Physician Investment in Hospitals: Specialization, Incentives, and the Quality of Cardiac Care

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Abstract

Physician ownership of hospitals involves several competing economic forces. Physician-owners may be incentivized to "cherry-pick" and treat profitable patients at their facilities. However, physician-owned hospitals are often specialized and may provide higher-quality care. This paper uses a structural choice-outcome model to estimate hospital quality, patient-hospital matching, and preferences for treating patients at owned vs. competing hospitals. Instrumental variables analysis of cardiac mortality is used to capture quality; I document a significant mortality improvement at physician-owned hospitals. I use new data on ownership to estimate physician-owner preferences; controlling for matching and baseline patient preferences, there is little evidence of physician-owner cherry-picking.

In the U.S., most patients receive inpatient care at acute care hospitals that provide a broad range of services and are operated by nonprofit or for-profit organizations. Physician diagnostic and treatment services are a key input in inpatient care, yet physicians and hospitals typically operate as distinct entities and physician compensation is divorced from hospital performance. It has been argued that this structure does not serve patients well, and the past two decades saw entry of a new organizational form: the physician-owned specialty hospital.

The potential for efficiency gains from specialization has been a focus of economists since Adam Smith. In health care, where inefficiency is a major concern for policy mak-

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ers, specialization has been held up as a way to reduce cost while improving quality. On the other hand, physician ownership may involve distorted incentives as owners may benefit from cherry-picking high-margin, low-cost patients into their own facilities, to the detriment of competitors. Because cherry-picking profitable patients and optimally matching heterogeneous patients to high-quality, specialized care can be indistinguishable – specialty hospitals have low mortality rates, but see the healthiest patients – determining the welfare impacts of specialization is a difficult empirical task. This issue is not only manifest in health care; in most markets, when one considers the welfare impact of entry, we face a tradeoff between the efficiency impacts of greater competition from innovative new firms and the welfare loss associated with business stealing.

In this paper, I develop and estimate a structural model in which patient health outcomes may vary based on hospital type, illness severity, or the interaction thereof, and in which hospital choice is based on expected outcome as well as other financial and non-financial preferences. Patient characteristics determine hospital choice through their effect on profits as in a model of physician cherry-picking, and through their effect on expected outcome across hospitals (matching). I estimate the outcome and choice processes jointly to separately identify these mechanisms. Focusing on cardiac care, I use mortality data to estimate hospital quality both on average and varying with patient characteristics. Instrumental variables are employed to contend with omitted variables bias. A new data source containing information on physician ownership is used to estimate differential incentives of physician-owners – after controlling for optimal matching, I compare the choice behavior of physician-owners to that of non-owners to provide evidence on potential cherry-picking behavior on the part of investors.

A key empirical challenge in this work and more broadly in the economic literature on quality measurement in areas such as health and education is to separate favorable selection from improvements in outcomes. Although previous work has found evidence that physician-owned hospitals treat observably different patient populations,[1] this may not constitute evidence of cherry-picking for at least two reasons. First and foremost, patient characteristics could differ because of optimal matching – different hospitals may

[1] See Mitchell (2005) and Chollet, et al. (2006), which explore patient characteristics explicitly to investigate cherry-picking.

be better suited to treating different types of patients.[2] Second, patient populations may vary based on the demographic and health characteristics of the communities they serve.

My model allows for differential physician-owned hospital (POH) quality, optimal matching, and distorted incentives of physician owners. I estimate the model parameters using data from the Centers for Medicare and Medicaid Services (CMS) for a large sample of cardiac patients in markets containing specialized cardiac and/or physician-owned hospitals. I use mortality data and a rich set of demographic and clinical characteristics to estimate average quality and quality heterogeneity. I allow for unobserved illness heterogeneity to impact both choice and outcome using instrumental variables (IV) in combination with a structural methodology from the discrete choice literature. Geographic distance to physician-owned hospitals is used as an IV for treatment at a POH. I then estimate selection on unobservables using the systematic unexplained patient mortality for each physician-hospital type combination, holding facility quality fixed.

I use the joint distribution of hospital choice and patient outcomes for different physician types to separately identify the behavior of owners and non-owners, after accounting for optimal matching. A factor which has hampered research in this area is an unfortunate lack of data on physician ownership. I have collected a unique dataset on ownership of all physician-owned hospitals providing cardiac care. The data include aggregate physician ownership shares as well as the number of physician owners. As individual physician-investors are not identified, I use a probabilistic approach with these data to distinguish the behavior of owners from that of non-owners; results are robust to alternative ownership identification methods.

My results indicate large mortality gains at physician-owned specialty hospitals. In the preferred specification, I estimate a 1.2 percentage point decrease in 90-day mortality risk for the average sample patient, a large effect size relative to sample mortality risk of 6.35%.[3] Estimation using driving distance to instrument for hospital choice does not reject the null of no endogeneity conditional on controls. I also find that hospitals which

[2] Other researchers have argued that there is substantial scope for matching between health care providers and patients; see, e.g., Dranove, et al. (2003). For example, in this setting, cardiac patients with additional, non-cardiac illnesses such as diabetes may not be well-suited to treatment in specialized environments such as physician-owned cardiac hospitals.

[3] This effect is of a similar magnitude to that reported by observational studies in the previous literature; e.g., Cram, et al. (2005).

are not physician-owned but which are specialized in cardiac care provide a significant improvement in mortality risk comparable to that of POHs. Estimates of the effects of POH treatment on mortality for patients in different quintiles of overall sickness indicate that quality improvements pertain primarily for low- to moderate-severity patients. Thus, there is some evidence of an optimal matching rationale for treating sicker patients at community hospitals rather than at POHs. However, standard errors are too large to permit ranking of the quality effects across patient types.

