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Investment subsidies and the adoption of electronic medical records in hospitals

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ABSTRACT

In February 2009 the U.S. Congress unexpectedly passed the Health Information Technology for Economic and Clinical Health Act (HITECH). HITECH provides up to $27 billion to promote adoption and appropriate use of Electronic Medical Records (EMR) by hospitals. We measure the extent to which HITECH incentive payments spurred EMR adoption by independent hospitals. Adoption rates for all independent hospitals grew from 48 percent in 2008 to 77 percent by 2011. Absent HITECH incentives, we estimate that the adoption rate would have instead been 67 percent in 2011. When we consider that HITECH funds were available for all hospitals and not just marginal adopters, we estimate that the cost of generating an additional adoption was $48 million. We also estimate that in the absence of HITECH incentives, the 77 percent adoption rate would have been realized by 2013, just 2 years after the date achieved due to HITECH.

1. Introduction

Critics of the United States health sector have long pointed to its combination of high costs and poor outcomes, such as a high rate of medical errors (IOM, 2001). An often discussed source of these problems is the relative low utilization of information technology compared to other industries (Gartner, 2010). Many health policy analysts and academics suggest that the widespread adoption of Electronic Medical Records (EMR) will transform the US healthcare system, simultaneously reducing costs and improving outcomes (Hillestad et al., 2005; Buntin and Cutler, 2009). Several studies suggest that increasing the use of EMR will increase efficiency and either decrease health care expenditures, increase quality, or ideally both (McCullough et al., 2010; Miller and Tucker, 2011; Freedman et al., 2014). Summarizing this literature, Buntin et al. (2011) found that over 90 percent of studies found positive outcomes from EMR.

Despite these purported benefits, EMR adoption has, until recently, been largely confined to large healthcare systems; smaller and independent hospitals, as well as other medical providers, have remained on the sidelines. This suggests that either (a) there is a meaningful market failure that creates a separation between the private and social benefits of EMR, or (b) many providers are unconvinced about the benefits of EMR and have taken a "wait-and-see" approach to this investment decision.

Several unique features of the health market could cause a market failure with respect to EMR adoption. For example, hospitals have found that being a high quality provider has a relatively weak relationship to patient volume (Culter et al., 2004). The lack of a strong volume response limits the potential profits from investments in quality. In addition, the existing reimbursement system for most hospitals means much of the lower costs resulting from more efficient care or better health outcomes flows to other entities. Absent an increased use of bundled payments or more effective shared savings programs, hospitals are unable to fully capture the value created by their spending on EMR. Instead, these benefits are split across a wide variety of public and private payers, none of which individually has the incentive to increase reimbursement rates to the level necessary to cover the costs of EMR.

Given the potential collective action problem, there could be a case for taxpayer subsidies for EMR. This would alter the benefit/cost calculus for potential adopters, leading more providers to conclude that benefits outweigh the (now subsidized) costs. This may be a justification for the United States government's heavy

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involvement in promoting the adoption of these benefits. These efforts culminated in the 2009 passage of the Health Information Technology for Economic and Clinical Health Act (henceforth, simply HITECH). HITECH provides up to $27 billion to promote adoption of EMR and encourage the adoption and what regulators have described as the "meaningful use" of these systems by hospitals and physicians[1]. HITECH also specifies future cuts to Medicare reimbursement rates for hospitals that do not maintain meaningful use standards (ARRA, 2009).

Of course, a large number of providers failing to adopt EMR is not conclusive evidence of a market failure. Many hospitals may have remained on the EMR sidelines because adoption costs are high and they are not convinced that these systems will deliver the promised benefits. Indeed, while many studies have found positive effects from EMR, the magnitude of the cost savings are, at best, modest in comparison to the large installation costs (Agha, 2014; Lee et al., 2013; Himmelstein et al., 2010). Other studies find that the quality improvements are fairly small or limited to specific circumstances (DesRoches et al., 2009; Himmelstein et al., 2010). Some studies reveal a great deal of heterogeneity in the benefits across hospitals and areas (McCullough et al., 2010; Dranove et al., 2014). It also could be that the technology itself, or the knowledge about how best to implement the existing products, is improving over time. If any or all of these factors are in play, then many providers will choose not to adopt EMR at any given time. We might instead expect the relatively smooth pattern of adoption that existed in the market prior to HITECH. If this were the case, investment subsidies would simply shift investments in time and not change the ultimate adoption decisions of firms. Moreover, subsidizing the installation of EMR might cause inefficiently high adoption rates at a time when many hospitals are struggling to find how best to extract the benefits of the technology.

Regardless of the merits of EMR or the cause of the lack of widespread adoption to date, it is not immediately clear that HITECH subsidies would materially affect the investment decisions of private firms. Prior research suggests that, despite their intentions, such subsidies may not actually stimulate private investment. Peltzman (1973) introduces the notion that government subsidies might crowd-out private investment, and provides evidence of dollar-for-dollar crowd out in investments in higher education. Most of the subsequent research evidence also casts doubt on effectiveness of government subsidies for promoting aggregate private investment. For example, reviews of national "industrial policies," in which nations subsidize capital investments in specific sectors, find no connection between sector subsidies and sector capital accumulation (Pack and Saggi, 2006). Other studies fail to reject 100 percent crowd out from government R&D subsidies (Dranove, 2000; Lach, 2002). On the other hand, Gonzalez and Pazo (2008) find that public subsidies for R&D do not produce 100 percent crowd-out of private R&D.

Tax incentives, which are of course closely related to investment subsidies, also seem to have little net effect on investments. In a review article, Hanlon and Heitzman (2010) state "the literature has had little success documenting a link between tax incentives and investment." In an earlier review of the research on tax policy, Hassett and Hubbard (2002) state: "[t]he apparent inability of tax incentives to stimulate aggregate investment spending is one of the major puzzles in the empirical investment literature." Goolsbee (1998) offers one potential explanation for some of these findings: government subsidies may fail to spur investment because they are captured by capital suppliers through higher prices. A similar concern is relevant in our setting, as the EMR market is concentrated, with the top seven vendors holding a market share of 75 percent with even higher concentration in various hospital segments[2]. It is therefore possible that vendors captured much of these HITECH incentive payments through increased prices.

In this paper we measure the extent to which the HITECH incentive payments spurred EMR adoption. Applying the rules governing HITECH payments to information from annual hospital cost reports, we calculate each hospital's expected HITECH incentive payments and estimate the effect of these incentives on adoption[3]. Our research setting is somewhat different than most of these earlier studies of government subsidies on investments in other settings. HITECH represents a large lump sum subsidy for a large fixed cost investment, whereas most of the existing research examines marginal responses to marginal subsidies and tax incentives. In addition, we are able to document the timing of investments, so we can assess whether the incentive payments increase aggregate investments or simply change the timing of the investment decision. If the incentives simply shift forward the timing of the investments they likely provide fewer welfare benefits than if they change the ultimate adoption decision of a firm.

As we discuss below, HITECH subsidies did not merely target new adopters. Hospitals that had previously adopted EMR were also eligible for incentive payments, in part as a way to encourage "meaningful use." We therefore also estimate the cost per new adopter—a necessary metric for evaluating the efficacy of this incentive scheme.

