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Abstract

We examine hospital Electronic Medical Record (EMR) vendor adoption patterns and how they relate to market structure. Hospitals have incentives to both coordinate with, and differentiate from, local competitors in their choice of vendors, with some of these incentives even linked to receipt of government subsidies through the HITECH Act of 2009. We find that hospitals tend to agglomerate in their vendor choices, and the level of agglomeration grows stronger with competition. These findings suggest that incentives to coordinate dominate incentives to differentiate overall, and the relative balance grows stronger in favor of coordination as markets become more competitive. Hence, a potential downside of hospital competition, i.e., increased difficulty in information sharing due to increased incentive to differentiate, does not appear to materialize in this market.

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1. Introduction

Electronic Medical Records (EMRs) software has become a major industry, with \$27 billion in revenues as of 2015.¹ Over the past decade the fraction of hospitals utilizing EMR systems has increased drastically. The U.S. federal government began incentivizing EMR adoption in 2011 and as of 2015, 96% of hospitals have implemented a system that meets government certification standards.² There are many EMR products sold by competing vendors that hospitals can choose from, and systems sold by different vendors are typically not interoperable. At the same time much of the perceived productivity and health related benefits of EMR adoption hinge on hospitals being able to share patient information electronically. As a result, EMR-adopting hospitals face a classic challenge in networked industries when making their EMR vendor choice – is it optimal to differentiate from or coordinate with competing hospitals?

How hospitals answer this question is of more than just academic interest, and is relevant well beyond just the players in this market. There is significant public interest in these decisions both due to the passing of the Health Information Technology for Economic and Clinical Health (HITECH) Act and challenges facing antitrust agencies in the face of accelerated consolidation in hospital markets. Specifically, the HITECH Act explicitly subsidizes interoperability, pushing hospitals toward coordination. In addition, it is neither theoretically or empirically clear whether changes in hospital competition drive hospitals to coordinate more or less in their vendor choices, rendering any potential coordination benefits or costs from changes in market

¹ <http://www.prnewswire.com/news-releases/kalorama-information-27-billion-dollar-market-for-electronic-medical-records-new-study-finds-300254182.html>

² <http://dashboard.healthit.gov/evaluations/data-briefs/non-federal-acute-care-hospital-ehr-adoption-2008-2015.php>

concentration unclear for antitrust agencies. Understanding this empirical relationship is likely to be particularly important at a time where hospital consolidation has been accelerating.

In this paper, we examine EMR vendor choice by U.S. hospitals for their Clinical Data Repository (CDR) system – a hospital’s database of patient information. We also examine how market competition influences this choice. More specifically, we study whether hospitals exhibit differentiation or coordination relative to their geographic competitors, and whether the level of differentiation or coordination is impacted by competitive market structure.

As in many network technology adoption decisions, hospitals face countervailing incentives in their EMR vendor choice. Choosing the same vendor as local competitors would allow hospitals to exploit network effects, by making it easier to exchange patient information with other local providers. This could have a number of benefits for a hospital. Information exchange can potentially improve patient care and lead to cost efficiency. As an additional incentive for hospitals to coordinate, information exchange and interoperability is a requirement to justify “meaningful use” and qualify for incentive payments under the 2009 HITECH Act. Coordination in vendor choice also could make adoption less costly. For example, there could be knowledge spillovers from nearby hospitals that could facilitate the adoption and use of an EMR from the same vendor. Lastly, there could be better technical support if vendors tend to invest more resources in markets where they have greater penetration. We categorize those potential benefits as network effects, which could lead to coordination.³

However, there are also costs associated with choosing the same vendor as local competitors. If hospitals can easily exchange patient information, patients may be more likely to

³ These same network externalities may dampen the rate at which hospitals adopt the technology. Here we focus specifically on which vendor a hospital chooses, conditional on already having chosen to adopt EMR.

switch providers. Additionally, if similar EMR systems at nearby hospitals decrease a physician's switching cost, they may be more likely to change hospitals as well. Therefore, hospitals may have incentives to differentiate in order to lock-in their patients and physicians. We categorize these potential costs as business stealing effects.

Given the countervailing incentives of network and business stealing effects, it is an empirical question of what factors determine their relative strengths and which effect is likely to dominate. In this paper, we characterize the overall net effect of these two forces in EMR adoption by quantifying the extent to which markets exhibit adoption patterns characterized by agglomeration or by dispersion. We then examine the role market concentration plays in determining whether a market is more agglomerated or dispersed. While the net effect of network and business stealing effects is ambiguous, the effect of market structure on this relationship is ambiguous as well. On one hand, greater market concentration could dampen the network benefits, since each hospital is less reliant on coordination with other hospitals. On the other hand, greater market concentration could dampen the business stealing effects since hospitals have less competitive pressure. Our analysis provides direct evidence on how market competition affects the market equilibrium of vendor choice.

Using the multinomial test for agglomeration and dispersion (MTAD) (Augereau et al. 2006) for CDR vendor choices, we find that hospitals tend toward agglomeration. In addition, we find that the level of agglomeration increases with competition. That is, as markets become less concentrated, we observe greater tendencies toward agglomeration. This relationship holds true among early adopters who had adopted CDR as of 2005, and becomes even more exaggerated as the technology diffused between 2005 and 2012.