Turning to the choice results, I find that physician-owners divert a large number of patients to their owned facilities, but there is no strong evidence of owners cherry-picking healthier patients than non-owners. The point estimates of the preferred specification indicate that owners select slightly sicker patients into POHs than non-owners. Estimates are small relative to standard errors, but the extreme bounds of the 95% confidence interval on cherry-picking behavior accounts for at most one-third the favorable patient selection observed at POHs. Finally, physician-owner behavior appears to be driven by ownership *per se* rather than variation in per-physician financial stake. In sum, the evidence indicates that favorable patient populations observed at physician-owned hospitals relative to competitors cannot be attributed to physician-investor cherry-picking.

My findings have important policy implications. The Affordable Care Act banned further physician ownership in part because of cherry-picking concerns.[4] While such concerns were potentially well-founded based on observational studies, my analysis reveals that, in the case of inpatient cardiac care, patient populations are not distorted by physician-owner cherry-picking after controlling for patient-hospital matching and baseline preferences over hospitals. On balance, holding physician behavior and market structure otherwise fixed, the results suggest that overall cardiac patient mortality would increase if physician-owned hospitals were eliminated from their markets. The evidence of comparable quality at non-physician-owned cardiac specialty hospitals suggests that specialization rather than ownership accounts for measured quality improvements.[5]

[4]Existing physician-owned facilities are grandfathered in, but cannot expand physician investment. Exceptions may be granted to certain facilities, including those that serve a high Medicaid population.

[5]This finding may be interpreted as suggesting that physician-ownership of hospitals can be eliminated without damaging cardiac patients' health; however, the strong association between ownership and specialization in the market for cardiac care implies that the specialized model may be difficult to implement without physician investment.

The rest of the paper proceeds as follows. In Section 1, I describe the origins of physician ownership in hospitals and some industry background. In Section 2, I lay out my model of joint hospital choice and patient outcome and provide intuition for identification. I then describe my empirical approach to estimating the model and detail the assumptions needed for identification. Section 3 describes the data used in this application. Section 4 discusses the model estimation and Section 5 presents empirical results. Section 6 discusses some robustness checks. Section 7 concludes.

1 Background

1.1 Physician-owned specialty hospitals: origins and entry

Physician ownership is not a new model among U.S. hospitals. In the beginning of the 20th century, most for-profit hospitals were small facilities owned by doctors in rural areas and small communities, but by 1960 they accounted for only 15% of the hospital care market (David, 2009). In the late 1980s, the Office of the Inspector General issued a Special Fraud Alert regarding physician-hospital relationships; of particular concern was the potential for physician investors to refer patients to joint venture entities providing clinical diagnostic laboratory services, durable medical equipment (DME), and other diagnostic services in exchange for profit distributions (OIG, 1994). The Omnibus Budget Reconciliation Act (OBRA) of 1989 contained a provision (the "Stark I" provision) barring self-referrals for Medicare clinical laboratory services. OBRA 1993's "Stark II" provision expanded the definition of self-referral to include most institutional services, such as inpatient and outpatient hospital care.[6] The updated law included a number of exceptions. Under the presumption that a physician's behavior would not be significantly impacted by a small investment interest in an entire hospital, the ban included a "whole hospital exception," which held that the ban does not apply if a physician is authorized to perform services at the hospital *and* the investment interest is in the whole hospital. Between 1993 and 2003, the number of physician-owned *specialty* hospitals tripled, not including the 20 facilities under development in 2003 (Kimbol,

[6]See Kimbol (2005) for a description of the Stark laws. Under the Stark II law, physicians "may not make referrals to an entity in which the physician or an immediate family member has a financial relationship, for the furnishing of designated health services for which payment may be made by Medicare or Medicaid" (42 U.S.C. §1395nn). Physicians violating the Stark laws faced non-payment for services rendered in addition to potential civil penalties and/or full loss of Medicare/Medicaid certification.

2005). Most physician-owned hospitals operating in recent decades are specialized in the fields of cardiac care, orthopedics, or general surgery.

The regulatory loophole described above made ownership in a specialty facility a viable alternative for physicians seeking an investment share in a hospital, but expansion in hospital capacity is regulated in many states. For this reason, physician-owned specialty hospital entry has required the presence of a large specialty group and lax regulation of hospital capacity expansion (Casalino, et al., 2003). I focus my analysis on regions which have experienced entry by specialty hospitals providing cardiac care, whether physician-owned or not. Cardiac care is of particular interest because it generates a quality measure in the form of mortality outcomes.

1.2 Physician ownership and patient selection

As noted above, there are multiple explanations for physician-owned and community hospitals treating different patient populations. The explanation favored by proponents of physician ownership is one in which some patients are better suited to treatment at physician-owned facilities than others.[7] In the case of cardiac care, this optimal matching story would apply if, for example, specialty heart hospitals are optimal for the treatment of high-acuity cardiac patients, but not for patients with non-cardiac conditions like end stage renal disease, which may require access to dialysis facilities.

The criticism that physician-owned hospitals (POHs) will cherry-pick profitable patients is theoretically well-founded due to physician agency in hospital care; indeed, Nakamura, et al. (2007) find that tertiary care hospitals' acquisitions of primary care settings led to increased referrals. It is also supported by several empirical facts. Specialty hospitals generally focus on profitable services such as cardiac care and orthopedic surgery, and are less likely than general hospitals to have emergency departments. I focus on Medicare patients, who are by definition insured and who comprise the majority of the cardiac population, and on cardiac POHs, which generally have emergency departments. Thus, this paper considers a physician's incentives to cherry-pick profitable patients *given* her average patient population, as a function of patient severity.