The stylized facts suggest that HITECH encouraged adoption by at least some hospitals. Time series evidence shows a marked increase in adoption following the passage of HITECH. As of 2008, about 48 percent of independent hospitals and 60 percent of system hospitals had adopted at least one of two advanced EMR technologies, physician documentation (PD) and computerized practitioner order entry (CPOE). By 2011, these adoption rates for both independent and system members had risen to 76 percent[4].

The coincident timing of this increase provides only suggestive evidence about the causal role of HITECH in EMR adoption. Prior to the passage of HITECH, EMR adoption had been steadily rising, so at least part of the growth is simply the continuation of this pre-existing trend. In addition, while on its face $27 billion is a substantial pool of funds, it was not exclusively targeted towards new adopters. Hospitals that had previously installed EMR were also eligible for this program, suggesting that the incentive payments for new adopters were far smaller. If a large market failure was actually creating a meaningful difference between the costs and benefits of EMR adoption for the hospitals which had not installed EMR by 2009, it is possible these smaller payments for new adopters may not bridge the gap.

As noted above, adoption rates for all independent hospitals grew to 76 percent by 2011. Absent HITECH incentives, we estimate that the adoption rate would have instead been 66 percent. Thus, HITECH promoted adoption among independent hospitals by an additional 10 percentage points. While this may seem like a substantial effect, when we consider that HITECH funds were available for all hospitals and not just marginal adopters, we estimate that the cost of generating an additional adoption was $47 million, which is more than enough to cover the cost of a generous EMR system. We also estimate that in the absence of HITECH incentives, the 76 percent adoption rate would have been realized by 2013, just 2 years after the date achieved due to HITECH.

[1] We explain the meaningful use standard in detail in Section 2.

[2] See for example, http://thehealthcareblog.com/blog/2012/08/06/numbers-dont-lie-the-ehr-market-must-consolidate/.

[3] Because adoption by system hospitals may be decided by corporate parents, we primarily focus our analysis on independent hospitals.

[4] Authors' calculation using HIMSS data.

Notwithstanding the potential benefits of "meaningful use," our findings suggest that HITECH's subsidies were not a particularly cost effective way to spur EMR adoption. Understanding the role of government funds to spur the adoption of technology is important for reasons beyond simply evaluating the efficacy of HITECH. Future attempts at solving market failures within healthcare may require meaningful government investments, and it is therefore critical to understand the effect of incentive payments in this economic context.

2. HITECH act

Congress passed HITECH in February 2009 as part of the American Recovery and Reinvestment Act. HITECH authorized Medicare and Medicaid incentive payments totaling up to $27 billion to clinicians and hospitals when they use EMR to achieve specified improvements in care delivery. In order to qualify for the incentive payments, providers must own an EMR system certified specifically for the EMR Incentive Programs and demonstrate "meaningful use" of the technology. Meaningful use requirements include a set of core objectives such as electronic entry of clinical information, patient demographics, active medications allergies, diagnoses and smoking status. Clinicians must employ clinical decision support tools, use EMR to enter clinical orders and prescribe medications, and provide patients with an electronic copy of their health information on request. Importantly, these incentives payments were available to hospitals that had EMR prior to the passage of the legislation.

We focus on the effect of incentive payments on the decision to adopt EMR and not on the role of meaningful use standards on hospital behavior. We do this for two primary reasons. First, most hospitals with EMR state that they have or are determined to meet meaningful use requirements and receive HITECH incentive payments (Botta and Cutler, 2014). Second, and more practically, it is difficult to measure whether a hospital has met these standards in available data.

Hospitals can receive incentive payments from the Medicare and/or Medicaid programs. Roughly speaking, the size of the incentive payment is a function of the percentage of the hospital's inpatients covered by Medicare or Medicaid and the total number of number of inpatient acute care discharges. We describe the precise payment rules in Section 3.3. Hospitals receive the full incentive payment in the first year after meeting meaningful use requirements. The payment is then multiplied by a "transition factor" that effectively reduces the incentive payments by 25 percentage points each year. Hospitals can receive up to four years of payments from each of the two incentive programs[5]. Thus, hospitals will normally receive a total of 250 percent of the first year payment. Hospitals can begin receiving Medicaid incentives in any year from 2011 to 2016 and can receive Medicare incentive payments in any year from 2011 to 2015, although those who started in 2014 or later will receive a reduced Medicare payment[6]. Providers must meet meaningful use requirements every year to receive the incentive and to avoid an adjustment in their Medicare reimbursement payment, which will be applied to Medicare eligible hospitals who are not meaningful users starting from October 1st, 2014[7].

The formulae for computing Medicare and Medicaid subsidies differ in a handful of ways. The Medicare incentive is linear in Medicare utilization and is computed contemporaneously with utilization; i.e. payments for a given year are based on Medicare utilization for that year. In contrast, Medicaid incentive payments are based on a one-time calculation using data from the year prior to the one in which a hospital starts receiving incentive payments[8]. Perhaps more importantly, hospitals must reach a 10 percent Medicaid patient volume threshold to receive any payments[9]. The Medicaid share is based on a 90 day "reporting period." Hospitals need only reach the 10 percent threshold during one reporting period to be eligible for the incentive payments for the entire year.

3. Data

We compile data from three main sources. Data on adoption decisions and hospital characteristics come from the Healthcare Information and Management Systems Society (HIMSS) Analytics data base. We derive estimates of HITECH incentive payments using data from the Medicare Healthcare Cost Report Information System (HCRIS). We limit the incentive calculation to the pre-HITECH period (i.e. 2006–2008) so that we may account for endogeneity problems that might arise if hospitals manipulate their patient composition in order to boost incentive payments. As we describe below, such manipulation is not costless, and by using pre-HITECH utilization data, we can directly model the costs of manipulation and the net benefits of HITECH's subsidies. We determine whether a hospital belongs to a health system using American Hospital Association (AHA) data. Finally, we construct a number of controls using data from the AHA and the United States Census.

3.1. EMR adoption

The Healthcare Information and Management Systems Society (HIMSS) Analytics Dataset is the industry standard for information on EMR adoption (e.g. Dranove et al., 2013; McCullough et al., 2013; Miller and Tucker, 2009). HIMSS data report adoption status and implementation history of over 100 Health Information Technology applications, in a variety of categories, for more than 5300 healthcare providers. We focus on applications in the "Electronic Medical Records" category. Previous studies categorize these applications into "basic" and "advanced" EMR (e.g. Dranove et al., 2013). The Basic EMR types reported in HIMSS are Clinical Decision Support, Clinical Data Repository, and Order Entry/Results, all of which are relatively easy to implement and were relatively widely adopted prior to HITECH. The Advanced EMR types reported in HIMSS are Physician Documentation and Computerized Physician Order Entry (CPOE), both of which are costly and complex. Adoption costs vary by the size of the hospital and sophistication of the applications, but generally exceed $10 million and can go

[5] Medicaid payments are calculated for a "theoretical4̈-year period, but the amount can be paid over a minimum of a three-year period and a maximum of a six-year period.

