3
Inpatient charges pre and post system implementation.

$$Charges = \beta_0 + \beta_1 Post + \beta_2 Severity + \beta_3 Age + \beta_4 Gender + \beta_5 NewReimb + \beta_6 Infect + \beta_7 OperComplic + \beta_8 Readmit + \varepsilon \quad (1)$$

$$Charges = \beta_0 + \beta_1 Post + \beta_2 Severity + \beta_3 Severity * Post + \beta_4 Age + \beta_5 Gender + \beta_6 NewReimb + \beta_7 Infect + \beta_8 OperComplic + \beta_9 Readmit + \varepsilon \quad (2)$$

	Equation (1)			Equation (2)		
	Predicted sign	Coefficient	*t*-Statistic	Predicted sign	Coefficient	*t*-Statistic
Intercept		22,796.000	170.025***		22,490.000	139.028***
Post	–	−71.765	−1.650*	?	533.388	3.048**
Severity	+	957.696	25.353***	+	1085.387	21.048***
Severity * Post	–			–	−250.947	−3.351***
Age	?	−1.554	−0.966	?	−1.571	−0.969
Gender	?	46.784	1.732+	?	45.692	1.693+
NewReimb	+	249.650	4.453***	+	245.312	4.405***
Infect	?	−12.339	−0.176	?	−21.828	−0.312
OperComplic	?	−70.579	−0.799	?	−60.722	−0.685
Readmit	?	279.823	0.732	?	223.890	0.574
Adj. *R*-squared		0.380			0.386	
F-Statistic		224.50			204.94	
		$p < 0.0001$			$p < 0.0001$	
N (patient level data)			2923			2923

Notes: Variables are defined as follows:
Charges equals the total hospital charges accumulated for resources used during each patient's treatment.
Post equals 1 if the patient was treated on or after March 1, 2001and 0 otherwise.
Severity equals the patient's severity of illness score: 1 for outpatients and 2–4 for inpatients. *Age* equals the patient's age.
Gender equals 1 if the patient is male and 0 otherwise.
NewReimb equals 1 if the admission date is after June 1, 2001, when reimbursement levels changed and 0 otherwise.
Infect equals the infection rate during the month of treatment.
OperComplic equals the frequency of complications during the month of treatment.
Readmit equals the monthly rate of readmission within 14 days of surgery.
All *t*-statistics are two-tailed unless there is a sign prediction and are corrected for heteroskedasticity as in White (1980).
* Significance at the 5% level.
** Significance at the 1% level.
*** Significance at the .1% level.
\+ Significance at the 10% level.

Table 4
Inpatient charges pre and post system implementation *additional analyses*.

$$Charges = \beta_0 + \beta_1 Post + \beta_2 DiseaseCt + \beta_3 DiseaseCt * Post + \beta_4 ICDct + \beta_5 ICDct * Post + \beta_6 Age + \beta_7 Gender + \beta_8 Newreimb + \beta_9 Infect + \beta_{10} OperComplic + \beta_{11} Readmit + \varepsilon \quad (3)$$

	Predicted sign	Coefficient	*t*-Statistic	Chi-Sq. test
Intercept		22,255.000	40.259***	
Post	?	773.717	1.049	
DiseaseCt	+	1,354.328	5.159***	21.94 $p < 0.0001$
DiseaseCt * Post	–	−304.015	−0.879	
ICDct	+	57.667	2.319*	4.67 $p < 0.04$
ICDct * Post	–	−114.920	−3.148**	
Age	?	−2.236	−1.151	
Gender	?	58.000	1.810+	
NewReimb	+	243.763	3.911***	
Infect	?	−0.376	−0.005	
OperComplic	?	−124.172	−1.145	
Readmit	?	601.304	1.443	
Adj. *R*-squared		0.089		
F-Statistic		26.94		
		$p < 0.0001$		
N (patient level data)		2923		