Our findings have important implications both for the public interest in interoperability (as shown through the HITECH Act) and antitrust policy. They show that, as hoped, hospitals do tend toward agglomeration, leading to greater interoperability. However, the role of the HITECH Act in driving this tendency toward agglomeration is not clear, and is left to future research. Regarding antitrust policy, our results shed light on whether competitive market structure can influence the extent of interoperability. They indicate that increased competition does not push hospitals to differentiate, at least on their choice of EMR vendor. Hence, a potential downside of hospital competition, i.e., increased difficulty in information sharing due to increased incentive to differentiate, does not appear to materialize in this market.

Our findings contribute to the existing literature in a number of ways. First, while other papers have explored the extent to which firms differentiate or coordinate when adopting network technologies (e.g. Augereau et al. 2006, Gowrisankaran and Stavins 2004, Desai 2014, Lin 2015), our paper is the first to our knowledge to explicitly examine the role of competition in shaping the market equilibrium adoption outcomes.⁴ Our data allow us to measure market competition in the hospital setting using information on patient admission and to examine how the extent of coordination changes as the competitive landscape changes. Our project is also different from most of the previous work on standards wars, because, while there is a well-defined choice set for firms to purchase EMR products, there is greater variety than other previously studied industries like internet service providers and banking. In our context 10 firms hold 90% of the market share. Therefore, we are able to explore coordination and differentiation in a context with more options for firms to choose from.

⁴ Desai (2014) is the most related paper to our work. The primary difference between our project and her work is that we focus on the market equilibrium of coordination/differentiation and how it is affected by market concentration.

Our paper also makes important contributions to the literature on health information technology. A growing literature explores the determinants of EMR adoption (Dranove et al. 2015b) and the effects of EMR adoption on outcomes like cost and quality (e.g. Ahga 2014, McCullough et al. 2013, Miller and Tucker 2011, Freedman et al. 2015, Dranove et al. 2015a). Our paper advances the literature on adoption decisions by exploring the decision of which vendor to adopt rather than just the extensive margin of whether to adopt EMR technology or not⁵.

2. EMR Software Industry

EMR refers to a wide variety of technologies that hospitals use to track patient information. Basic EMR systems gather and organize patient information to inform clinicians and to be used in the billing process. More advanced EMR features allow providers to interact with the software at the point of care, allowing physicians to make electronic orders, receive decision support, and record documentation in real time. As we discuss in more detail below, we focus on vendor choices of a basic EMR technology, clinical data repository.

The EMR vendor market is relatively concentrated. As we discuss in Section 3, five vendors, Meditech, Cerner, McKesson, Epic and Siemens Healthcare, have a combined market share of 75% of the hospitals that have adopted a basic EMR system, and the top ten vendors hold a 91.7% market share. There is some regional variation in vendor market penetration; however, the top five vendors all operate in at least 38 states and the rest of the top 10 operate in 16 to 31 states.

⁵ This is similar to Lin (2015), who finds evidence of profit complementarities in EMR vendor choice in a dynamic structural model.

The choice of EMR vendor can be an important decision for a hospital. The Congressional Budget Office (CBO, 2008) estimates the cost of EMR adoption for a typical urban hospital to range between \$3 and \$9 million, along with between \$700,000 and \$1.35 million per year for maintenance. Software packages differ across vendors, and switching vendors can be both time intensive and expensive.

3. Data

3.1 EMR Adoption and Vendor Choice

To conduct our analyses, we use three primary data sources. First, we use the Health Information and Management Systems Society (HIMSS) Analytics Database from 2005 and 2012 to identify hospital EMR adoption and vendor choices. The HIMSS Analytics Database is an annual survey of the information technology capabilities of over 3,000 hospitals nationwide with more than 100 beds, which covers about 75% of U.S. hospitals. The HIMSS survey collects a wide range of information on over 100 different health information technology applications used in hospitals.

We focus our analysis on a hospital's vendor choice for their Clinical Data Repository (CDR) system. CDR is a hospital's database of patient information, likely to include "test results, drug utilization, pathology reports, patient demographics, and discharge summaries" (Dranove et al. 2015a). We chose this technology for two key reasons. First, CDR has been widely diffused by the time of our study period. 89% of hospitals had implemented CDR by 2012. Therefore, we can explore vendor choices among the set of hospitals that have adopted the technology. Second, unlike other tools that provide decision support or better means of communicating orders within

a hospital, CDR represents the piece of EMR technology that could produce network effects since it stores the patient information that could be shared with other hospitals. In addition, while some hospitals do purchase different EMR components from a mix of vendors, we have found that the vast majority purchase more advanced tools like Computerized Physician Order Entry (CPOE) from the same vendor that they purchase CDR from.⁶ CDR vendor choice has also been studied in other works such as Desai (2014) and Lin (2015).

3.2 Hospital Characteristics and Market Structure

We utilize the American Hospital Association (AHA) Annual Survey of Hospitals to identify hospital characteristics such as geographic location, number of discharges, ownership type, system membership, and teaching status. Some of these hospital characteristics are used as covariates in our regression analysis, which we discussed in more detail in Section 4. The AHA data also allow us to identify a market and construct measures of market structure.