[6] One potential limitation of our analysis is that we are not able to capture the effects of these payments on whether hospitals meet meaningful use requirements. We believe that this is an important avenue for future work, but note that at the current point it is not clear in practice how binding these penalties actually are, and it appears that the payment reductions will be small compared to the size of the incentive payments we measure in our analysis. For example, we note that only a fraction of hospitals that did not receive an incentive payment for installing a system are suffering reductions in their Medicare reimbursement rates (Bowman, 2014 and authors' calculations).

[7] Non-CAH hospitals who are not meaningful users will receive a reduced update to the Inpatient Prospective Payment System (IPPS) standardized amount (IPPS) payment rate for these hospitals. The reduction is 25% in 2015 and gradually increases to 75% for 2020 and later. See http://www.cms.gov/Regulations-and-Guidance/Legislation/EHRIncentivePrograms/Downloads/PaymentAdj_Hardship ExcepTipsheetforHospitals.pdf

[8] Medicaid payments are calculated for a "theoretical" 4-year period; the amount is paid over a minimum of a three-year period and a maximum of a six-year period.

[9] Certain types of hospitals, such as children's hospitals are exempted from meeting the 10% threshold.

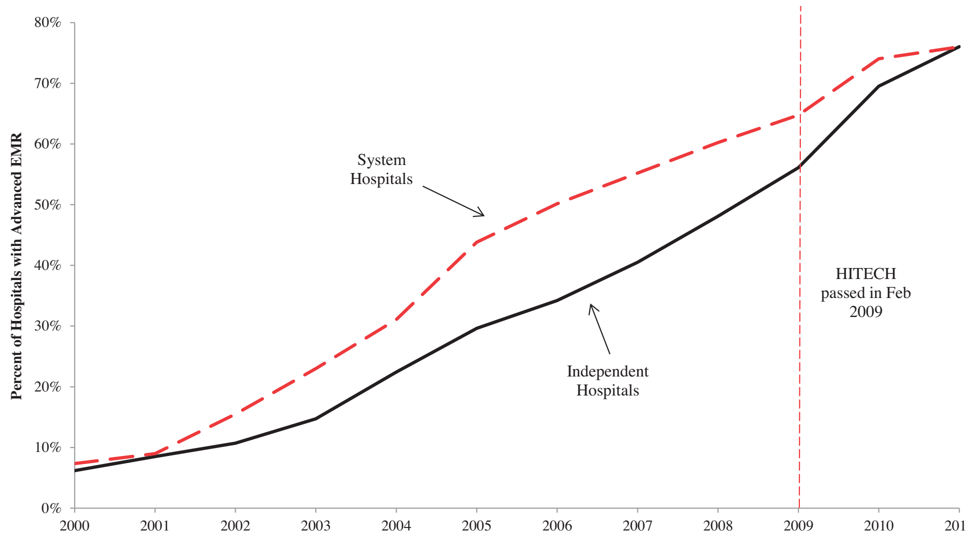

Fig. 1. Cumulative hospital advanced EMR adoption rates.

much higher[10]. Advanced EMRs contain key functionalities that are critical for hospitals to achieve meaningful use. For example, hospitals must use CPOE for medication orders for more than 30 percent of patients taking medications (Blumenthal and Tavenner, 2010). For these reasons, we examine the effect of HITECH incentive payments on hospitals' adoptions of advanced EMR.

We define the adoption of advanced EMR as a dummy variable that equals 1 if the hospital has adopted CPOE or Physician Documentation[11]. The adoption year is defined as the "contract year," i.e. the year in which a hospital first entered a contract with their EMR vendor. Fig. 1 shows the cumulative adoption rate of advanced EMR for independent hospitals and system hospitals that meet the sampling restrictions described below. Cumulative adoption rates are higher among system hospitals than independent hospitals. After an initial surge, adoption rates level off in about 2006, and then increase again after HITECH. Both samples show an uptick in adoption following the implementation of HITECH, with a bigger increase for independent hospitals, so that the gap disappears by 2011. Given that the initially swift adoption rate is likely indicative of the decisions of a specific set of early adopter hospitals, in our empirical analysis we compare adoption in the post-HITECH period with adoption in the more stable pre-period of 2006–2008. This trend more closely represents the adoption pattern of the remaining hospitals as of the passage of HITECH.

Fig. 2 separates hospitals into terciles by the strength of the incentives that they face. The highest incentive hospitals had the lowest levels of adoption prior to 2009, but show an increase in adoption beginning in 2010.

3.2. Sample restrictions

Table 1 details the effect of a series of restrictions on sample size. We begin with the full sample of hospitals in the AHA data base. Only short term acute care hospitals are eligible for HITECH incentive payments so we remove all other hospitals from the sample. We are able to match the vast majority of these hospitals to HCRIS and use the HCRIS data to compute incentive payments[12]. We exclude Critical Access Hospitals because they are subject to a different set of incentive payments that are not easy to compute with available data[13]. Similarly, we eliminate Children's Hospitals because they are exempted from the 10 percent Medicaid patient volume threshold requirement and are likely to differ from general acute care hospitals in their financing and objectives. Excluding Critical Access and Children's Hospitals eliminates approximately 25 percent of our sample. Next, we restrict our sample to hospitals with non-missing adoption data in HIMSS. Finally, in our estimation, we exclude hospitals which had already adopted advanced EMR prior to the beginning of our analysis period. Cumulative adoption rates are presented in Table 2.

EMR adoption by system hospitals may be made by corporate parents and likely represents a decision that is beneficial for the entire system and not one specific facility. It can therefore be difficult to compute the effective HITECH incentives for individual members of a system. Thus, we focus our attention on hospitals that did not belong to systems in 2008[14]. The vast majority of these hospitals remained independent in 2011, and our results are qualitatively similar for a sample of hospitals that remain independent in all years.

3.3. HITECH incentives

We measure each hospital's HITECH incentive by calculating the additional payments from Medicaid and Medicare that the hospital would expect to receive in its first year of eligibility as a percentage of its operating costs. As discussed earlier, hospitals that achieve meaningful use by 2015 will receive total incentive payments that are approximately 250 percent of their first year payment.

Medicare and Medicaid rely on different formulae to determine incentive payments. Both payments depend upon the hospital's

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[10] Based on personal conversations with chief technology officers at various hospitals and health IT consultants.

[11] HIMSS occasionally reports data for more than one sub-facilities within a Medicare facility. Our incentive data is defined by the Medicare facility. We select a unique facility within the HIMSS data to match to each facility in the Medicare data by selecting the facility with the largest number of beds. In the case of a tie, we select the facility with the lowest ID number within the HIMSS data. Using Monte Carlo methods we confirm that this decision does not meaningfully affect our results.

[12] We also dropped around 0.5% of the sample due to "invalid" values for incentive payments, i.e. Medicaid or Medicare share greater than 1, or charity charges greater than total charges. We consider them to be data errors.

[13] CAHs are reimbursed by Medicare based upon "reasonable costs", with Medicare paying a share of reasonable costs increasing in the hospital's Medicare share. They receive $(\text{reasonable costs}) * (.2 + \%\,\text{Medicare})$ if $* (.2 + \%\,\text{Medicare}) < 1$ and their reasonable costs otherwise. Looking at actual reimbursements to CAHs, they are only minimally correlated with Medicare share and with measures of size.