Notes: Variables are defined as follows:
Charges equals the total hospital charges accumulated for resources used during each patient's treatment.
Post equals 1 if the patient was treated on or after March 1, 2001 and 0 otherwise.
DiseaseCt equals the total number of disease codes for the patient.
ICDct equals the total number of ICD-9 (procedure) codes for the patient.
Age equals the patient's age.
Gender equals 1if the patient is male and 0 otherwise.
NewReimb equals 1 if the admission date is after June 1, 2001, when reimbursement levels changed and 0 otherwise. *Infect* equals the infection rate during the month of treatment.
Infect equals the infection rate during the month of treatment.
OperComplic equals the frequency of complications during the month of treatment.
Readmit equals the monthly rate of readmission within 14 days of surgery.
All *t*-statistics are two-tailed unless there is a sign prediction and are corrected for heteroskedasticity as in White (1980). The Chi-Square test investigates whether the sum of the coefficients before and after system implementation is significantly different from zero.
* Significance at the 5% level.
** Significance at the 1% level.
*** Significance at the .1% level.
\+ Significance at the 10% level.

allow for both intercept and slope effects for system implementation. In these two models, severity of illness score *(Severity)* is the severity metric.

Eq. (1) tests for an intercept shift in charges and indicates an overall decrease in charges after system implementation. The coefficient on *Post* is −71.765 ($p < .05$, one-tailed). In addition, the coefficient on *Severity* is 957.696 ($p < 0.001$) suggesting that charges are increasing in severity of illness. Charges are also higher for male patients ($p < .10$).[15]

Eq. (2) allows for both a slope and intercept effect. The coefficient on *Severity* of 1,085.387 ($p < 0.001$, one-tailed), indicates that charges are increasing in severity of illness. Although the coefficient on the dummy variable for system change is significantly positive (*Post* = 533.388, $p < 0.05$), the coefficient on the interaction (slope) term is significantly negative (*Severity* * *Post* = −250.947, $p < 0.001$). When evaluated at the mean of the severity index, these results suggest an overall decrease in charges post-implementation. Note that in Table 2, Panel A, the mean severity index for inpatients is 2.405. This indicates an average decrease in resource utilization for inpatients after system implementation (−70.140 = 533.388 + (−250.947 × 2.405)).[16] These results are consistent with efficiencies being found for a broad range of activities associated with treatment of cataracts. The more severely ill patients receive greater intensity of treatment, which provides more opportunities for cost savings. Inpatient charges do not appear to be associated with the quality metrics and male patients tend to have higher charges (*Gender* = 45.692, $p < 0.10$ two-tailed).

[15] The models reported in Tables 3–6 omit influential observations (as identified by their studentized residuals). Models that include all observations have weaker results. Most of the models indicated presence of heteroscedasticity. Following Barth and Kallapur (1996), all t-statistics are based on White-adjusted residuals (White, 1980) to control for heteroscedasticity. In the models, Shapiro-Wilk (where $N < 2000$) and Kolmogorov-Smirnov tests generally reject the hypothesis of normally distributed residuals. Where possible, we re-estimated the models using log of charges and the results were qualitatively similar. Finally, there does not appear to be strong multicollinearity in any of the models; all condition indices are less than 30 (Belsley, Kuh, & Welsch (1980)).

[16] When evaluating inpatients at low levels of severity (i.e., when the severity of illness code equals 2), the results suggest an increase in resource utilization (31.494 = 533.388 + (−250.947 × 2). This could occur if the least severe patients are likely to be treated as outpatients after system implementation. Thus, the inpatients remaining might require somewhat more care than before implementation. However, there is an overall decrease, on average, in resource utilization after system implementation.