[7] As noted by Alan Pierrot, a member of the Board of Directors of the American Surgical Hospital Association, "every hospital tries to do those things for which it is best suited and whenever possible sends other cases to a better equipped facility. Such behavior is appropriate and in the best interests of patients." (109 Cong. Rec., 2005)

Medicare's reimbursement system encourages this type of selection directly. For physician services, reimbursements are tied to physician charges and additional care entails a greater reimbursement. However, for hospital and nursing home care, Medicare's prospective payment system reimburses facilities on a fixed-fee basis for each diagnosis-related group (DRG), so that a physician with an ownership stake in a POH will profit from treating low-cost patients in the POH and lose money on high-cost patients.[8] Per-patient hospital profit for cardiac care is high, but variable, and evidence suggests that POHs treat less severe, higher-margin cardiac patients. In 2002, the average marginal profit was $9,600 per patient for a coronary artery bypass graft (CABG) with cardiac catheterization, a common surgery used to treat patients with angina and coronary artery disease. However, the lowest-severity CABG with catheterization patient is 1.86 times as profitable as the highest severity patient (MedPAC, 2005).[9] A study performed by MedPAC in 2005 found that, based on DRG case mix alone, twelve specialty heart hospitals studied were expected to be six percent more profitable than competitor hospitals, and further that specialty hospital patients were in lower severity classes, resulting in a further 3 percent increase in expected profitability (MedPAC, 2005).

Finally, there is evidence that owners and non-owners exhibit different preferences among POHs vs. competitor hospitals, with owners referring up to 34 percentage points more patients to POHs than non-owners in three hospitals studied (CMS, 2005).[10]

My analysis extends this literature by decomposing hospital choice into several mechanisms that impact patient distribution: quality-based matching, baseline preferences over hospital characteristics, and differential owner selection behavior.

1.3 Physician ownership, specialization, and facility quality

While the potential for distorted incentives is perhaps a fundamental problem with the physician-owned hospital model, proponents argue that physician-owned and specialty

[8]CMS altered the reimbursement grouping system in 2007, after the study period for this project, to include richer measures of severity.

[9]Reimbursements are not generally structured to provide zero profit on average; as implied by this example, some treatments involve positive profit for even the most severe patients.

[10]See also Mitchell (2005), which found that physicians that treated at least 10% of their cardiac patients at the Tucson Heart Hospital or Arizona Heart Hospital treated a less severe case mix of both cardiac surgical and medical DRGs than physicians only treating their cardiac patients in non-physician-owned competing facilities, and Chollet, et al. (2006), which found that physician-owners in specialty facilities in Texas admitted significantly more patients to their owned facilities than non-owners, though the difference in treatment patterns did not vary in patient characteristics.

hospitals are high-quality facilities, and that quality improvements dominate concerns about physician incentives. One possible channel for quality improvements and/or lower costs at POHs is ownership itself – physicians "know best" and physician input in the design and mission of a facility will lead to improvements, or perhaps ownership leads to physician-owners internalizing the externality they impose on hospitals through their involvement in inpatient care. The most common explanation focuses on the specialized nature of most POHs, characterizing them as similar to "focused factories," in which specialization implies dedicated equipment and staff and tailored management, and that these characteristics in turn imply high quality, low cost care.[11]

POHs are perceived by patients as having finer amenities (e.g., spacious private rooms) and more attentive, knowledgeable staffs than competitors (Greenwald, et al. (2006)). They also receive favorable reviews from physicians; in Casalino, et al. (2003), POH physicians noted increased productivity, as they chose their own surgical equipment, staff, and scheduling, and reduced down time between procedures.

Physicians also claim better patient outcomes as a motivation for specialty hospital affiliation. The evidence for such effects is mixed. In one study of markets with four cardiac facilities, cardiac specialty hospitals did perform better than a set of competitor hospitals on three of four procedures studied and each of two conditions studied (CMS, 2005).[12] Barro, Huckman, and Kessler (2006) focuses on Medicare cardiac patient outcomes before and after specialty hospital entry using data from 1993, 1996, and 1999 and finds evidence of weakly detrimental impacts of entry on patient outcomes as measured by survival and readmission rates relative to control markets. In this study, I focus on entry markets only and estimate mortality effects allowing for potential bias due to patient selection based on unobservable health status.

Finally, one argument made in favor of POHs is that they provide care at a lower cost. There have been several studies of the effects of specialty hospital entry on health care expenditures using longitudinal data. Barro, Huckman, and Kessler (2006) find

[11] See Casalino, et al. (2003) for a discussion.

[12] See also Cram, et al. (2005) and Nallomothu, et al. (2007), which study mortality outcomes for specific cardiac procedures and diagnoses, respectively. These studies use patient characteristics to generate risk-adjusted quality measures and find evidence of quality improvements at specialized cardiac facilities relative to competitors. However, Cram, et al. note that improvements are not statistically significant when specialty hospitals are compared to competitors with similar procedural volumes, and Nallomothu, et al. find substantial variation in quality among specialized facilities.

that specialty hospital entry markets experienced significantly slower growth in cardiac health expenditures, on the order of \$524-\$763 per patient, relative to control markets. Schneider, et al. (2011) use a two-stage least squares approach to analyze the effects of all types of POHs (including all types of specialties and non-specialized facilities) on expenditures using Medicare data from 1998-2005 and find that POH entry markets had 1% lower expenditures per enrollee, but the difference was not statistically significant.

2 Model

The goal of this project is to estimate the quality of treatment at physician-owned and/or specialized hospitals, and the extent to which optimal matching and physician ownership influence hospital choice. I evaluate this question using a model of hospital choice and patient outcome, in which hospital choice is based on expected outcome as well as other financial and non-financial preferences.[13] Patient characteristics affect both the potential for a good outcome as well as profitability across hospitals. First, I describe my approach to separating these effects in a full information setting. I then describe my estimation approach, in which illness and ownership may be partially observed.

2.1 Full information benchmark

Suppose that market m has J_m hospitals, each of which is either a physician-owned hospital or a nonprofit community hospital.[14] The dummy d_k^{PO} indicates that hospital k is physician-owned. Each cardiac specialist p may treat their patients at all J_m hospitals. Specialist p may be a physician investor in one POH in the market; $d_p^{own} = 1$ if physician p is a physician investor and τ_{pk} is physician p's ownership share in hospital k. Denote patient i's characteristics by $\mathbf{X}_i$.