[14] Results remain similar if we restrict our sample to hospitals that are always independent.

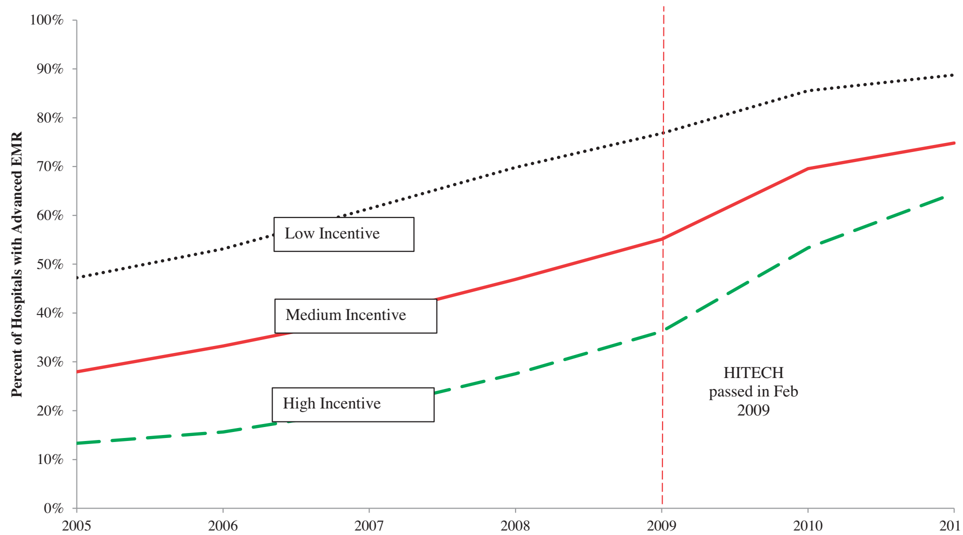

Fig. 2. Cumulative hospital advanced EMR adoption rates by incentive strength.

Table 1
Impact of sample restrictions on sample size.

	2004	2005	2006	2007	2008	2009	2010	2011
Observations in AHA data	5739	5739	5997	5997	5952	5952	5952	5952
Short term acute care hospitals	4745	4745	4754	4754	4729	4729	4729	4729
Matches to 2006–2011 HCRIS	4517	4517	4609	4609	4593	4593	4593	4593
Valid incentive payments	4152	4152	4414	4414	4451	4451	4451	4451
Non-critical access and non-children's hospitals	3092	3092	3150	3150	3180	3180	3180	3180
Matches to HIMSS	3028	3028	3080	3080	3103	3103	3103	3103
Final sample (clean advanced EMR adoption)								
System and independent sample	2976	2976	3028	3028	3051	3051	3051	3051
Independent sample	1191	1191	1202	1202	1210	1210	1210	1210

Table 2
Advanced EMR adoption by year.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Adopted by current year	72	99	125	172	267	353	411	487	582	679	841	920
Full sample	1166	1166	1169	1169	1191	1191	1202	1202	1210	1210	1210	1210
Share adopted (%)	6	8	11	15	22	30	34	41	48	56	70	76

share of Medicare or Medicaid, respectively, as well as the total number of all discharges. The variable *discharges* is the average number of discharges that a hospital has per year for 2006–2008. Similarly, *% Medicare* and *% Medicaid* equal the share of a hospital's inpatient bed days from each government payer (adjusted by the share of non-charity care) for the pooled 2006–2008 time period. Payments under the Medicare and Medicaid program are a function of discharges and take the following form:

$$f(\text{discharges}) \begin{cases} = 2000,000 & \text{if discharges} < 1150 \\ = 1770,000 + 200 * \text{discharges} & \text{if discharges} \in (1150,\ 23,000) \\ = 4370,200 & \text{if discharges} > 23,000 \end{cases}$$

The formula for the Medicare incentive payment is[15]:

$$\$\ \text{Medicare incentives} = f(\text{discharges}) * (\%\ \text{Medicare})$$

The Medicaid incentive payments are calculated in the following manner:

$$\$\ \text{Medicaid incentives} = f(\text{discharges}) * (\%\ \text{Medicaid}) * I[\%\text{Medicaid} > 10\%]$$ [16]

In our analysis below, we note that the statutory threshold of 10 percent of patients from Medicaid is not completely binding in practice. In many states the Medicaid report period is relatively short and well known to hospitals. Therefore, hospitals near the threshold can potentially alter their patient flow over that short term and thus may view the Medicaid incentive payment as essentially continuous.

In our results below we first present estimates using the statutory incentive schedule. We then present our preferred

[15] In particular, we use as our starting point the formula that CMS says it is using for reimbursements: https://questions.cms.gov/faq.php?id=5005&faqId=3377. There was a major cost report redesign in 2010, and while CMS provides a formula for pre-2010, it relies upon fields that are not reported pre-2010. We use an altered formula that allows us to both reproduce the recommended formula for 2010+, and at the same time apply the formula to prior years.

[16] States have leeway in determining how % Medicaid is calculated. We abstract from this, calculating % Medicaid from the Cost Reports using a methodology analogous to the one we use for calculating % Medicare.

Table 3
Summary statistics.

Independent variables	Mean	SD	Min	Max
HITECH incentive (100 × $ incentive/$ operating costs)				
Medicare	3.46	3.63	0.08	14.29
Medicaid (continuous)	1.00	0.98	0.00	3.95
Medicaid (discontinuous)	0.81	0.94	0.00	3.73
Total	4.48	4.42	0.21	17.36
HITECH incentive ($ million)				
Medicare	1.64	0.65	0.12	3.37
Medicaid (continuous)	0.56	0.46	0.00	2.14
Medcaid (discontinous)	0.52	0.50	0.00	2.17
Total	2.22	0.90	0.16	4.73
Components of HITECH incentive				
Share Medicare	0.55	0.13	0.22	0.85
Share Medicaid	0.18	0.11	0.00	0.48
Average total discharges (1000)	6.86	7.62	0.004	63.31
Average total operating expenditure (million $)	115	127	3	604
Controls				
Teaching	4%			
For Profit	8%			
Number of Beds	160.4	134.7	4	614
Number of hospitals	853			

Notes: all variables are winsorized at mean ± 2.33 standard deviation.

specification, where we smooth the discontinuity in the payment formula for Medicaid incentives in the following manner. First, we assume that hospitals can admit as many Medicaid patients as they desire. Second, we calculate from the HCRIS data that the average cost of treating each patient is $7000. Medicaid has long been thought to pay less than the cost of providing care. In 2009, the American Hospital Association (AHA) estimated this underpayment was 89 percent of costs, suggesting that Medicaid pays $6230 per patient[17]. Using this information, Medicaid incentive payments for hospitals are calculated as the payment amount (after bringing additional Medicaid patients to achieve the 10% threshold) minus the loss resulting from treating these patients (i.e. 11% × $7000 per patient), as long as the value is non-negative. Using this continuous measure of Medicaid incentive payments, 86.1 percent of the hospitals whose Medicaid shares are below the 10% threshold are expected to receive a non-zero incentive payment should they adopt advanced EMR.