We next decompose the severity of illness metric into *DiseaseCt*, reflecting the number of disease codes (conditions) and *ICDct*, reflecting the number of procedures. These are two components (for which we have measures) used for derivation of the severity of illness code. Table 4 reports the results of the OLS regression for Eq. (3) for inpatients. Charges are increasing in the number of diseases ($p < 0.001$), but there is no change following system implementation. Charges are also increasing in the number of procedures ($ICDct = 57.667$, $p < 0.05$). However, this relation is significantly lower in the post-implementation period ($ICDct * Post = -114.920$, $p < 0.01$) which indicates that each incremental procedure is performed using fewer resources. The Chi-Square statistic for the sum of *ICDct* and *ICDct * Post* (Chi-Square = 4.67, $p < 0.04$) indicates that after implementation, the cost of additional procedures was significantly negative. This potentially counterintuitive result likely occurs because the system implementation gave physicians an opportunity to examine their processes and make less-costly substitutions in procedures. In summary, it appears that resources associated with treating additional conditions did not change following implementation, while resources used per procedure decreased.

As predicted, the coefficient on *NewReimb* is significantly positive in both Tables 3 and 4. This result is consistent with physicians adjusting their practice patterns relative to the new reimbursement level. We therefore see evidence that physicians increased overall resource utilization when the reimbursement levels increased (indicated by the positive coefficient on *NewReimb* in Tables 3 and 4). Overall, these results support H1a and suggest that for inpatients, physicians used fewer resources following system implementation.

Table 5 presents results for outpatients using modifications of Eqs. (1) and (2). We test for an intercept effect with Eq. (1). The coefficient on *Post* (163.33) is significantly positive ($p < .05$ two-tailed), indicating that, on average, outpatient charges increase following system implementation. This could result if physicians are treating more severely-ill patients on an outpatient basis. Because the severity of illness score for all outpatients takes the value of one, we use the count of procedure codes (*ICDct*) as the severity of illness metric. As expected, a greater number of procedures (*ICDct*) is associated with higher charges ($p < .05$, one-tailed). In this regression, none of the control variables are significant.

In the results for Eq. (2) a greater number of procedures is also associated with higher charges ($ICDct = 125.674$, $p < 0.001$, one-tailed), as one would expect. Although the coefficient on the dummy variable for system change is significantly positive ($Post = 482.482$, $p < 0.001$ two-tailed), the coefficient on the interaction term for the number of procedures and the post-implementation period is significantly negative ($ICDct * Post = -172.620$, $p < 0.001$,

Table 5
Outpatient charges pre- and post system implementation.

$$Charges = \beta_0 + \beta_1 Post + \beta_2 ICDct + \beta_3 Age + \beta_4 Gender + \beta_5 NewReimb + \beta_6 Infect + \beta_7 OperComplic + \beta_8 Readmit + \varepsilon \quad (5)$$

$$Charges = \beta_0 + \beta_1 Post + \beta_2 ICDct + \beta_3 ICDct * Post + \beta_4 Age + \beta_5 Gender + \beta_6 NewReimb + \beta_7 Infect + \beta_8 OperComplic + \beta_9 Readmit + \varepsilon \quad (6)$$

	Equation (5)			Equation (6)		
	Predicted sign	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Chi-Sq. test
Intercept		22850.000	68.176***	22,751.000	67.407***	
Post	?	163.333	2.321*	482.482	3.337***	
ICDct	+	49.400	2.207*	125.674	6.115***	1.10 $p < 0.30$
ICDct * Post	–			−172.620	−3.535***	
Age	?	3.895	0.931	3.638	0.889	
Gender	?	36.462	1.128	35.601	1.120	
NewReimb	+	−182.904	1.444	−132.894	−1.028	
Infect	?	−64.814	−0.556	−50.693	−0.449	
OperComplic	?	229.272	1.444	203.920	1.344	
Readmit	?	−632.389	−1.255	−258.677	−0.547	
Adj. *R*-squared		0.0514		0.0775		
F-statistic		3.01		3.76		
		$p < 0.003$		$p < 0.0002$		
N (patient level data)		297		297		