I model hospital choice as the outcome of the physician's decision process. The physician is an imperfect agent for the patient and maximizes an additive function of patient and physician utility.[15] Regarding timing, I assume that patient i experiences

[13] In this section, I refer to patient "profitability" at a given hospital as convenient shorthand for all physician preferences, both financial and otherwise, which are not related to patient outcome.

[14] In practice, the empirical approach allows for a number of other variations, including specialization and other ownership models. For the sake of brevity, here I only contrast community hospitals and physician-owned hospitals.

[15] One may view hospital choice as a joint decision between the physician and the patient; my data do not allow me to separate the two.

a cardiovascular illness and arrives in the care of cardiac specialist p,[16] at which point specialist p evaluates the patient and observes $\mathbf{X}_i$ as well as $(d_k^{PO}, \tau_{pk})_{k=1}^{J_m}$ and her own idiosyncratic preferences $(\epsilon_{pk})_{k=1}^{J_m}$ over all hospitals in the market. The specialist then chooses hospital j as the location to admit and treat patient i.[17] Finally, patient i's outcome (mortality) m_{ipj} is observed.

Denote the utility physician p derives from treating patient i at hospital j as u_{ipj}, an additive function of the physician's profit from treating patient i at hospital j, π_{ipj}, the expected latent mortality outcome of patient i at hospital j, $\hat{m}_{ipj}$ (which will next be described in detail), and $dist_{ij}$, the distance from patient i to hospital j (as a proxy for patient convenience):

$$u_{ipj} = \pi_{ipj} + \rho_1 \hat{m}_{ipj} + \rho_2 dist_{ij} + \epsilon_{ipj}.$$

The physician will choose to treat the patient at hospital j if $u_{ipj} > u_{ipk}$ for all $k = 1, ..., J^m$, $k \neq j$. The term "profit" is used as a convenience; it may in fact capture both financial and non-financial preferences of the patient and physician.[18]

I allow physician profit to vary with patient, hospital, and physician characteristics, alone and interacted; for detail, see Appendix A, which derives the following expression from the well-known reimbursement structure for Medicare patients:[19]

$$\pi_{ipj} = d_j^{PO}\omega_1 + \mathbf{X_i} * d_j^{PO}\omega_2 + d_j^{PO} * d_p^{own}\omega_3 + \mathbf{X_i} * d_j^{PO} * d_p^{own}\omega_4 + \tau_{pj}\left(\lambda_1 + \mathbf{X}_i\lambda_2\right).$$

Hospital-specific profitability is determined by non-owner physicians' average preferences for POHs (ω_1 – this may include the average patient's taste for POH amenities),

[16]As illustrated in Figure C.1 in Appendix C, there are a number of ways for a patient to arrive in the care of a cardiac specialist. To the extent that the distribution of patient characteristics across physicians is not affected by these pathways, they are irrelevant to the current model. I will return to this issue when I discuss econometric identification in Section 2.3.

[17]In this project, I focus on a specific subset of cardiac patients, those who are severely ill enough to warrant hospital admission but who are admitted on a non-emergency basis. The former restriction is imposed to decrease the amount of unobservable variation in patient illness; without it, for example, the model would infer that hospital admission is harmful to patients because admitted patients are much more likely to die than outpatients, when in fact this is likely due to admitted patients being much sicker ex ante, conditional on all observable patient characteristics. The latter restriction ensures that the decision-making specialist has the opportunity to choose the hospital of admission, which may not be possible for emergency patients.

[18]Since I will be focusing on Medicare patients exclusively in this project, there is no explicit price of treatment in this model, as the price faced by the patient does not vary across hospitals.

[19]Note that patient characteristics alone do not appear in this equation, as there is no outside option to hospital care by assumption – patient characteristics only enter the profitability term insofar as patient profitability varies across hospitals.

the effect of patient characteristics $\mathbf{X_i}$ on non-owner physician preferences for POHs (ω_2 – sicker patients may be harder to treat in physician-owned or specialized environments), and the additional preference of a physician-investor of treating a patient at a physician-owned facility, on average (ω_3 – "home base" preference; and λ_1 – how home base preference varies with investment level) and varying with patient characteristics (ω_4, λ_2). Cherry-picking behavior is captured by ω_4 and λ_2. All together, we have

$$\begin{aligned} u_{ipj} &= d_j^{PO}\omega_1 + \mathbf{X_i} * d_j^{PO}\omega_2 + d_j^{PO} * d_p^{own}\omega_3 + \mathbf{X_i} * d_j^{PO} * d_p^{own}\omega_4 + \tau_{pj}\left(\lambda_1 + \mathbf{X_i}\lambda_2\right) \\ &\quad + \rho_1 \hat{m}_{ipj} + \rho_2 dist_{ij} + \epsilon_{ipj}. \end{aligned}$$

Hospital choice is determined by profitability, physician preferences over patient mortality (ρ_1), and physician preferences for patient convenience (ρ_2).

I model mortality *given hospital choice* as a function of patient, hospital, and physician characteristics plus an idiosyncratic shock which is unobserved to the physician. I employ a latent mortality model with $\Pr\left\{m_{ipj} = 1\right\} = \Pr\left\{m_{ipj}^* > 0\right\}$. The baseline model for latent mortality of patient i with physician p treated at hospital j is:

$$m_{ipj}^* = \alpha + \mathbf{X_i}\beta + d_j^{PO}\nu + (d_j^{PO} * \mathbf{X_i})\gamma + d_p^{own}\kappa + (d_j^{PO} * d_p^{own})\psi + v_{ipj} = \hat{m}_{ipj} + v_{ipj}.$$

The model allows flexibly for patient characteristics $\mathbf{X_i}$, hospital ownership d_j^{PO}, and physician investor status d_p^{own} to influence mortality directly and interacted with one another. v_{ipj} is an idiosyncratic shock. The parameters of primary interest are ν, which describes the average effect of physician ownership on expected mortality, and γ, which characterizes the relative suitability of physician-owned hospitals as patient health status varies (optimal matching). If $\nu > (<)0$, then the average patient does worse (better) at physician-owned hospitals. If $\beta > 0$ (high $\mathbf{X}$ implies sicker patients), then $\gamma > 0$ implies sick patients do relatively worse than healthy patients at POHs and it is optimal for physicians to alter choice patterns away from POHs for such patients.