To validate our measures, we compared our predicted incentive payments to the actual Medicare payments and to the Medicaid payments in the states where incentive payment data is available (New York and Arizona). Fig. A1 contains scatter plots for these outcomes and shows a very strong relationship between our continuous measure and actual payments.

Hospitals may differ in their response to incentive payments. Both the benefits and costs of adoption may depend on the total number and complexity of patients that a hospital treats. In order to account for this heterogeneity across hospitals, we standardize the incentive payments using hospitals' operating costs. We control for a hospital's number of beds, teaching status and for-profit status. We also include interaction terms of these controls with the dummy variable indicating the policy change to allow a differential effect of these controls before and after HITECH. Finally, we include yearly county-level unemployment rate from the Bureau of Labor Statistics (BLS) to control for changes in the local economy.

4. Results

Table 3 provides summary statistics for the components of HITECH incentives, as well as other variables that might affect adoption. To illustrate the sources of variation affecting our measure of incentives, Fig. 3 plots the distributions of the incentive measures. Given the variation in Medicaid and Medicare share by hospital, it should not be surprising that our measure of incentives shows dispersion, both in absolute terms and as a percentage of operating costs.

To calculate the effect of HITECH on the adoption decision of hospitals we estimate a series of Cox proportional hazard models. We define HITECH_i to be the level of HITECH incentive payments for hospital *i*. Our primary goal is to determine whether hospitals that had larger payments under HITECH experienced a larger increase in their adoption likelihoods after HITECH relative to hospitals with smaller payments. To do this, we estimate a model where the probability that a hospital that has not adopted by $t-1$ adopts by t is:

$$h(t) = h_0(t)\, e^{\lambda(\text{HITECH}_i)+\lambda_t * I(\text{year}=t) * (\text{HITECH}_i)+X_i\beta_t * I(\text{year}=t)} \qquad (1)$$

In this equation, λ gives the average effect of HITECH_i on adoption in 2006 (our base year) and λ_t gives the additional effect on adoption in year t relative to 2006 and $h_0(t)$ is a baseline hazard function for hospitals in year t, which is allowed to vary nonparametrically with t. We include a number of controls (X_i) that were discussed above.

Table 4 presents our estimates of Eq. (1). Columns (1) and (2) contain the estimates using the statutory definition of the Medicaid incentive system with the latter estimates including time varying control variables. Our preferred specification, which accounts for the fact that hospitals have some control over their Medicaid population, is contained in columns (3) and (4). In both sets of results, the coefficient λ (i.e., the effect of HITECH for the base year 2006) is less than one. This indicates that as of 2006, hospitals that would ultimately be presented with stronger HITECH incentives were less likely to adopt. This suggests that HITECH appears to have effectively targeted marginal as opposed to inframarginal hospitals.

Fig. 4 plots the coefficients λ_t and their confidence intervals[18]. The coefficients are stable for 2006–2008, but they increase substantially in 2009 and 2010. Thus, HITECH's incentives did not affect adoption prior to the start of the program. Following the implementation of HITECH, however, the incentives were associated with higher adoption rates than would have been expected in

[17] According to the American Hospital Association's, "Underpayment by Medicare and Medicaid Fact Sheet" (December 2010). Access from: http://www.aha.org/content/00-10/10medunderpayment.pdf.

[18] Because confidence intervals are asymmetric, we elect not to include the standard errors.

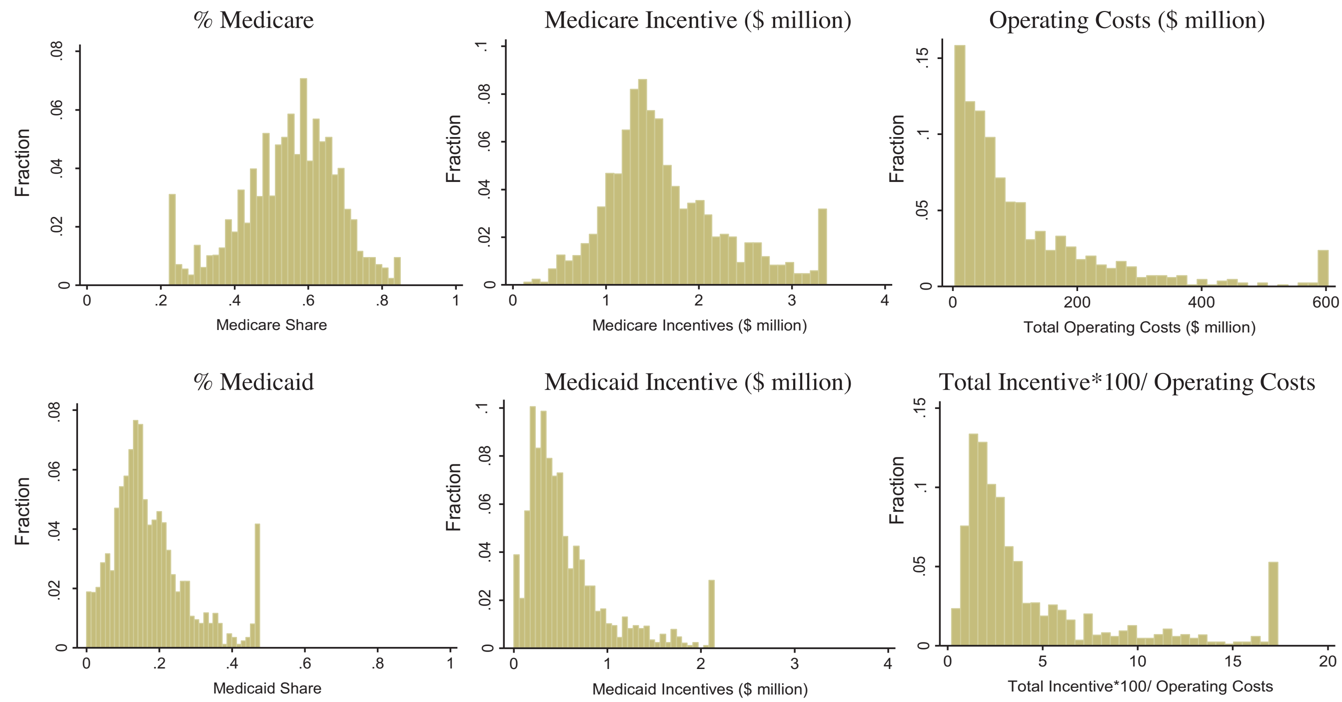

Fig. 3. Distributions of components of incentive measure.

the absence of the program. This suggests that HITECH incentives had a causal effect on adoption. Of course, the confidence intervals in Fig. 4 are quite large. To produce a more precise estimate of HITECH's effect, we run a pooled version of the prior regression:

$$h(t) = h_0(t)\, e^{\lambda(\mathrm{HITECH}_i)+\lambda_{\mathrm{post}} * I(\mathrm{year}>2008) * (\mathrm{HITECH}_i)+X_i\beta+X_i\beta_{\mathrm{post}} * I(\mathrm{year}>2008)} \quad (2)$$

Panel A of Table 5 presents estimates of Eq. (2). Column (1) and (2) shows the result using the total HITECH incentive payments calculated based on actual (discontinuous) Medicaid payments, with and without interactions between our controls and the post period. We replace actual incentives with values after smoothing the discontinuity in Medicaid payments in Column (3) and (4), and get similar results. Our coefficient estimate of the post-2008 effect is roughly 1.12, implying that a hospital receiving HITECH payments in a given year amounting to one percent of its operating costs would increase its adoption probability by about 12 percent in each year.