Notes: Variables are defined as follows:
Charges equals the total hospital charges accumulated for resources used during the patient's treatment.
Post equals 1 if the patient was treated on or after March 1, 2001 and 0 otherwise.
ICDct equals total number of ICD-9 (procedure) codes for the patient.
Age equals the patient's age.
Gender equals 1 if the patient is male and 0 otherwise.
NewReimb equals 1 if admission date is after 6/1/2001, when reimbursement levels changed and 0 otherwise.
Infect equals the infection rate during the month of treatment.
OperComplic equals the frequency of complications during the month of treatment.
Readmit equals the monthly rate of readmission within 14 days of surgery.
All *t*-statistics are two-tailed unless there is a sign prediction and are corrected for heteroskedasticity as in White (1980). The Chi-Square test investigates whether the sum of the coefficients before and after system implementation is significantly different from zero.
* Significance at the 5% level.
*** Significance at the .1% level.

Table 6
Inpatient length of stay pre- and post system implementation.

$$Length\ of\ Stay = \beta_0 + \beta_1 Post + \beta_2 DiseaseCt + \beta_3 DiseaseCt * Post + \beta_4 ICDct + \beta_5 ICDct * Post + \beta_6 Age + \beta_7 Gender + \beta_8 NewReimb + \beta_9 Infect + \beta_{10} OperComplic + \beta_{11} Readmit + \varepsilon \quad (4)$$

	Predicted sign	Coefficient	*t*-Statistic	Chi-Sq. test
Intercept		0.472	1.723[+]	
Post	?	−0.637	−1.741[+]	
DiseaseCt	+	0.437	3.509[***]	6.152 $p < 0.0001$
DiseaseCt * Post	–	0.356	1.980	
ICDct	+	0.040	2.309[*]	0.866 $p < 0.39$
ICDct * Post	–	−0.055	−2.252[*]	
Age	?	−0.001	−1.025	
Gender	?	0.032	1.533	
NewReimb	+	0.016	0.387	
Infect	?	0.016	0.300	
OperComplic	?	−0.064	−0.889	
Readmit	?	0.466	1.706[+]	
Adj. *R*-squared		0.055		
F-Statistic		16.39		
		$p < 0.0001$		
N (patient level data)		2915		

Notes: Variables defined as follows:
Length of Stay equals the number of days the patient was an inpatient;
Post equals 1 if the patient was treated on or after March 1, 2001and 0 otherwise;
DiseaseCt equals the total number of disease codes for the patient;
ICDct equals the total number of ICD-9 (procedure) codes for the patient;
NewReimb equals 1 if the admission date is after June 1, 2001, when reimbursement levels changed and 0 otherwise;
Age equals the patient's age;
Gender equals 1 if the patient is male and 0 otherwise;
Infect equals the infection rate during the month of treatment;
OperComplic equals the frequency of complications during month of treatment;
Readmit equals the monthly rate of readmission within 14 days of surgery.
All *t*-statistics are two-tailed unless there is a sign prediction and are corrected for heteroskedasticity as in White (1980).
[*] Significance at the 5% level.
[***] Significance at the .1% level.
[+] Significance at the 10% level.

one-tailed). When evaluated at the mean of *ICDct*, the results indicate an overall increase in charges post-implementation. For outpatients, the mean of the number of procedure codes is 2.47, as shown in Table 2, Panel B. Applying this mean indicates that, on average, resource utilization increased for outpatients after the system implementation (56.111 = 482.482 + (−172.620 × 2.47)). Thus, on average, overall outpatient charges increased following system implementation, but physicians used fewer resources per incremental procedure.[17] Similar to inpatients, these results are consistent with substitution of less costly procedures following system implementation. None of the other control variables are significantly different from zero.

