

Internet Appendix

Updating Accounting Systems: Longitudinal Evidence from the Health Care Sector

Contents

A. Additional information on data sources and procedures	1
B. Variable definitions	3
C. Additional information, validation, and robustness checks on Table 2.....	5
D. Additional information, validation, and robustness checks on Table 4.....	6
References.....	7

A. Additional information on data sources and procedures

To allow us to consistently identify specific applications over time, we examined all application types identified in the survey over the sample period and classified each business application with one of 21 labels used in Setia, Setia, Krishnan, and Sambamurthy (2011). Of these 21, 8 are consistent with our definition of AS and hence the subject of this paper. We define these AS below. All AS are tracked throughout the entire sample period, other than EIS and Credit/Collections which are tracked from 1993 onwards. Where multiple applications are classified in the same category, we record an update when any of the applications are updated; however, the data only contain one observation per hospital-application type-year.

Supporting basic financial transactions:

- Accounts payable system: manages the accounts the hospital owes money to, to help make timely payments.
- General ledger system: maintains the overall financial accounts of the hospital (e.g., income statement, balance sheet) and collects the journal and ledger transaction records.

Enhancing analytical capabilities:

- Costing system: estimates the cost of treatments and patients.
- Budgeting system: plans and coordinates the acquisition and allocation of resources and ensures a balance between expenditures and income can be achieved.
- Executive Information System (EIS): integrates information from throughout the hospital to give high-level performance indicators for decision-making.

Patient-focused financial systems:

- Case mix system: calculates cost and revenue by patient category.
- Credit/collection system: manages patient accounts that are past due.
- Patient billing system: processes patient charges and claims.

We use three dates in our updating analysis. The contract date is the date on which a hospital contracted to purchase an AS model. The implementation date is the first year for which an AS was listed as “fully operational.” The install date is the date on which an AS model was installed. We observe an average lag of 4 to 8 months between the install and implementation date, indicating that they mark the beginning and end of application installation, respectively. Only the contract date is available and precisely measured for the entire sample period (with the exception of the first year, 1987), so we focus on this date. We replace missing contract dates with the install date (when available) in order to calculate the time since the last model update. Where both the contract and install dates are available, the median difference is 0 years (less than a year on average), so this substitution seems reasonable. We further replace remaining missing contract dates with the implementation year, adjusted for the median difference between contract and implementation year by application type. These substitutions affect approximately one fifth of the dates in our sample. In addition, we take steps to alleviate various small errors, such as contract dates which are unreasonably old or fall years after the survey dates. Updates for which we cannot determine the time since the last update (left censored) are excluded from the sample.

We use AS model names and dates to identify model updates. Because some models are not tracked every year, we check whether the current AS model (specific vendor and model version) was used by the hospital in *any* of the preceding four years and only record an update if it was not. We identify model updates if the contract date has occurred within the last two years.¹ We only identify model updates using this method if the AS was not also updated in the previous year. If both the contract date and model name are available, we recognize model updates if the model has not been used in the previous four years and the AS contract year is at most three years before the current year. Additionally, so as to not wrongly identify updates because of minor changes to vendor names, three research assistants reviewed all AS vendors to reliably track unique vendors over time, paying particular attention to years when the survey changed (1998 and 2005).²

¹ The surveys were not collected in 1996 and 1997, and we do not have access to the 1989 data. We extend this period to three years for the 1998 and 1990 observations.

² To prevent inconsistent model names falsely indicating an update, we only classify the changed model name as an update if the contract or installation date corroborates evidence of an update by showing a change in the last two years.