In the choice model above, $\beta > 0$ and $\omega_4 < 0$ imply that physician-owners are cherry-picking healthier patients into their owned hospitals; further, $\lambda_2 < 0$ implies that cherry-picking behavior is exacerbated by greater ownership shares.[20]

[20] In practice, ρ_1 will be normalized to equal -1 in the current analysis, as all hospital characteristics and interactions therewith in the mortality specification also enter the choice model and physician preferences over hospital characteristics in the choice model can only be interpreted relative to ρ_1. Identification using nonlinearity of the CDF function is not sufficient in practice, as most available

Under the assumption of a normal error in the mortality model and type-I extreme value error in the choice model, the above specifications can be put together to obtain the following joint probability of observing mortality outcome m and choice $c_{ipj} = 1$:[21]

$$\Pr\{c_{ipj} = 1, m_{ipj} = m\} = \frac{\exp u_{ipj}}{\sum_{k \in J_m} \exp u_{ipk}} * (\mathbf{\Phi}(\hat{m}_{ipj})^m (1 - \mathbf{\Phi}(\hat{m}_{ipj}))^{1-m}).$$

With perfectly observed $\left(\mathbf{X_i}, d_p^{own}, \left(d_j^{PO}, \tau_{pj}, dist_{ij}\right)_{j=1}^{J_m}\right)$, it is straightforward to estimate this model using maximum likelihood.

2.2 Accounting for unobservables

In practice, even with exceedingly rich data on patients, hospitals, and physicians, $\mathbf{X_i}$ and τ_p are imperfectly known. Using an approach closely related to the random coefficients mixed-logit approach commonly used in the discrete choice literature (Train, 2009), I impose some structure on the distributions of $\mathbf{X_i}$ and τ_p and integrate over those distributions to obtain an expected log-likelihood in lieu of the exact log-likelihood. That is, the expected probability of observing (m_i, c_{ipj}) will be

$$\int_{\tau_p} \int_{\mathbf{X_i}} \frac{\exp u_{ipj}}{\sum_{k \in J_m} \exp u_{ipk}} * (\mathbf{\Phi}(\hat{m}_{ipj})^m (1 - \mathbf{\Phi}(\hat{m}_{ipj}))^{1-m}) dF_{\mathbf{X_i}} dF_{\tau_p}.$$

First, in this application, individual physician ownership share τ_{pj} is not perfectly observed. Instead, for each hospital, I observe how many physician-investors there are, the aggregate physician ownership share, and the identity of all physicians practicing at that hospital; see Appendix B. I assign each potential owner physician p a probability μ_{pj} that she is an owner based on the ratio of practicing physicians (potential owners) to actual owners at hospital j. I also have data on the aggregate physician ownership share at each POH. I do not have further information on the distribution of ownership shares across individual physicians, so I assume that aggregate physician ownership is spread equally among all physician-investors. That is, for each hospital j, let O_j be the count of owners, P_j be the count of practicing physicians, and A_j be the aggregate

hospital characteristics are binary.

[21] This expression is obtained by using Bayes' rule:

$$\Pr\{c_{ipj} = 1, m_{ipj} = m\} = \Pr\{m_{ipj} = m | c_{ipj} = 1\} * \Pr\{c_{ipj} = 1\}.$$

physician ownership. Then:

$$\mu_j = \frac{O_j}{P_j} \quad \textbf{and} \quad \tilde{\tau}_{pj} = \begin{cases} \frac{A_j}{P_j} & \text{with probability } \mu_j \\ 0 & \text{with probability } 1 - \mu_j \end{cases}$$

I also observe hospital choice for all sample patients admitted by each physician. Intuitively, observing many patients treated by a given physician allows me to assign her a behavioral type. I then compare the distribution of physician types to the known physician mix (proportion of owners vs. non-owners) across hospitals to infer the association between ownership status and behavioral type. There is substantial variation across POHs in the physician mix; for example, there are POHs where more than 80% of practicing physicians are investors, and there are POHs where fewer than 30% of practicing physicians are investors. This variation makes the probabilistic strategy more powerful. At hospitals where nearly all practicing physicians are investors, I can identify the behavior of physician-investors relatively well; at hospitals primarily staffed by non-owners, I can identify the behavior of non-owners relatively well.

In the estimation, I use a Bernoulli mixing distribution over the likelihood function for all patients treated by each potential owner physician. For physician p treating patients $1_p, ..., N_p$ in market m, the expected probability of observing outcomes $((m_{1_p}, c_{1_p}), ..., (m_{N_p}, c_{N_p}))$ then becomes

$$E\left(\Pr\left\{(c_i, m_i)_{i=1_p}^{N_p}\right\}\right) = \mu_j \prod_{i=1_p}^{N_p} \Pr\left\{c_i, m_i|\tilde{\tau}_p\right\} + (1-\mu_j) \prod_{i=1_p}^{N_p} \Pr\left\{c_i, m_i|\mathbf{0}\right\}.$$

Next, conditional on all patient characteristics which are observed to the econometrician, the physician may observe that some patients are more severely ill. For example, a patient may have difficulty climbing stairs, which is likely to affect hospital choice and mortality but not be reflected in data otherwise. In some specifications, I allow for patient type to be characterized by the set of observable characteristics $\mathbf{X_i}$ as well as a unidimensional unobserved shock to illness severity, s_i:

$$m^*_{ipj} = \alpha + \mathbf{X_i}\beta + d_j^{PO}\nu + (d_j^{PO} * \mathbf{X_i})\gamma + d_p^{own}\kappa + (d_j^{PO} * d_p^{own})\psi + s_i = \hat{m}_{ipj} + s_i.$$