Analysis of length of stay

We next analyze the impact of the system implementation on inpatient length of stay. Table 6 presents the results of estimating Eq. (4), with the dependent variable *LOS* replacing *Charges*. We use more detailed measures of severity of illness in this analysis to isolate the length of stay associated with procedures versus complications associated with multiple illnesses. If physicians respond to implementation by reducing their use of resources, we expect a decrease in length of stay (H1b). The results indicate that the coefficient on *Post* is negative and marginally significant (−0.637, $p < 0.10$, two-tailed). Unsurprisingly, the coefficients on *DiseaseCt* and *ICDct* are significantly positive, indicating that overall, inpatients with additional conditions and additional procedures have a longer length of stay. Contrary to our prediction, however, after system implementation, patients with more medical conditions do not have a relatively shorter length of stay per additional disease (*DiseaseCt * Post* = 0.356). However, there is a significant decrease in the additional length of stay resulting from additional procedures (*ICDct* = −0.055, $p < 0.05$ one-tailed). The total effect is not significantly different from zero (Chi-Square = 0.866, $p > 0.10$). These results suggest improvements in efficiency after system implementation; physicians appear to be shifting resources to sicker patients. Taken together, the results of

[17] It is possible that physician response to the new system could be temporary. In some settings, process improvements occur simply because of an environmental change, not because of any actual environmental improvement (Mayo, 1946). One means of addressing this potential explanation is to examine changes in physician response over time. As a sensitivity analysis, we split the post-implementation period into two subperiods to see if the changes we see persist during the post-implementation period. While this analysis is somewhat problematic because of sample size and the timing of the change in reimbursements during the middle of the post-implementation period, we do not find evidence that the changes we find were temporary.

Table 7
Cataract inpatient admissions and outpatient visits and distribution of number of icd codes (procedures) per patient.

	Number of procedures			Total
	One	Two	Three	
Panel A: Inpatient admissions				
Prior to implementation	358	464	593	1,415
After implementation	384	502	592	1478
Chi-Square 0.6037 $p < .74$				
Panel B: Outpatient visits				
Prior to implementation	112	20	22	154
After implementation	11	53	79	143
Chi-Square 129.79 $p < .0001$				

H1a and H1b provided support for H1, that when users participate in developing a new accounting system, users will change their behavior in accordance with system foci.

In a supplemental analysis, Table 7 investigates changes in the number of procedures per patient before and after system implementation. Panel A reports results for inpatients; the number of procedures provided to inpatients does not differ before and after system implementation. Panel B reports the same statistics for outpatients. The distribution of number of procedures provided to outpatients changes significantly following system implementation, with a higher average number of procedures after the change (Chi-Square = 129.79, $p < .0001$). This indicates that post-implementation, physicians are performing more procedures in the outpatient (more resource-efficient) setting.[18]

Use of cost data by head of the department

We interviewed the head of the Ophthalmology Department about his use of cost information before and after system implementation to determine whether there were any other events that could drive our results. For several years prior to system implementation, the department head had organized monthly cost analysis meetings to provide cost information to physicians. These data included mostly traditional cost information, consisting of department financial statements with aggregate cost information. Once the new system was implemented, cost reports included costs for teaching and research activities and the revenues and costs for patient treatment activities. In addition, the department head asked all physicians to follow the new clinical pathways whenever possible, to help contain costs. There were no other changes in overall hospital management during the time period of this study. In addition, over the past several years, the hospital had focused on capacity and productivity management, and had encouraged physicians to use cost information. This emphasis began prior to our test period and did not change during our sample period. To determine whether this emphasis might have influenced physician behavior, we analyzed data from another hospital department that would have been subject to overall hospital initiatives, but that did not involve physicians in developing a new accounting information system.

Results for a department with no change in accounting information system

To help rule out the effects of any other changes in overall hospital operations, we asked the hospital accountants to identify services similar to those provided by the Ophthalmology Department. The accountants chose hernia surgery because it is a surgical procedure that can be performed on either an inpatient or outpatient basis and it requires similar resources in terms of doctors' and nurses' time, and patient length of stay or time in short-stay surgery. Further, this department had not been subject to any initiatives from the accounting department. The accountants gave us information for 688 inpatients and 179 outpatients undergoing hernia surgery from July 1, 2000 through August 30, 2001, the same time period examined above. The hospital was unable to provide an identical set of study variables for these patients, but we had enough data to analyze any changes in practice patterns for hernia patients during this time period. Hospital accountants and administrators had been pressuring all hospital departments to contain costs after the introduction of prospective payment. Accordingly both departments received similar pressure to reduce costs, although the ophthalmology department was the only one to participate in developing and using a new accounting information system.