We define two alternative definitions of markets, based on Hospital Referral Regions (HRR) and based on counties. HRRs are defined by the Dartmouth Atlas of Healthcare as regional healthcare markets. They are determined based on regions in which most patients in the geographic area are referred to the same set of hospitals for tertiary care. There are 306 HRRs in the country, and our data include 299 of these regions. While HRRs provide natural definitions of markets, they may be too large to capture more localized competition and EMR vendor coordination. Therefore, we also explore results using counties as markets. We observe 493 counties with at least two hospitals, which is necessary for calculating our measure of coordination or differentiation. We define market shares for each hospital based on the hospital's

⁶ 93% of hospitals that have adopted CPOE in 2012 had the same vendor for both their CPOE and CDR systems.

share of discharges within its HRR or county. We then use these market shares to calculate HRR and county specific measures of HHI.

We also use data from the Dartmouth Atlas of Healthcare to control for HRR level demographic information. These variables pertain specifically to the Medicare population, but are used as proxies for overall demographic mix of people demanding health care in HRRs. These variables include the percent above the age of 75, percent white, percent black, percent Hispanic, percent in Fee for Service Medicare, percent in nursing homes, and percent eligible for Medicaid. At the county level, we control for similar variables from the Area Resource File, including the unemployment rate, the uninsurance rate, the poverty rate, and the fraction of the population above the age of 65.

4. Empirical Methods

The methods we use in this paper build on those in Augereau et al. (2007) and Rysman and Greenstein (2005). To test for agglomeration vs. dispersion, we apply what they term the multinomial test for agglomeration and dispersion (MTAD). The idea behind this test is as follows. Suppose there are two different vendors between which hospitals can choose, vendor A and vendor B. Consider a market with, say, 10 hospitals, each of which chooses between vendor A and vendor B. If hospitals split on this decision – 5 choosing vendor A and 5 choosing vendor B – we would say this market is dispersed. In contrast, if the hospitals all align on this decision, e.g., all choosing vendor A, we would say this market is agglomerated. The essence of the test is that there are many ways to be dispersed but few ways to agglomerate. To see this, note that

there are $\binom{10}{5} = 252$ ways to be dispersed but only one way to be agglomerated on vendor A (and one way to be agglomerated on vendor B).

The MTAD uses the basic combinatorics difference between dispersion and agglomeration – i.e., there are many combinations that lead to dispersion and only few that lead to agglomeration – to construct a test for whether markets exhibit either adoption pattern against the null of independent adoption decisions. More formally, MTAD takes the following approach, which we again illustrate using our example with two vendors. Suppose we assume each hospital adopts exactly one vendor, and the population-level probability of adopting vendor A is p_A (implying the probability of adopting vendor B is $(1-p_A)$). Next, suppose we observe a market with 10 hospitals, of which 3 use vendor A and 7 use vendor B. If we treat the adoption decisions as independent, then this observed adoption pattern is the realization of a binomial with 10 draws and probability of adopting vendor A of p_A . Hence, the probability of what we observed is: $\binom{10}{3} p_A^3 (1 - p_A)^7$.

We can then compare this probability to what we'd expect it to be, where we take the expectation over all possible adoption patterns. Roughly speaking, this comparison centers on the difference in the number of combinations that can generate what we actually observed and the expected number of combinations for a hypothetical observation: $\binom{10}{3} - E_s[\binom{10}{s}]$. For example, if p_A is 0.5, then $E_s[\binom{10}{s}] = 180.4$, and the difference is $120 - 180.4 = -60.4$. Hence, the observed adoption pattern is actually more agglomerated than what we would have expected, as evidenced by the difference being negative. In contrast, if p_A is 0.2, then $E_s[\binom{10}{s}] = 66.95$, and the difference is $120 - 66.95 = 53.05$. In this case, the observed adoption pattern is more

dispersed than what we would have expected, as evidenced by the difference being positive. This intuition easily extends to the more general multinomial case, with more than two adoption possibilities; for example, with three vendors and ten hospitals, the combinatorics becomes $\binom{10}{s_1 s_2 s_3}$, where s_1 is the number of hospitals adopting vendor 1, and so on.

Formally, we calculate MTAD by taking the log-likelihood of the observed adoption pattern, X , over M markets. We then subtract the expected likelihood from the likelihood of the observed adoption pattern and divide by the standard deviation. As Rysman and Greenstein (2005) show, this statistic converges to a standard normal as the number of markets gets large.⁷

We use MTAD to examine whether EMR vendor adoption across markets exhibits a pattern of dispersion or agglomeration. We then break the statistic down to a finer level, and examine whether there is a link between agglomeration/dispersion tendencies and market structure, as measured by the number of hospitals and HHI. When comparing markets, we calculate MTAD based on the expected likelihood and the standard deviation from the group of markets within the same HHI or number-of-firms quintile.