B. Variable definitions

Variable Name	Variable Description
%Clinical_Updates	The percent of a hospital's clinical information systems which were updated in the current year.
%Medicaid	The percent of the hospital's total patient days that are for Medicaid patients. Available starting in 1998.
%Medicare	The percent of the hospital's total patient days that are for Medicare patients. Available starting in 1998.
%MR_Updates	The percent of a hospital's medical record information system which were updated in the current year.
Academic	Indicator variable coded 1 if the hospital is classified as an academic hospital in the HIMSS data, or if the HCRIS data has positive intern salary or is classified as a teaching hospital.
Apps_Age	The average age (years since last update) of all applications in the current hospital-year (excluding the current application observation).
Bedsizes	Number of licensed beds in the hospital
Business_Depth	The number of unique software applications that are categorized as "Business Office" for a given hospital-year.
Clinical_Depth	The number of unique software applications that are categorized as "Clinical" for a given hospital-year.
Celebrity_Peer_Update	An indicator variable coded 1 if the hospital is within 15 miles of another hospital which was identified on the 100 Most Wired list published by Hospitals and Health Networks (https://www.hhnmag.com/mostwired/results/awardanddemographics) in the current year <i>and</i> the celebrity hospital updated the AS of interest. The 100 Most Wired list was published starting in 2000.
CMI	Case Mix Index obtained from CMS (Centers for Medicare and Medicaid Services). The CMI represents the average diagnosis-related group (DRG) relative weight for that hospital, where the value assigned to each DRG indicates the amount of resources required to treat patients in that group.
County_Peer_Update	An indicator variable coded 1 if a hospital in the same county-year updated the AS of interest.
Duration	The number of years since the last update of the given AS (measured since the prior update if the AS was updated in the current year).
Fair_Pricing	Indicator variable coded 1 if fair pricing measures were implemented in the state in the prior year. In order to identify this, we use the enactment dates of fair pricing laws for each state reported in Table 1 of Batty and Ippolito (2016). We also hand-collected enactment dates for the 6 states reported in their Footnote 6 which fall within our sample period. We include Wisconsin, although this state did not technically introduce a fair pricing <i>law</i> , yet its major hospital systems revised their policies to limit charges for uninsured patients after the state's attorney general filed complaints about their billing practices. Because measures that become effective in the second half of the year do not apply to the majority of the decisions made in that year, fair

	pricing measures that became effective in July and later are coded as occurring in the following year. In all, 12 states in our sample enacted fair pricing laws.
For_Profit	Indicator variable coded 1 if the hospital is ever classified as a for-profit entity in either the HIMSS or HCRIS data.
Growth_Bedsize	$(\text{Bedsize}_t - \text{Bedsize}_{t-1}) / \text{Bedsize}_{t-1}$
HHI	Yearly Herfindahl-Hirschman Index of hospital concentration measured at the county-year level using all hospital-year observations available.
Hospital_Update_Count	The number of applications (excluding the current AS) that a hospital updated in the current year.
In_System	An indicator variable coded 1 if the hospital is within a multi-hospital system and 0 otherwise.
Med_Record_Depth	The number of unique software applications that are categorized as “Medical Records” for a given hospital-year.
Op_Ex	Operating expenses per bed (i.e., total operating expenditures/bedsize), obtained from the HIMSS data. Operating expenditures are not available from the HIMSS data for the years 1987, and 1998-2003; missing values of operating expenditures after 1996 are filled in from the HCRIS cost reports data where available. Cost of AS updates and maintenance are typically expensed immediately, while licensing costs and capital expenditures on computers to support the AS are depreciated over 3 years (AmericanHospitalAssociation, 2013).
Op_Rev	Net operating revenue of the hospital per bed, obtained from the HIMSS data. Operating revenues are not available from the HIMSS data prior to 2005; missing values of net operating revenues after 1996 are filled from the HCRIS cost reports data where available.
Prep_Year	An indicator variable coded 1 if the data year is 2002 or 2003 (the two years after the passage of Sarbanes-Oxley during which firms could prepare to be SOX-compliant before 2004).
Price_Transparency	Indicator variable coded 1 if the state adopted a price transparency website in the prior year. Dates obtained from Table 1 of Christensen, Floyd, and Maffett (2014) and Christensen, Floyd, and Maffett (2015). Because measures that become effective in the second half of the year do not apply to the majority of the decisions made in that year, price transparency measures that became effective in July and later are coded as occurring in the following year. In all, 29 states in our sample adopted price transparency websites.
Rural	Indicator variable coded 1 if the hospital is located within a zipcode for which at least 50% of the population lives in a rural area, according to the 2000 U.S. Census, or if the hospital reported it was in a rural area in at least one HCRIS cost report.
Self_Developed	Indicator variable coded 1 if the AS was self-developed by the hospital. Many self-developed AS are identified in the HIMSS database itself; additionally, three research assistants manually