In an un-tabled analysis, we estimate versions of Eq. (4) omitting the physician and quality control variables and disease count. For inpatients, we find no difference in length of stay before and after the system implementation. However, we find that hernia charges *increased* over time; the coefficient on the time dummy is significant and positive at the 0.02 level. We find no significant changes across time for the hernia outpatient population. These results suggest that the changes we document in the ophthalmology department occur as a result of development and implementation of a new accounting system and are not part of a hospital-wide trend.

Discussion

To our knowledge, the inherent linkage between ABC implementation and non-accountant participation has not been explored in prior research. A key feature of ABC is that employees who perform productive tasks are asked to help identify cost pools and cost drivers. This involvement takes place as part of the analysis and design phase and should lead to greater use of the system (Hunton & Price, 1994; Ives & Olson, 1984). When an ABC system is used in a professional setting, the professionals become involved in analyzing their activities and designing the system and consequently, the system should more likely

[18] Using limited quality data (monthly averages) we find no significant change in quality measured by changes infection and complication rates after system implementation. We find that the patient return rate decreased significantly ($p < 0.06$), indicating higher quality. Because the number of data points is limited, these results are only suggestive of overall trends.

affect their behavior than would a traditional information system developed by accountants. We explore this issue in a healthcare setting where a subset of physicians admits that they had ignored traditional accounting reports, much to the frustration of hospital accountants.

Our study setting is the ophthalmology department in a large hospital in Taiwan. The previous costing system was based on average costs and was developed by the accounting department. The new system required that physicians examine the inputs to their treatment decisions, including their time, clinic employee time, and all supplies used to develop activity-based cost pools and cost drivers. Once this cost information was developed, physicians were asked to use it to reassess clinical pathways that had been developed previously. The modified clinical pathway information became new standard costs for the department. Physicians were thus highly involved in developing the new system. This involvement linked cognitive and motivational factors to the ultimate success of the system because as the physicians report, they were willing to use the new information, whereas they had ignored information from the old system. Further, new disaggregated information reported the costs of their activities in patient care, teaching, and research. Because revenue was received only for patient care, the new report allowed physicians to better gauge the effects of their activities on both costs and revenues. Our hypotheses predict that physicians would change their resource consumption decisions after system implementation to align with the system goals. We find that after implementation physicians reduce resource utilization for inpatients and perform more procedures on an outpatient basis. Resources used per procedure decrease for all patients. Further, we find that physicians use hospital resources more efficiently. Overall, cataract inpatient length of stay decreased, as did the length of stay associated with additional procedures. Resources appear to have become more focused on patients who are more severely ill; length of stay is more positively associated with the patient's number of conditions after the change in cost system. We also examine the overall effects of the system implementation on financial performance. We find preliminary evidence of improved financial performance after implementation through both increased revenues and decreased costs.

We contribute to the literature that examines the influence of participation in accounting information system design and other factors on post-implementation outcomes. For example, Choe (1998) uses self-reported satisfaction and use as proxies of system performance success. His results suggest that task uncertainty and specific information characteristics influence the success of user participation in system design. Satisfaction with the accounting information system was highest when task uncertainty was high, information was aggregated and timely, and user participation was high. Hartwick and Barki (1994) review research findings concerning information systems and how users' participation influences their post-implementation beliefs that: (1) the system is important and personally relevant; and (2) that they would be more inclined to use the system. A weakness of this line of research is that success is measured by self-reported satisfaction and use.

We also contribute to the hospital accounting information system literature. Kim (1988) analyzes responses from business managers and hospital accounting information system directors from 28 US hospitals and finds that characteristics of the tasks, problem analyzability, coordination methods, and group size affect the performance of hospital accounting information systems. Measures of system performance are self-reported beliefs about satisfaction with the system, and include perceptions about system qualities such as accuracy, amount, and understandability, among others.