It has become increasingly common over the past decade for hospitals to be acquired by multihospital systems. In our main results, we treat hospitals as individual firms, both when calculating MTAD and HHI. We recognize that treating each hospital separately could underestimate MTAD, because hospitals within the same market that are members of the same system are likely to have the same EMR vendor. In fact 46% of systems with multiple hospitals in the same market adopt the same EMR vendor across each of the hospitals and 80% adopt the same system in at least half of their hospitals. Likewise, treating hospitals as independent will

⁷ A full discussion of the details behind MTAD is in Rysman & Greenstein (2005).

underestimate HHI and make markets appear more competitive than they actually are if hospitals within the same system do not compete against each other. In our regression analysis described below we control for the fraction of hospitals within a market that are affiliated with a system. In addition, we conduct a separate analysis where we calculate MTAD and HHI treating system hospitals within a market as a single firm. In calculating MTAD in this case, we take the vendor chosen by the most hospitals within the system-market pair as the system's chosen vendor in that market.

Lastly, we use the MTAD statistic within a regression framework in order to again link agglomeration/dispersion to market structure, but including market-level controls. We estimate the following regression equation:

$$MTAD_m = \beta_1 + \sum_{i=2}^5 \beta_i Q_m^i + \alpha_s + \gamma Demog_m + \delta HospChar_m + \varepsilon_m$$

We estimate two versions of this regression, one where Q_m^i is a set of dummies for quintiles based on the number of hospitals in market m and one where Q_m^i is a set of dummies for quintiles of HHI in market m . Note, we define the HHI quintiles with the first quintile being the most concentrated markets so that interpretation of coefficients will be in the same direction as in the number of firms specification.

We will also present estimates adding various sets of control variables. Although endogeneity concerns are not as obvious in this setting compared to one linking price to market structure, these controls can help alleviate any potential endogeneity concerns that exist. We first add state dummy variables, α_s , to help control for the possibility that vendors do not all

have national reach, and so markets may appear agglomerated only because some vendors were not available. We then add the demographic variables, $Demog_m$. These controls could be important if certain population characteristics impact hospital incentives to consolidate and also to coordinate vendors. For example, the fraction of the population in fee for services insurance relative to managed care plans could impact both market structure and EMR coordination incentives. Finally, we add measures of a market's hospital characteristics, $HospChar_m$, including the fraction of government owned hospitals, nonprofit owned hospitals, teaching hospitals, and system affiliated hospitals. System ownership in particular could be an important determinant of vendor coordination if markets with a large amount of hospitals within the same system utilize the same EMR vendor.

5. Results

In this section, we present our main findings concerning agglomeration versus differentiation on EMR vendors in general, and if/how market concentration affects this measure (i.e., MTAD). We then discuss possible endogeneity concerns and their potential impact, and present additional results designed to, at least partially, address them. Lastly, we present some dynamic analysis, where we examine how agglomeration/differentiation has evolved in these markets over time, and the role of concentration on this evolution.

5.1 Summary Statistics

Here we present summary statistics of the EMR vendor market and our measures of market structure and coordination. Table 1 lists the number of hospitals and share of hospitals that have implemented a CDR system by vendors. We list the top 10 vendors along with a

category for self-developed and other. The top 10 vendors represent 91.7% of the market with another 4.08% of hospitals using a self-developed system and 4.22% purchasing from a vendor outside the top 10. As a result, we define a hospital's choice set as these top 10 vendors, self-developed, or other, for a total of 12 choices. Therefore, while our context does contain a well-defined choice set, it differs from most previous work, such as Augereau's et al. (2006) study of the ISP market, in which 2 choices are available to firms.

Table 2 provides evidence of the extent of agglomeration or dispersion of vendor choices within markets. We calculate MTAD as described above, both overall and by census region. For all calculations of MTAD presented here, we specify the market shares in Table 1 as the baseline probabilities for each vendor. The overall MTAD statistic is -17.897 – i.e., 18 standard deviations below the test statistic mean – thus showing strong evidence of agglomeration. While all census regions show evidence of agglomeration, there is some regional variation with the Northeast and South being the most agglomerated, followed by the Midwest and the West.

Table 2 also reports summary statistics of market structure overall and by census region, using the HRR market definition. Our markets contain 14.88 firms on average and the mean HHI is 2,517. For our analysis of the relationship between market structure and MTAD, we divide markets into quintiles based on the number of hospitals and based on HHI. Table 3 presents summary statistics of these two market groupings. The lowest quintile of number of hospitals has 4.67 hospitals ranging to 37.44 in the highest quintile. The lowest HHI quintile, defined so that low quintiles are less competitive, has an HHI of 4,962. The highest quintile is highly unconcentrated with an HHI of 755.

Figure 1 plots MTAD by these two HRR-level market structure groupings. Here MTAD is calculated using the market shares from Table 1, but the expected likelihood and standard deviation from all markets within each quintile. MTAD is generally decreasing in the number of hospitals. In the lowest two quintiles, MTAD is negative but close to zero. It is negative in all other quintiles and drops greatly from the fourth to fifth quintile. This suggests that markets with more hospitals are much more agglomerated than markets with fewer hospitals. We find a similar pattern when considering HHI as our measure of market structure. We find a decreasing relationship with respect to competitiveness (or the inverse of HHI), with highly concentrated markets having close to random vendor distributions and very competitive markets having strong agglomeration.

Figure 2 presents figures at the county level, and we find similar patterns. Counties at low levels of competition have small but negative values of MTAD. MTAD decreases with both measures of competition, and we again find a stark change from the fourth to the fifth quintile.