The coefficient of 1.69 in the fourth row of Panel B implies that HITECH incentives cause the average hospital to increase its adoption probability by 69 percent above the baseline annual hazard rate

Table 4
Cox proportional hazard model estimates of the effect of HITECH on advanced EMR adoption.

	(1)	(2)	(3)	(4)
HITECH incentive	0.850	0.884	0.846	0.875
	*[−2.64]****	*[−1.69]**	*[−2.71]****	*[−1.83]**
HITECH Incentive × (year == 2006)	1.000	1.000	1.000	1.000
	(constrained)	*(constrained)*	*(constrained)*	*(constrained)*
HITECH incentive × (year == 2007)	1.012	0.968	1.027	0.99
	[0.15]	*[−0.34]*	*[0.35]*	*[−0.11]*
HITECH incentive × (year == 2008)	1.051	1.010	1.061	1.027
	[0.70]	*[0.12]*	*[0.85]*	*[0.31]*
HITECH incentives × (year == 2009)	1.118	1.081	1.125	1.095
	*[1.67]**	*[0.95]*	*[1.78]**	*[1.11]*
HITECH incentives × (year == 2010)	1.159	1.132	1.165	1.143
	*[2.35]***	*[1.60]*	*[2.42]***	*[1.73]**
HITECH incentives × (year == 2011)	1.225	1.134	1.228	1.145
	*[3.16]****	*[1.60]*	*[3.21]****	*[1.73]**
Medicaid Incentives	Discontinuous	Discontinuous	Continuous	Continuous
Controls × (year indicators)	N	Y	N	Y
Observations	3846	3846	3846	3846
Subjects	853	853	853	853
Adoptions	564	564	564	564

Notes: reported coefficients are Hazard Ratios. *T*-statistics are reported in []. Years are 2006–2011. All models control for ln(No of Beds), profit status, teaching status and country-level unemployment rate (not interacted with year indicators in all models).

* *P*-value ≤ 0.10.

** *P*-value ≤ 0.05.

*** *P*-value ≤ 0.01.

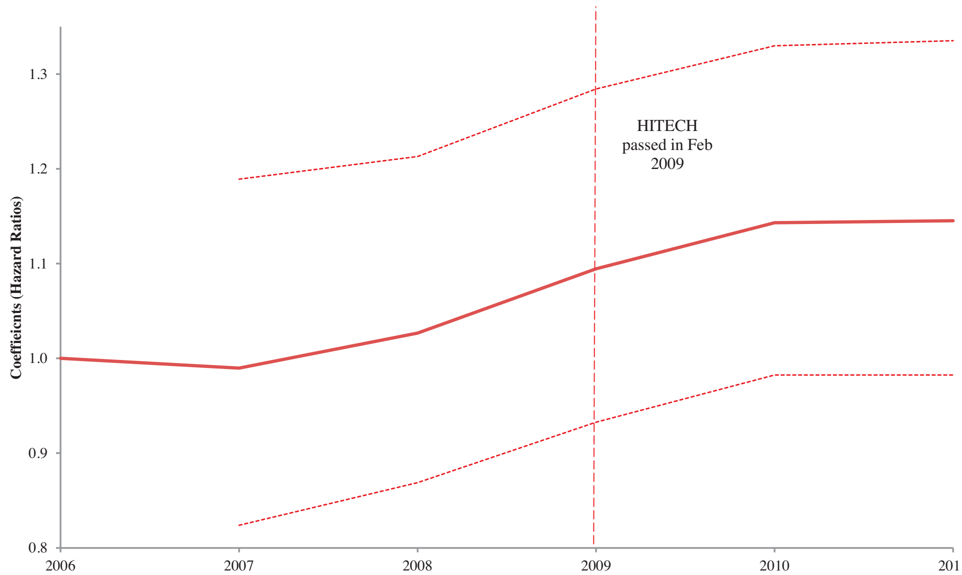

Fig. 4. Time-varying effect of HITECH incentives on advanced EMR adoption rates. *Notes*: coefficients are from Column (4) in Table 4, and include as controls country-level unemployment rate, yearly interactions with ln(No of Beds), Profit.Status, Teaching Status. Coefficients are multiplicative changes in the probability of adoption relative to 2006.

Table 5
Cox proportional hazard model estimates of the effect of HITECH on advanced EMR adoption.

Panel A: model results				
	(1)	(2)	(3)	(4)
HITECH incentives	0.875	0.879	0.879	0.883
	*[−4.49]****	*[−3.85]****	*[−4.49]****	*[−3.84]****
HITECH incentives × (year > 2008)	1.136	1.129	1.13	1.124
	*[4.26]****	*[3.22]****	*[4.26]****	*[3.22]****
Medicaid Incentives	Discontinuous	Discontinuous	Continuous	Continuous
Controls × (year > 2008)	N	Y	N	Y
Observations	3846	3846	3846	3846
Subjects	853	853	853	853
Adoptions	564	564	564	564
Panel B: interpreting model results				
Effect of 1 SD change in incentives on annual adoption, 2009+				
Point estimate	1.71	1.67	1.72	1.68
95% CI	1.34	1.22	1.34	1.23
	2.19	2.27	2.21	2.31
Effect of full HITECH incentives on annual adoption, 2009+				
Point estimate	1.73	1.69	1.73	1.69
95% CI	1.35	1.23	1.34	1.23

Notes: reported coefficients are Hazard Ratios. *T*-statistics are reported in []. Years are 2006–2011. All models control for ln(No of Beds), Profit Status, Teaching Status and Country-Level Unemployment Rate (not interacted with (year > 2008) in any model).
* *P*-value ≤ 0.10.
** *P*-value ≤ 0.05.
*** *P*-value ≤ 0.01.

of 9.6 percent for 2006–2008. The 95 percent confidence interval for the estimate is large, but we can rule out increases of less than 23 percent.

Fig. 5 plots the actual cumulative adoption rates of independent hospitals, our model predictions, and our model predictions had HITECH not happened (i.e., the counterfactual). Our model predicts that HITECH caused an additional 10 percent of hospitals to adopt advanced EMR. In Fig. 6, we fit the counterfactual adoption rate to a logistic model in which we predict the post-2011 adoption rates without HITECH. We find that had HITECH not been passed, the adoption rate would have reached the same level as the actual 2011 adoption rate in 2013, i.e. HITECH accelerated adoption by two years.

One concern with our results is that they may be driven by hospital characteristics that are correlated with incentive payments, but that the incentive payments did not cause adoption. The coefficient estimate is unaffected when we add in interactions between our controls and the post period. This relaxation of the proportional hazards assumption suggests incentive payments are not simply capturing hospital size, for-profit status, or teaching status.