We add to this literature by providing evidence that participation in developing an ABC information system resulted in post-implementation improvement in resource utilization. These results are consistent with Hunton and Gibson (1999), who find improvement in error rates when employees participate in the design and development of a new accounting information system. Our results show not only a reduction in overall resource utilization, but also a redeployment of resources toward sicker patients.

Our approach and research question are somewhat different from Bhimani (2003). His work examined how organizational culture became embedded in a new accounting system and how alignment of personal culture with the organizational culture expressed in the system affected perceived success of the system. In his study, while not specifically investigated, statistics on culture scores indicate that the system did not appear to play a role in changing personal culture. Using similar terminology, we believe that in our setting the new system helped to better align the personal culture of the physicians with the organizational culture that management had been trying (unsuccessfully) to embed in the hospital. In a sense, the new system did a better job of expressing the belief system that the hospital was trying to communicate. The result is that the physicians were more willing to consider cost in their treatment decisions.

Prior research on the success of ABC system implementations has ignored the effects of participation on both the system users' perceptions of success and the systems' successes. Future research analyzing ABC system success needs to consider the effects of user involvement. While prior ABC research examined users' beliefs and attitudes to help identify successful implementations, no one has directly measured user input throughout an ABC system implementation to determine the influence of such involvement on the use and success of the system.

In addition to underscoring the importance of considering user participation in analyzing system success, our study illustrates the importance of examining changes at a more micro level. The change in resource utilization that we found is not merely comprised of cost reductions. Our analysis of resource redeployment toward outpatients and more severely-ill patients provides a much richer description of the impact of the system change.

Our study is subject to several limitations. We did not formally survey physicians to determine the extent to which their involvement in system development influenced their willingness to use information produced by the system. However, we are able to capture behavioral changes that occurred post-implementation that suggest physicians did use the new information. Anecdotally, one physician told us that he paid attention to the new cost information because, rather than being seemingly arbitrarily assigned by the accountants, the costs were now "real." This is a particularly striking statement, given that the difference between the pre- and post-ABC standard costs ranged from 2.6% to 3.1% – an amount that is unlikely to make a material difference for most decision-making contexts. In addition, while our study sample period is somewhat limited, our results hold at both the beginning and end of the sample period, indicating that the improvements are unlikely to be a temporary phenomenon. We also did not track costs to develop and implement the ABC system to know whether the department cost savings outweighed the costs of accounting department time and effort.

There are features of our setting that potentially limit the generalizability of our findings. Future research could investigate these characteristics to help better understand how participation can help with system success. First, the professionals that we study are physicians. Cost considerations are not a part of their education or culture. It may be the case that we find results due to the educational aspects of the ABC process—the physicians developed a better understanding and appreciation of cost. It might be interesting to investigate whether there are similar improvements in a setting where cost is a part of the professionals' education and culture, such as in an accounting firm. Another characteristic of our setting is that it is fairly simple—ABC was introduced for only two processes (inpatient and outpatient treatment of cataracts), there is a culture of developing treatment protocols, and there are limited opportunities for resource substitution (e.g., many tasks that physicians perform cannot be performed by nursing staff). Future research could investigate how systems such as ABC impact decision-making in more complex settings where there are more activities to manage and more substitutable resources, such as the banking industry. Finally, ABC systems do not fully separate fixed and variable costs. In the setting for this study, capacity utilization is quite high, so the opportunity cost of capacity is a clear consideration. Inappropriate inclusion of overhead is likely more of a concern in organizations that have excess capacity and ABC systems may not result in similar improvements. Some newer accounting information systems, such as GPK (Grenzplankostenrechnung) and RCA (Resource Consumption Accounting) have the participatory features of ABC, but more carefully separate fixed and variable costs. Future research could examine the effects of participation and resource utilization changes in these types of systems relative to ABC and capture any differential impacts of these systems based upon capacity utilization.

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