5.2 Regression Results

Table 4 provides regression evidence of the relationships plotted in Figure 1. Column 1 directly corresponds to Figure 1 for number of hospitals and HHI in their respective panels. The coefficients imply a slight negative, though not statistically significant, relationship between competition and MTAD through the first four quintiles with a very large and statistically significant decrease in the fifth quintile (-18.765 for number of hospitals and -23.113 for HHI). Column 2 adds state fixed effects to control for any regional differences in agglomeration propensity and to account for the fact that some vendors are more prominent in some regions. These estimates that exploit within state variation in concentration show the same pattern with

similar magnitudes. Column 3 adds demographic controls and Column 4 adds hospital characteristic controls. Again, the estimates imply the same pattern, with a large increase in agglomeration (decrease in MTAD) in the fifth quintile.⁸

Table 5 presents results at the county level. As at the HRR level, the regression results confirm that the relationships between market structure and MTAD are robust to the inclusion of controls. We find negative coefficients for all quintiles relative to the first quintile, and large, statistically significant coefficients for the fifth quintile.

Our results to this point suggest that incentives to differentiate or coordinate with nearby hospitals vary greatly with market structure. The pattern of results suggests that the network effect outweighs the business stealing effect in EMR adoption, which confirms previous findings such as in Lin (2015). We also find the dominance of the network effect is stronger in highly competitive markets. The stability of these results to state fixed effects and other controls suggests endogeneity may not be a large problem in this context.

5.3 Robustness Checks

In this section we discuss a variety of robustness checks and potential endogeneity concerns. A wide literature in health economics attempts to estimate the causal impact of hospital competition on prices and quality of care (e.g. Dafny 2009, Gaynor et al. 2013). However, the nature of the identification concern is different from that in this paper. For

⁸ While the inclusion of these controls has little impact on the estimate, we note that in results not reported in the table the fraction of hospitals with a system affiliation has a strong negative impact on MTAD. As expected, many hospitals in a market with system ownership leads to agglomeration; however, our results imply that this is independent of the market competition channel.

example, studies of competition and quality are concerned with reverse causality, since a high quality provider in a market will draw more patients and lead to increased concentration.

The potential for endogeneity in our case is less clear. Most unobserved determinants of competition seem unlikely to also relate to *which* EMR vendor a hospital chooses. That being said, one potential factor that may bias our results is “management quality.” Bloom et al. (2015) find that competition leads to better management, as measured from a survey instrument designed to quantify management quality. If better managers are also more or less likely to coordinate vendor choices with nearby hospitals, our estimates may be biased. However, to the extent that competition is a causal driver of better management, this unobserved factor is not a source of bias, but rather a channel through which competition causes agglomeration or dispersion. Further, we note that it is unclear whether better managers would respond more strongly to differentiation or coordination incentives, so the sign of this bias/effect could be in either direction.

While we cannot explicitly test for the presence of any omitted variable bias that may exist, we believe the robustness of our results to a variety of controls mitigates endogeneity concerns. In order to further mitigate such concerns, we also replicate our HRR-level results using the measure of MTAD calculated in 2012 but with the measure of market structure calculated in 2005. Because both market structure and EMR adoption changed greatly over this time period, we expect unobserved determinants of MTAD to have a much lower correlation with market structure many years earlier. These results are presented in Table 6 at the HRR level, and are very similar to our main results in Table 4, providing further support to our conclusions.

Another possible endogeneity concern is that there might exist some unobserved market-level heterogeneity that affects both entry of hospitals and EMR vendors. For example, a highly profitable market would attract not only more hospitals (which affects market competition), but also more vendors (which affects the choice menu of EMR adoption and therefore our measure of agglomeration and dispersion). However, this would work against our finding that more competitive markets are more agglomerated. Alternatively, certain vendors may specifically target their marketing towards certain types of markets. If a particular set of vendors targeted markets that are also more competitive, our estimates would be biased towards finding an association between competition and agglomeration. We have run regressions of each of the top 10 vendor market shares on our measures of market structure, with results in Table 7. We do not find any evidence that certain vendors are more likely to have a presence in more competitive markets, suggesting that the overall vendor choice set of hospitals does not depend on hospital market structure.

Finally, we also test whether our results are robust to accounting for multi-hospital systems. First, we calculate our overall measure of MTAD by treating hospitals owned by the same system within a market as a single firm. For example, if an HRR has 10 hospitals, but 3 of them are owned by a single system, we treat this HRR as if it has 8 firms. When calculating MTAD we assign the most commonly chosen vendor of these system hospitals as the firms' vendor choice. We find that the overall value of MTAD is -4.2. While the magnitude is much smaller than our measure that treats each hospital independently, it is still negative and indicates a statistically significant level of agglomeration.

We also estimate regressions with this (system) version of MTAD along with versions of our market structure variables that also treat system hospitals as a single firm within a market when counting the number of hospitals and constructing HHI. The results are presented in Table 8. Here we find a similar pattern to our main results in Table 4. We continue to find that more competitive markets have higher levels of agglomeration, particularly in the highest quintile. Not surprisingly, the magnitudes of the coefficients are smaller, since the overall value of MTAD is closer to zero, but the relationship with market structure is similar.