The unobservable component s_i may affect both mortality and choice preferences:

$$\begin{aligned} u_{ipj} &= d_j^{PO}\omega_1 + \mathbf{X_i} * d_j^{PO}\omega_2 + s_i * d_j^{PO}\omega_2^u + d_j^{PO} * d_p^{own}\omega_3 + \mathbf{X_i} * d_j^{PO} * d_p^{own}\omega_4 \\ &\quad + s_i * d_j^{PO} * d_p^{own}\omega_4^u + \tau_{pj}\left(\lambda_1 + \mathbf{X_i}\lambda_2 + s_i\lambda_2^u\right) + \rho_1\hat{m}_{ipj} + \rho_2 dist_{ij} + \epsilon_{ipj}. \end{aligned}$$

The "u" superscripts denote preference parameters for unobserved sickness. E.g., if $\omega_4^u < 0$, physician-investors treat unobservably healthier patients in their owned hospitals as in a model of cherry-picking. Note that it is convenient to let s_i be the only unobservable shock in the mortality equation, as one cannot empirically distinguish unobservable sickness which is observable to the physician but does not affect choice from unobservable sickness which is also unobservable to the physician.

With this modification to the model, the average quality at physician-owned hospitals is not separately identified from selection on unobservable health – intuitively, the same patterns in mortality could be explained by higher quality (lower mortality) at physician-owned hospitals and no selection on unobservables, or by no difference in quality at physician-owned hospitals and physician cherry-picking on unobservable sickness. Thus, I perform the estimation in two steps. First, I estimate mortality parameters using instrumental variables to purge any selection on unobserved sickness. Second, I estimate the joint model holding quality parameters fixed. Now, selection on unobservables is identified by unexplained differences in mortality rates across hospital and physician types – if, for a physician-owner, I observe that mortality is systematically higher at the community hospital and lower at the physician-owned hospital than expected given IV estimates, I can infer that cherry-picking is taking place.

In practice, I use patients' distance to the nearest POH as an instrument for treatment at the POH, and I assume that s_i are i.i.d. standard normal.[22] I then integrate the probability of observing (m_i, c_{ipj}) as a function of s_i, holding mortality parameters fixed, over the standard normal CDF.

2.3 Identification

In my model, I make several assumption regarding the data generating process that allow me to identify quality, matching, and owner behavior.

[22] This normalization is imposed because the magnitude of mortality parameters can only be identified relative to the magnitude of the error term.

First, I assume that unobserved sickness s_i is i.i.d. standard normal across all patients and physicians and that my instrumental variables approach is valid (distance to a POH does not impact mortality directly). Physician-owners may attract a different patient population. For example, they may be more experienced, or perhaps primary care physicians send sicker patients to staff physicians *because* physician investors would more likely treat them at the community hospital. This would lead me to underestimate profit incentive effects in my model because "cherry-picking" would not be observed in subgame perfect equilibrium. It may also be the case that POHs enter in areas with unobservably healthier patients. In the former case, the assumption $s_i \sim \mathcal{N}(0, 1)$ would fail. In the latter, my distance instrument would be correlated with mortality absent its effect on hospital choice and my exclusion restriction would fail. I explore these issues in Section 6 using panel data for 2000-2007; the results indicate no evidence of bias.

Second, I assume that if treatment by owners implies different quality than treatment by non-owners, then this differential quality is not varying in unobservable patient health. It may be the case that physician quality is hospital-specific. For example, a "name on the door" effect could pertain due to owners caring more about perceived POH quality; on the other hand, physician-owners may be more likely to skimp on materials at the POH. If this quality differential of different types of physicians across physician-owned and community hospitals also depends on unobservable patient severity s_i, for example, if skimping on materials by physician investors harms severely ill patients more, then I cannot separate the physician's profit incentive from physician altruism at the margin of hospital choice (the physician *knows* severe patients will receive worse care, so treating them at a community hospital would be optimal). Such an effect would lead me to overestimate cherry-picking. This assumption seems unlikely to be problematic, but is unfortunately untestable.

Finally, I assume that each patient can treat their patients at any hospital in their market. It is important for my analysis to correctly specify the choice set of each physician; otherwise, I may find that a physician has a strong preference for her own hospital when in fact that is the only hospital with which she has admitting privileges. I excluded one market from my sample because I found evidence of economic credentialing, a practice in which physician privileges are based in part on issues of competition.[23] A search of U.S. news articles for the period 1997 to present uncovered evidence of no further suits for the physician-owned hospitals in my sample.

3 Data

This paper uses information from several datasets. Patient encounter data are taken from the 100% Centers for Medicare and Medicaid Services (CMS) inpatient admissions database. In my main specifications, I analyze the population of non-emergency cardiac patients admitted by a cardiac specialist in all hospital referral regions (HRRs[24]) containing at least one physician-owned hospital. I also provide evidence on markets containing at least one cardiac single-specialty hospital (SSH).[25]

The inpatient claims database includes patient demographics (age, sex, race), dates of admission and discharge, diagnosis-related group (DRG), ten diagnosis codes in addition to codes for principal diagnosis and diagnosis at admission, six procedure codes, discharge status, length of stay, unique hospital identifier, and physician identifiers.[26] Cardiac patients were identified using DRG and principal diagnosis descriptors.[27] Following the procedure used by the Medicare Payment Advisory Commission (MedPAC), cardiac single-specialty hospitals were defined as those for which at least 45 percent of their Medicare cases were cardiac in nature (MedPAC, 2005).[28] My sample only includes

[23]A group of cardiologists in Little Rock, Arkansas was denied admitting privileges at the Baptist Health hospital system after the group obtained an ownership interest in the Arkansas Heart Hospital; the subsequent lawsuits continued throughout my entire sample period (Sorrel 2007).

[24]HRRs were designed by the Dartmouth Atlas Working Group to explicitly account for regional health care markets for tertiary medical care such as major cardiovascular surgical procedures and neurosurgery. Each HRR in the U.S. has at least one city where both major cardiovascular surgical procedures and neurosurgery are performed. See http://www.dartmouthatlas.org/data/region/. Each HRR in my sample contains at least 3 hospitals providing high-acuity cardiac care.