Our findings do not materially change when we implement a number of alternative specifications, which we show in Table A1[19].

[19] We also performed two closely related robustness checks. First, we constructed a measure of basic EMR adoption, defined as the adoption of any of the three basic EMR applications: Clinical Decision Support, Clinical Data Repository and Order Entry/Results. We then reran our main specification, but substituted the basic EMR adoption indicator variable for the advanced EMR adoption indicator variables. We found no evidence that basic EMR is increasing for the high-incentive hospitals prior to HITECH. There is, however, evidence that basic EMR adoption also increased at the time of HITECH. These results demonstrate that our main estimates are not driven by differences in the relative adoption rate of technology prior to 2009. As a second

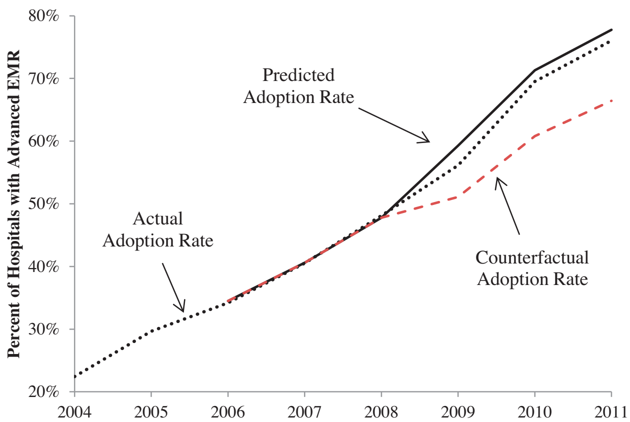

Fig. 5. Effect of HITECH on cumulative hospital advanced EMR adoption. *Notes*: number of hospitals = 853. Predictions and counterfactual are based on regression output from Table 5, Column (4).

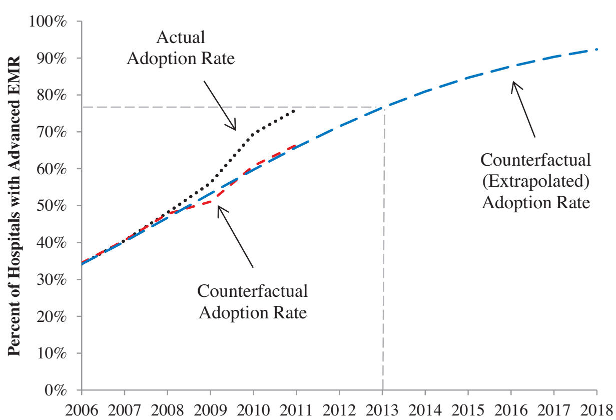

Fig. 6. Effect of HITECH on cumulative hospital advanced EMR adoption.

In particular, we: (1) restricted $h_0(t)$ to be a Weibull distribution; (2) and (3) generated hospital incentives using the 2009–2011 (i.e. post-HITECH) cost reports with and without smoothing the discontinuity in Medicaid incentives; (4) changed the length of reporting period from 1 year to 3 months when calculating the continuous measure of Medicaid incentive; (5) changed our measure of adoption to having both of the advanced EMR applications; (6) restricted the analysis to hospitals that are never a part of a system. The marginal effect of HITECH on adoption across these specifications varies from 1.33 to 1.77.

In our main analysis, we restricted our sample to independent hospitals for two primary reasons. First, system and independent hospitals may face different costs and benefits of EMR adoption. For example, a system may have larger benefits to coordinating referrals therefore be more likely to adopt than independent hospitals. If system hospitals and independents differ on observables, but also on unobservables that affect adoption (like the value of better coordination), then pooling the two groups will result in biased estimates. The second reason for restricting the analysis to independent hospitals is that the adoption decisions for hospital within a system are interconnected with the adoption decisions of other hospitals within the system, which makes it difficult to measure the benefits of adoption for each system hospital individually.

5. Discussions and conclusions

Many prior studies find that government subsidies fully crowd out private investments. In contrast, we find that HITECH increased the cumulative adoption of advanced EMR among independent hospitals by 10 percentage points in a short period of time. Given that slightly over half of independent hospitals had advanced EMR by 2008, this implies that HITECH accelerated EMR adoption by more than one in five non-adopters. Our data do not permit us to extend the analysis forward; thus, HITECH may have promoted even further adoption than we are able to capture in our analysis. That being said, this level of adoption is not surprising. Based on the limited pricing information that is available, the cost of installing and operating an EMR system by an average-sized hospital is at least $10 million and could be much higher. The average non-adopter as of 2008 could have expected to receive $2.1 million in HITECH subsidies for the first year and $5.3 million in total. If adopters were at the high end of the subsidy spectrum, then incentive payments could be higher than $10 million—though it should be noted that many of these hospitals may also face higher adoption costs. Thus, these incentives represented a sizable percentage of adoption costs.

It is tempting to interpret these results as an unmitigated success, i.e. HITECH spurred adoption while only paying a fraction of the cost of these new systems. By revealed preference we can infer that the marginal adopters (i.e., adopters who would have remained on the sideline in the absence of HITECH incentives) believe that EMR contributed some value to their organization but were unable to adopt the technology without substantial incentive payments[20]. However, there are two reasons to take a more skeptical view of the merits of HITECH.

First, it may have been politically impractical to dedicate HITECH funds to these marginal adopters, both because this may have been seen as unfair to early adopters and also because HITECH incentives are also used to promote meaningful use[21]. As a result, total HITECH payments dwarfed the subsidies to marginal adopters. It is instructive to compute the total HITECH subsidies per adopting hospital. We estimate that 66 percent of hospitals would have adopted by 2011 without HITECH and that 10 percent of hospitals adopted because of HITECH. The average incentive payments to all independent hospital that adopted EMR by 2011 is $6.2 million, so it costs $47 million ($6.2 million × (0.76/0.10)) in incentive payments for each adopting hospital in our sample to generate a single additional adoption. This covers more than the typical implementation costs and maintenance costs over first few years for the average sized hospital. As mentioned, such an expense was inevitable given the impracticality of restricting subsidies to marginal adopters and also helped encourage meaningful use among all hospitals. The importance of political considerations cannot be understated in this setting because future attempts to provide incentives for hospitals to adopt other programs will face similar political pressures.

robustness check, we also extended our sample period back in time and created a placebo policy variable beginning in 2005. We find no evidence of an "effect" in 2005. However, we caution that the HIMSS data quality is substantially worse in earlier years.

[20] The debatable value of these systems to these hospitals can also be seen in Dranove et al. (2013) where hospitals suffering financial shocks delay their adoption of EMR.

[21] More specifically, suppose HITECH promotes "meaningful use," and that our measure of adoption is a necessary, but not sufficient condition for meaningful use. In this case, HITECH may have spurred some of the hospitals that we consider to be "early adopters" into taking steps to go from satisfying our adoption measure to satisfying meaningful use. In this case, we may miss some of HITECH's benefits. For data reasons, we are unable to further investigate this hypothesis but think that over time this will be an interesting area for future work.