5.4. Dynamics

To this point, we have presented results using MTAD measured in 2012. Calculating MTAD in our most recent year of data captures the decisions made by hospitals as EMR technology diffused, and includes decisions made by both “early” and “late” adopters. As of 2012, 89% of hospitals had adopted CDR, but only 68% had adopted as of the beginning of our data period in 2005. In this section we explore how competition impacted the evolution of vendor purchase coordination.

In results not shown, we find that market structure in 2005 is correlated with MTAD, but the relationship is weaker, with the coefficients smaller in magnitude. In Table 9 we regress the change in MTAD from 2005 to 2012 on baseline 2005 market structure.⁹ The results for number of hospitals show that more competitive markets tended to see larger decreases in MTAD over this time period. In particular, with all controls included, MTAD decreased by 10.7 units more in the fifth quintile than in the first quintile. The results for HHI are noisier, but also suggest that MTAD decreased most in the highest quintiles of competition.

⁹ This regression includes the 274 HRRs for which we observe hospitals in the HIMSS data in both 2005 and 2012.

Taken with our previous results, these results concerning the dynamics of MTAD suggest that earlier adopters – in our case, those that had adopted by 2005 – exhibited more coordination in more competitive markets. In addition, in more competitive markets, later adopter behavior further exaggerated this relationship. This suggests that competition leads later adopters to be even more likely to coordinate with the adoption decisions of early adopters.

6. Conclusions

In this paper, we measure whether EMR adoption (specifically CDR adoption) by U.S. hospitals exhibits patterns characterized by agglomeration or by dispersion. We also examine if and how this pattern relates to competition. Using a statistical test of agglomeration and dispersion, MTAD, we find that hospitals tend toward agglomeration, and that the level of agglomeration increases with competition. Hence, as markets become less concentrated, we observe greater tendencies toward agglomeration. This relationship exists for relatively early adopters, i.e., those who had adopted CDR as of 2005, and it becomes even more pronounced as the technology diffused between 2005 and 2012.

Our findings suggest that market forces move hospitals toward potential interoperability. Future research should further explore whether the HITECH act pushed hospitals to further coordinate vendor choices. Our analysis also takes vendor coordination as a proxy for interoperability. Future research should explore whether hospitals in more competitive markets actually exchange information more fluidly. Our findings also have important implications for antitrust policy. As the hospital market continues to consolidate, our findings suggest that increased concentration may dampen the incentives to coordinate.

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Figure 1: MTAD by Number of Hospital and HHI Quintiles, HRR Level

Figure 2: MTAD by Number of Hospital and HHI Quintiles, County Level

Table 1: EMR Vendor Market Shares

Vendor	# of Hospitals	Market Share	Cumulative Market Share
Meditech	832	29.01	29.01
Cerner	392	13.67	42.68
McKesson	391	13.63	56.31
Epic	281	9.8	66.11
Siemens Healthcare	256	8.93	75.04
CPSI	152	5.3	80.34
Healthcare Management Systems	118	4.11	84.45
Allscripts	110	3.83	88.28
GE Healthcare	49	1.71	89.99
Quadramed	49	1.71	91.70
Self-Developed	117	4.08	95.78
Other	121	4.22	100

Notes: Authors' calculation from 2012 HIMSS data based on vendor choices among CDR adopting hospitals.

Table 2: Multinomial Tests of Agglomeration and Dispersion and Market Structure

	MTAD Calculations				Market Structure		
	Observed Likelihood	Expected Likelihood	Standard Deviation	MTAD	Mean # of Hospitals	Mean HHI	# of Markets
Overall	-10.452	-8.861	0.089	-17.897	14.88	2,517	299
Northeast	-13.267	-9.741	0.253	-13.910	13.16	2,351	43
Midwest	-9.533	-8.379	0.186	-6.206	16.37	2,464	78
South	-10.786	-9.204	0.120	-13.139	14.79	2,607	118
West	-8.973	-8.251	0.187	-3.864	14.37	2,529	60

Notes: MTAD is calculated from CDR vendor choices from the HIMSS data, and market structure is calculated from the universe of AHA hospitals. Markets are defined by HRRs.

Table 3: Summary of Market Structure Quintiles

Number of Hospitals			Competition		
Quintile	Mean	# of Markets	Quintile	Mean	# of Markets
1	4.67	81	1	4,962	59
2	7.92	52	2	3,057	60
3	11.43	54	3	2,289	60
4	16.53	55	4	1,563	60
5	37.44	57	5	755	60
Overall	14.88	299	Overall	2,517	299

Notes: Market structure is calculated from the universe of AHA hospitals. Markets are defined by HRRs.