[25]For patients with multiple admissions, the first admission in the year was analyzed.

[26]For this project, it is necessary to identify a unique decision-making physician for each patient. Whenever possible, each patient was assigned to the physician in the operating physician field, which was populated for 83.6% of sample cases. In the absence of an operating physician identifier, the decision-making physician was assumed to be the "other physician." In cases missing both "operating physician" and "other physician" identifiers, the decision-making physician was assumed to be the attending physician on staff.

[27]Cardiac DRGs were defined as those falling under the "circulatory system" major diagnostic category (MDC). Diagnoses were identified as cardiac in nature via a search of the full set of ICD-9 codes for the key word components of "cardio-," "heart," "coronary," and "chest." The full inpatient database for 2005 includes 13.8 million claims submitted by 8,705 providers for 7.9 million patients. 25% of all admissions were in cardiac DRGs.

[28]The average provider had only 11% of admissions in cardiac DRGs, compared to 72% for cardiac POHs.

hospitals capable of treating high-acuity patients; hospitals that admitted fewer than thirty patients in surgical cardiac DRGs (e.g., coronary artery bypass graft (CABG), percutaneous coronary intervention (PCI), open heart surgery) in 2005 were excluded. In the majority of analyses, I focus on patients treated in 2005.[29]

The inpatient claims were also linked to CMS's 100% denominator database, which contains information about enrollees' demographics, participation in Medicare, and date of death. HMO patients were eliminated from the sample in order to focus on patients without plan-based restrictions on hospital choice. ZIP code-level demographics (e.g., median income, population, percent of adult population with Bachelor's degrees) were linked to each patient from the 2000 U.S. Census.

I merged the cardiac inpatient sample with the American Hospital Association (AHA) annual surveys, which provide detailed data on hospital characteristics. Each patient's hospital choice set is defined as all hospitals in the local HRR for their home ZIP code. I used the Census TIGER database to find the latitude and longitude of the centroid of each ZIP code and obtained driving distance data using Stata's "traveltime" package; missing observations were filled in using the Great Circle formula.

I also merged the Medicare data with a self-collected dataset on physician ownership. The 20% carrier claims file was used in conjunction with the inpatient claims to flag potential owners of each physician-owned hospital; this flag is used with the probabilistic approach described in Section 2 to identify behavior of physician-investors at POHs. Details regarding the construction of this dataset and the potential owner flag are available in Appendix B. Section 6 presents estimates with physician investors assumed to be the top admitting physicians at each POH; results are largely unchanged.

My sample of physician-owned hospitals includes both cardiac specialty hospitals and non-specialized hospitals. These hospitals are identified in Table 1. Of the 20 physician-owned cardiac specialty hospitals in my sample, 12 were privately-owned in 2005, either independently by physicians or joint with a private corporation. Aggregate physician ownership shares range from 28% to 100%, split among 13 to 70 physician-investors. On average, each potential owner has about a 52% chance of being an actual owner, but this measure varies from 20% to 100%. The remaining physician-owned cardiac specialty

[29] 2005 is the first full year during which all sample POHs were open.

Table 1: Physician-owned hospital characteristics

Hospital	State	Opened	Type	Agg. Phys. Stake	Actual Owners	Potential Owners
Arizona Heart Hospital	AZ	Jun-98	Private Cardiac	29.4	17	86
Bakersfield Heart Hospital	CA	Oct-99	Private Cardiac	46.7	20	70
Dayton Heart Hospital	OH	Sep-99	Private Cardiac	33.5	36	75
Galichia Heart Hospital	KS	Dec-01	Private Cardiac	80	35	30
Heart Hospital of Austin	TX	Jan-99	Private Cardiac	29.1	60	75
Heart Hospital of Lafayette	LA	Mar-04	Private Cardiac	49	23	37
Heart Hospital of New Mexico	NM	Oct-99	Private Cardiac	28	35	81
Kansas Heart Hospital	KS	Feb-99	Private Cardiac	40	20	63
Louisiana Heart Hospital	LA	Feb-03	Private Cardiac	48.9	28	44
Lubbock Heart Hospital	TX	Jan-04	Private Cardiac	49	13	45
Nebraska Heart Hospital	NE	May-03	Private Cardiac	100	18	53
TexSAn Heart Hospital	TX	Jan-04	Private Cardiac	49	70	98
Avera Heart Hospital	SD	Mar-01	Partner Cardiac	33.3	25	60
Baylor Heart and Vascular	TX	Jun-02	Partner Cardiac	49	50	57
Fresno Heart Hospital	CA	Oct-03	Partner Cardiac	49	47	28
Indiana Heart Hospital	IN	Feb-03	Partner Cardiac	30	32	78
Oklahoma Heart Hospital	OK	Aug-02	Partner Cardiac	49	34	85
Saint Francis Heart Hospital	OK	Apr-04	Partner Cardiac	40	34	60
St. Vincent Heart Center	IN	Dec-02	Partner Cardiac	50	106	165
Tucson Heart Hospital	AZ	Oct-97	Partner Cardiac	21.2	52	59
Aurora BayCare	WI	Sep-01	Non-Specialized	40	73	161
Crestwood Medical Center	AL	1965	Non-Specialized	20	100	267
Harlingen Medical Center	TX	Oct-02	Non-Specialized	49	70	128
NEA Medical Center	AR	1976	Non-Specialized	40	53	123

Source: See Appendix B for description of dataset construction.

hospitals in my dataset are partnerships with nonprofit hospital systems. Hospitals partnered with non-profit community hospitals have aggregate physician shares of 21.2% to 50% split among 25 to 106 doctors. Other than physicians having at most a 50% ownership share, the overall distribution of ownership characteristics is similar for fully-private POHs and community hospital partners. The ratio of actual owners to potential owners is shifted slightly higher, ranging from 0.4 to 1 with an average of 73%.