	reviewed all of the application vendors in the database and identified those that are actually a hospital or hospital system itself instead of an outside vendor (i.e., the hospital listed itself as the vendor when it had self-developed the AS).
SOX_404	An indicator variable coded 1 for hospitals that were part of hospital systems that were subject to SOX 404 in 2004.
Specialty_Hosp	Indicator variable coded 1 if the hospital is a specialty hospital, according to data provided in the HCRIS dataset. Non-specialty hospitals: general short- and long-term hospitals. Specialty hospitals: cancer, psychiatric, rehabilitation, religious non-medical, pediatric, alcohol & drug, other.
System_Peer_Update	Indicator variable coded 1 if another hospital in the hospital's multihospital system or purchasing group updated the AS of interest in the current year.
Update	Indicator variable coded 1 if the hospital updated the AS of interest in the current year.
Vendor_Peer_Update	The proportion of other hospitals which share the same vendor for a particular AS type that updated the AS in the current year (varies between 0 and 1). When a hospital has changed vendor in the current year, this measure is the proportion of hospitals which shared its <i>prior</i> year vendor that updated this year. [Excludes hospital-AS-years where fewer than 2 other hospitals use the same vendor for the same AS. Also excludes observations where all hospitals that used a given vendor changed vendor in that year. This variable is set to 0 for all self-developed systems.]

Dollar amounts are deflated by CPI to be in constant year 2000 dollars.

C. Additional information, validation, and robustness checks on Table 2

- A few hospitals in our sample period are part of hospital systems that have been public at one time but which were not subject to SOX 404 in 2004, for example firms below the \$75 million public float cut-off or firms which became public and thus subject to SOX 404 later in our sample period. Our results estimating the effects of SOX 404 on updating are robust to excluding these hospitals.
- The presence of county-specific effects could raise concerns about correlated error terms among hospitals within the same county. Thus, in robustness tests, we cluster standard errors by county and find similar results.
- Because 2010 is the last year of our sample, our results are not impacted by the Health Care Information Technology for Economic and Clinical Health Act meaningful use criteria (HITECH 2009 Act) which could give a regulatory impulse to adopt more IT. Our results

are qualitatively similar when we drop 2010, indicating that we do not capture anticipatory effects of the HITECH Act.

- In our main tests, *Celebrity_Peer_Update* is a binary variable that takes a value of 1 if a hospital is within 15 miles of a “celebrity” hospital which updated the AS of interest that year. Results are consistent if we use 100 miles or instead create an indicator just for the presence of a celebrity adopter.
- While hospitals can always update their AS by switching vendors, and hence the hazard model is appropriate, updating is likely cheaper when hospitals’ existing vendors roll out updates, which does not happen every year. Such differential cost of updating simply constitutes an additional determinant of AS updating, and two analyses provide us with support for this notion. First, we hand-collected version updates between 2005 and 2010 by the top ten vendors of each AS using news releases available on Lexis-Nexis and other library sources in order to identify whether an update from the existing vendor was available in a specific year. While these hand-collected data from public sources are arguably noisy, we found some weak evidence that hospitals are more likely to update when their vendors release new software versions, consistent with the story of lower updating costs. In this small subsample, we still found that the other determinants in our hazard analysis behaved similarly to Table 2. Second, we ran our determinants analysis when only focusing on vendor changes (hospitals switching from one AS vendor to another for the same AS), and found similar results to Table 2. In addition, our determinants analysis controls for vendor peer updates, which will increase when new updates from the current vendor are available.

D. Additional information, validation, and robustness checks on Table 4

- We use the `xtivreg2` command in Stata in our instrumental variables analyses, with year and hospital fixed effects and standard errors clustered by hospital. Because our model is exactly identified (we have one endogenous regressor and only one instrumental variable in each specification), the `xtivreg2` GMM estimator simplifies to the 2SLS estimator (Hayashi, 2000, p. 206-213). This approach does not use the Forbidden Regression approach discussed by Angrist and Pischke (2008, p. 142-144); the first stage is a linear regression, even though our *Update* variable is non-linear, giving us consistent estimates.

- In untabulated tests we use the number of patient days instead of *Bedsize* as a scalar for *Op_Ex* and *Op_Rev* or no scalar at all. Inferences are similar.
- To the extent that AS of different types may be updated at the same time even after controlling for other determinants of updates, as demonstrated in Table 3, it is possible that the results of economically driven updates in Table 4 which we attribute to individual systems may be capturing the cumulative effect of updates of multiple AS. To rule out this possibility, we also control for concurrent updates of other AS, as well as include an indicator for whether each other AS is installed at the time of the update of the AS of interest. The untabulated results show that 16 of the 17 significant coefficients for economically driven updates in Table 4 remain significant, sometimes even at higher significance levels, confirming that the effects we document can be attributed to each of our 8 AS individually.³

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³ The marginally relevant coefficient in $t+1$ of credit/collections AS updating on revenue in Table 4 is the only coefficient that loses significance.