Table 4: Effect of Market Structure on MTAD

	# of Hospital Quintiles				10,000-HHI Quintiles			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Quintile 2	-0.771 (3.913)	-3.909 (3.718)	-2.219 (3.823)	-3.989 (3.750)	1.234 (2.368)	0.840 (2.573)	2.181 (2.470)	0.396 (2.595)
Quintile 3	-1.381 (4.384)	-3.384 (5.007)	-1.046 (5.324)	-1.660 (5.516)	-3.550 (3.402)	-4.744 (3.177)	-3.376 (3.182)	-5.604* (3.220)
Quintile 4	-3.803 (3.402)	-5.717 (3.891)	-4.261 (4.383)	-5.336 (4.119)	-2.512 (2.501)	-2.474 (3.367)	-1.951 (3.406)	-4.558 (3.750)
Quintile 5	-18.765*** (5.058)	-20.481*** (5.146)	-17.275*** (5.445)	-17.846*** (5.384)	-23.113*** (5.810)	-27.409*** (5.461)	-23.416*** (4.720)	-25.730*** (4.730)
State FE		X	X	X		X	X	X
HRR Demographics			X	X			X	X
Hospital Market Characteristics				X				X
N	299	299	299	299	299	299	299	299

Notes: Each column presents results from a different regression at the market level. Markets are defined by HRRs. The dependent variable is MTAD. Standard errors are clustered at the state level.

*** - $p < .01$, ** - $p < .05$, * - $p < .10$

Table 5: Effect of Market Structure on MTAD, County Level

	# of Hospital Quintiles				10,000-HHI Quintiles			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Quintile 2					-0.136 (1.983)	-0.598 (2.312)	-1.703 (2.251)	-1.325 (2.216)
Quintile 3	-0.513 (1.821)	1.283 (1.962)	1.355 (2.019)	1.016 (2.124)	-1.446 (1.836)	-1.913 (2.116)	-2.750 (2.229)	-2.419 (2.257)
Quintile 4	-3.484* (1.951)	-3.514* (1.850)	-3.221 (2.105)	-3.458* (1.977)	-2.111 (2.045)	-1.691 (1.950)	-3.008 (2.036)	-2.736 (2.103)
Quintile 5	-11.064*** (3.736)	-10.814*** (3.850)	-9.996*** (3.643)	-10.172*** (3.608)	-13.060*** (4.787)	-14.221*** (5.239)	-12.849** (5.116)	-12.225** (4.907)
State FE		X	X	X		X	X	X
County								
Demographics			X	X			X	X
Hospital Market				X				X
Characteristics								
N	493	493	493	493	493	493	493	493

Notes: Each column presents results from a different regression at the market level. Markets are defined by counties. There is no second quintile for number of hospitals, because 40% of counties have two hospitals. The dependent variable is MTAD. Standard errors are clustered at the state level.

*** - $p < .01$, ** - $p < .05$, * - $p < .10$

Table 6: Effect of 2005 Market Structure on MTAD

	# of Hospital Quintiles				10,000-HHI Quintiles			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Quintile 2	-3.941 (3.154)	-6.574* (3.551)	-5.119 (3.668)	-5.917 (3.642)	0.879 (3.075)	0.627 (3.436)	1.088 (2.697)	-0.729 (2.757)
Quintile 3	-1.079 (3.411)	-1.768 (3.987)	0.972 (4.334)	0.569 (4.161)	-3.282 (2.985)	-3.967 (2.931)	-1.100 (2.868)	-4.137 (2.678)
Quintile 4	-6.850** (3.001)	-9.349*** (2.976)	-6.661* (3.547)	-7.512** (3.467)	-3.031 (2.589)	-3.628 (3.238)	-3.508 (3.561)	-6.585* (3.622)
Quintile 5	-19.831*** (4.083)	-20.817*** (4.043)	-16.988*** (4.253)	-17.434*** (4.229)	-23.138*** (5.954)	-27.458*** (5.660)	-22.196*** (4.447)	-24.992*** (4.539)
State FE		X	X	X		X	X	X
HRR Demographics			X	X			X	X
Hospital Market Characteristics				X				X
N	299	299	299	299	299	299	299	299

Notes: Each column presents results from a different regression at the market level. Markets are defined by HRRs. The dependent variable is MTAD. Market structure is calculated based on 2005 AHA data. Standard errors are clustered at the state level.