Second, these HITECH funds may have simply accelerated an ongoing trend, and therefore the rate of adoption realized by 2011 would have been achieved soon thereafter – by 2013 according to our estimates – without HITECH funds. Again notwithstanding meaningful use, the expenditures of HITECH appear to have simply provided two additional years of EMR use at facilities that may have been unsure about the product's ultimate value. Given that hospitals are still trying to figure out how to systematically use HIT to boost quality and reduce costs, briefly accelerating adoption at this juncture is not obviously desirable. Thus, it may be better to ultimately judge HITECH on the impact of meaningful use requirements on outcomes such as costs and quality, something that has yet to be determined. And if meaningful use is the ultimate goal, it seems quite possible that this could have been achieved at a much lower cost. For example, HITECH already includes penalties in the former of lower Medicare reimbursements for hospitals that do not meet meaningful use standards after 2015.

Appendix A.

Table A1 and Fig. A1.

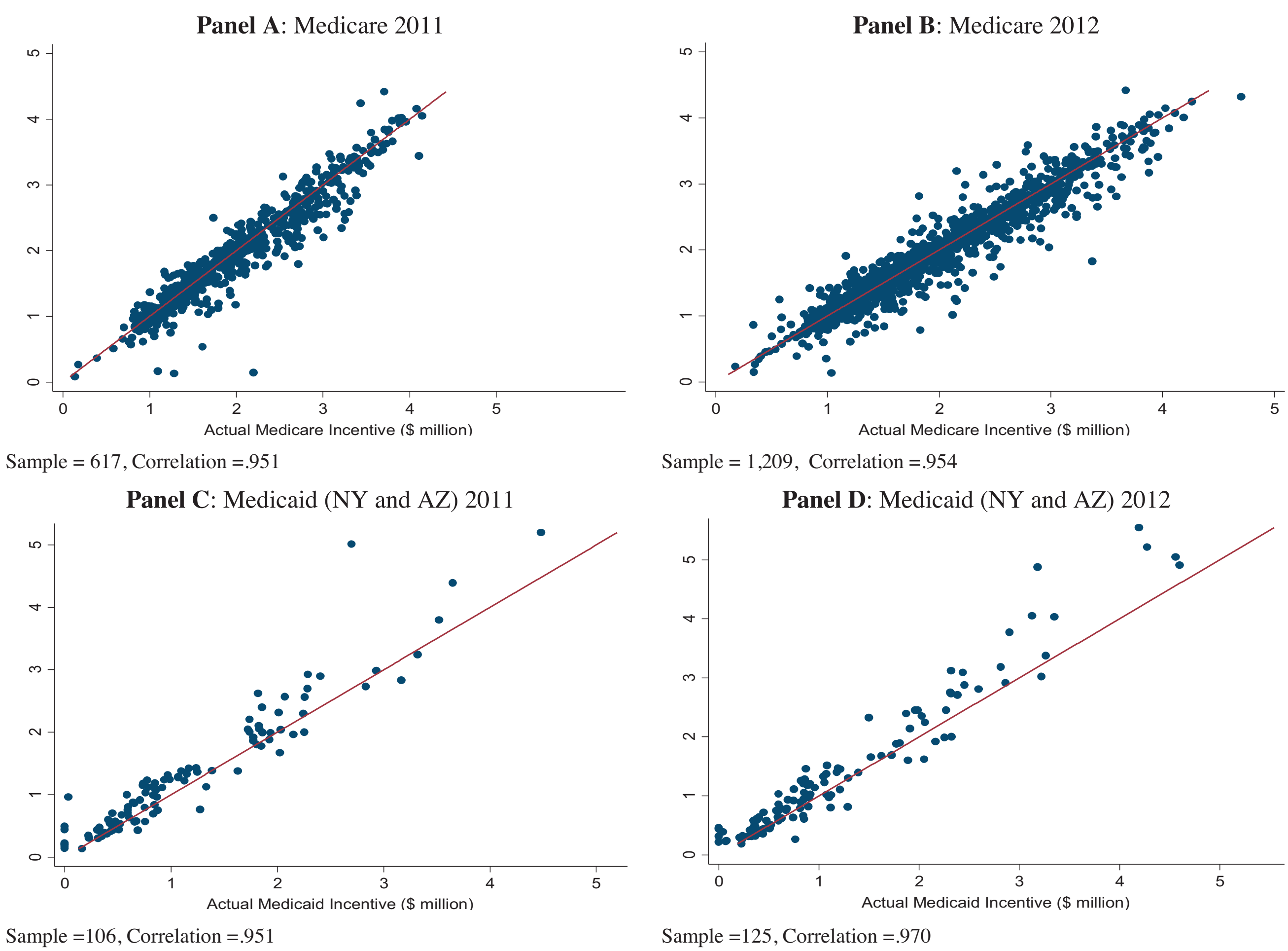

Fig. A1. Expected vs actual incentive payments.

Table A1
Robustness check.

Effect of the HITECH incentives on EMR adoption	(1)	(2)	(3)	(4)	(5)	(6)
HITECH incentive	0.916	0.882	0.88	0.882	0.833	0.886
	*[−3.30]****	*[−3.64]****	*[−3.58]****	*[−3.84]****	*[−3.59]****	*[−3.70]****
HITECH incentives × (year > 2008)	1.066	1.118	1.122	1.125	1.151	1.125
	*[2.43]***	*[2.87]****	*[2.86]****	*[3.23]****	*[2.58]****	*[3.21]****
Controls × (year > 2008)	Y	Y	Y	Y	Y	Y
Observations	3846	3846	3846	3846	5214	3574
Subjects	853	853	853	853	1051	797
Adoptions	564	564	564	564	516	536

Table A1 (*Continued*)

Effect of the HITECH incentives on EMR adoption	(1)	(2)	(3)	(4)	(5)	(6)
Effect of 1 SD change in incentives on annual adoption, 2009+						
Point Estimate	1.33	1.57	1.56	1.69	1.79	1.69
95% CI	1.06	1.16	1.15	1.23	1.15	1.23
	1.67	2.15	2.12	2.33	2.80	2.32
Effect of full HITECH incentives on annual adoption, 2009+						
Point Estimate	1.33	1.57	1.57	1.70	1.77	1.69
95% CI	1.06	1.16	1.15	1.23	1.15	1.23
	1.67	2.15	2.15	2.35	2.73	2.33

Notes: reported coefficients are Hazard Ratios. *T*-statistics are reported in []. Years are 2006–2011. All models control for ln(No of Beds), profit status, teaching status and country-level unemployment rate (not interacted with (year > 2008) in any model). (1) Restricted baseline hazard function to be distributed Weibull; (2) and (3) generate hospital incentives using the 2009–2011 (i.e. post-HITECH) cost reports with and without smoothing the discontinuity in Medicaid incentives; (4) changed the length of reporting period from 1 year to 3 months when calculating the continuous measure of Medicaid incentive; (5) change the measure of adoption to having both of the advanced EMR applications; (6) restrict to hospitals that are never a part of a system.

* *P*-value ≤ 0.10.

** *P*-value ≤ 0.05.

*** *P*-value ≤ 0.01.

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