*** - $p < .01$, ** - $p < .05$, * - $p < .10$

Table 7: Effect of Market Structure on Vendor Market Shares

	Allscripts	Cerner	CPSI	Epic	GE	HMS	McKesson	Meditech	Quadramed	Self-Developed	Siemens	Other
By Number of Hospitals												
Quintile 2	-0.014 (0.013)	-0.012 (0.031)	-0.035** (0.016)	-0.038 (0.031)	-0.002 (0.009)	-0.010 (0.015)	0.001 (0.031)	0.109*** (0.040)	-0.007 (0.009)	-0.021 (0.021)	0.020 (0.028)	0.010 (0.017)
Quintile 3	-0.008 (0.016)	0.053* (0.029)	0.024* (0.014)	-0.015 (0.034)	-0.008 (0.022)	0.008 (0.012)	0.001 (0.031)	-0.026 (0.047)	-0.024* (0.014)	0.022 (0.022)	-0.029 (0.027)	0.003 (0.018)
Quintile 4	0.008 (0.015)	-0.004 (0.029)	0.020 (0.017)	-0.026 (0.028)	-0.002 (0.008)	-0.015 (0.012)	0.019 (0.031)	-0.003 (0.040)	-0.019 (0.012)	0.007 (0.017)	0.011 (0.031)	0.005 (0.016)
Quintile 5	0.020 (0.015)	0.003 (0.031)	0.006 (0.012)	-0.016 (0.032)	0.000 (0.011)	0.004 (0.010)	-0.010 (0.027)	0.016 (0.038)	-0.022** (0.011)	0.013 (0.019)	-0.021 (0.027)	0.007 (0.017)
By HHI												
Quintile 2	-0.007 (0.014)	-0.009 (0.044)	0.021 (0.024)	0.013 (0.034)	-0.015 (0.011)	0.019 (0.016)	0.017 (0.042)	-0.040 (0.066)	-0.013 (0.014)	0.005 (0.014)	0.018 (0.031)	-0.009 (0.018)
Quintile 3	-0.001 (0.020)	0.050 (0.035)	0.007 (0.022)	0.060* (0.032)	-0.022 (0.023)	0.021 (0.020)	-0.028 (0.046)	-0.036 (0.062)	-0.014 (0.012)	-0.004 (0.012)	-0.023 (0.030)	-0.009 (0.020)
Quintile 4	-0.002 (0.015)	-0.004 (0.032)	0.011 (0.015)	-0.014 (0.032)	-0.004 (0.014)	0.003 (0.015)	0.027 (0.034)	-0.036 (0.041)	-0.015 (0.011)	0.023 (0.021)	0.003 (0.021)	0.007 (0.015)
Quintile 5	0.012 (0.020)	0.039 (0.032)	0.019 (0.015)	0.001 (0.037)	-0.008 (0.015)	0.004 (0.013)	-0.005 (0.031)	-0.008 (0.049)	-0.034** (0.015)	0.014 (0.019)	-0.030 (0.027)	-0.003 (0.019)
N	299	299	299	299	299	299	299	299	299	299	299	299

Notes: Each column presents results from a different regression at the market level. Markets are defined by HRRs. The dependent variables are each vendors' market share. Standard errors are clustered at the state level.

*** - $p < .01$, ** - $p < .05$, * - $p < .10$

Table 8: Effect of Market Structure on MTAD, Accounting for System Ownership

	# of Hospital Quintiles				10,000-HHI Quintiles			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Quintile 2	-0.183 (1.774)	-0.747 (1.770)	0.012 (1.697)	-1.573 (1.818)	-0.030 (2.402)	-1.589 (2.473)	-1.365 (2.378)	-1.306 (2.559)
Quintile 3	1.090 (1.581)	-0.132 (1.962)	1.856 (2.147)	-0.083 (2.536)	-0.946 (2.664)	-1.183 (2.965)	-0.415 (3.049)	-0.411 (3.264)
Quintile 4	-1.997 (2.090)	-2.198 (2.361)	-2.939 (2.397)	-5.938** (2.704)	-1.115 (2.222)	-2.340 (2.379)	-1.434 (2.878)	-1.210 (3.198)
Quintile 5	-5.689* (2.939)	-11.761*** (2.892)	-9.193*** (2.626)	-12.585*** (3.293)	-5.782** (2.949)	-8.486*** (2.800)	-6.054* (3.148)	-5.912* (3.512)
State FE		X	X	X		X	X	X
HRR Demographics			X	X			X	X
Hospital Market Characteristics				X				X
N	299	299	299	299	299	299	299	299

Notes: Each column presents results from a different regression at the market level. Markets are defined by HRRs. The dependent variable is MTAD. In these regressions hospitals within the same HRR and owned by the same system are counted as a single firm for calculating both MTAD and market structure. If a system's hospitals use more than one vendor, the most common vendor is used to calculate MTAD. Standard errors are clustered at the state level.

*** - $p < .01$, ** - $p < .05$, * - $p < .10$

Table 9: Effect of 2005 Market Structure on 2005 to 2012 Change in MTAD

	# of Hospital Quintiles				10,000-HHI Quintiles			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Quintile 2	1.315 (2.151)	-0.209 (2.154)	-0.716 (1.994)	-0.321 (2.043)	0.409 (3.189)	1.465 (3.218)	2.953 (3.088)	2.146 (3.263)
Quintile 3	-0.891 (2.800)	-2.581 (2.908)	-2.169 (3.121)	-2.441 (3.094)	2.522 (3.434)	2.350 (4.832)	3.663 (5.132)	3.073 (5.113)
Quintile 4	0.285 (2.741)	-1.906 (2.664)	-3.367 (3.038)	-3.589 (3.140)	-2.365 (2.896)	-1.557 (3.911)	-1.613 (4.323)	-2.195 (4.389)
Quintile 5	-9.590** (3.916)	-10.847*** (3.842)	-10.731*** (3.334)	-10.651*** (3.350)	-5.278 (3.893)	-4.860 (3.821)	-4.426 (4.048)	-4.715 (3.989)
State FE		X	X	X		X	X	X
HRR Demographics			X	X			X	X
Hospital Market Characteristics				X				X
N	274	274	274	274	274	274	274	274

Notes: Each column presents results from a different regression at the market level. Markets are defined by HRRs. The dependent variable is the change in MTAD from 2005 to 2012. Market structure is calculated from 2005 AHA data. The sample includes HRRs present in both data sets in both 2005 and 2012. Standard errors are clustered at the state level.

*** - $p < .01$, ** - $p < .05$, * - $p < .10$