My sample also includes four physician-owned hospitals which provide generalized care in addition to cardiac services.[30] They are quite different from physician-owned cardiac hospitals – although aggregate physician ownership is similar to nonprofit partner POHs (20-49%), there are generally more physician investors and the ratio of actual to potential owners for non-specialized POHs ranges from 37% to 55%.

Appendix Table C.1 displays the characteristics of the 299 sample hospitals in the 30 HRRs I identified with at least one physician-owned or cardiac specialty hospital.[31]

[30] These hospitals do not meet MedPAC's criteria for cardiac specialization, as described above.

[31] In the full 100% sample of Medicare admissions, the 8,705 hospitals submitting claims treated

13% of non-physician-owned general hospitals are government-owned; 22-30% of non-physician-owned hospitals are for-profit. 11-20% of non-physician-owned hospitals are teaching hospitals; no physician-owned hospitals are government-owned, nonprofit, or teaching hospitals. Both specialization and physician ownership are associated with a greater likelihood of adult cardiac surgery services, and with a lower likelihood of advanced scanning capabilities (e.g., CT scan, MRI, etc.) and emergency departments. Physician-owned and specialized hospitals are smaller, but tend to have more registered nurses per hospital bed and more cardiac intensive care beds.

Characteristics of my sample of 40,930 cardiac patients in POH market hospitals and 37,271 patients in specialized POH market hospitals are displayed in Appendix Table C.2. The average patient in my sample is a white man aged 75 years and comes from a relatively large, affluent, educated ZIP code. About 37% of patients have a primary diagnosis of coronary atherosclerosis. The most common included comorbidities are congestive heart failure and chronic pulmonary disease. 29% of sample patients are treated at a physician-owned hospital. Overall 90-day mortality in this sample of non-emergency patients is 6.3-6.4%, which is significantly lower than the 8.7% mortality rate among emergency cardiac Medicare admissions. The average distance between a patient's home and the hospital of treatment is 23 miles.

Table 2: Sample physician characteristics

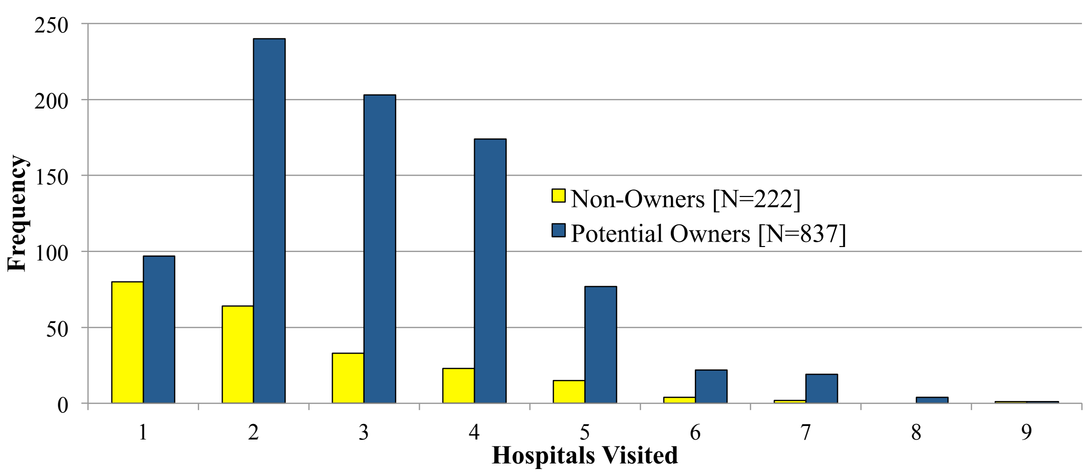
	Non-POH Physicians		POH, Non-Owners		Potential Owners	
	Mean	SD	Mean	Std. Dev.	Mean	Std. Dev.
Inpatient Admissions	117.774	115.892	147.234	131.409	158.870	122.585
Sample Admissions	8.705	15.404	11.027	22.297	22.655	27.545
N	2,368		222		837	

Notes: Sample physicians classified based on being non-owners never treating at POH, non-owners who treat at POHs, and potential owners. Sample admissions in POH markets only. Inpatient admissions counts include all admissions for which physician was listed in any physician identifier field. Sample admissions counts based on identifier of decision-making physician as described in Section 3.

an average of 1,277 patients in 1,582 inpatient encounters. Among the 5,573 hospitals treating non-emergency cardiac patients, claims were submitted for an average of 194 patients in 217 encounters in that category. In contrast, hospitals in my sample treated a far greater number of cardiac patients, submitting inpatient claims for 947 cardiac patients on average in 2005; 876 of those patients were treated by decision-making physicians classified as cardiac specialists. Further restrictions to non-disabled, non-HMO, non-emergency patients for whom the first facility of admission could be identified and who were treated in a market with a physician-owned or cardiac specialty hospital in 2005 leaves 65,594 patients treated in 30 markets including 299 hospitals capable of treating high-acuity patients.

Table 2 displays some statistics for sample physician treatment patterns. The average non-owner physician who did not admit patients at a local POH in my data was present on 118 inpatient admissions in 2005, compared to 147 inpatient admissions for non-owners who did admit at a local POH. In contrast, the average potential owner was present on 159 inpatient admissions. Among the non-emergency cardiac patients in my sample, non-owners were classified as the decision-making physician for 9-11 patients on average, the higher figure applying to non-owners treating patients at the local POH, while the average potential owner physician was the decision-making physician for 23 admitted patients. It is common for physicians to treat patients at more than one hospital in their market; Figure 1 is a histogram of the number of hospitals in which sample physicians treated admitted patients, focusing on physicians who ever treated patients at the local POH. Both non-owners and potential owners are more likely to see patients at multiple hospitals rather than at a single hospital, though the distribution is somewhat more skewed right for potential owners of POHs. This is consistent with my model of physicians choosing among multiple hospitals in their local market.

Figure 1: Patterns in physician treatment across multiple hospitals



Note: Hospital counts from all physician identifiers in 100% inpatient admissions file. Included physicians are those ever treating at a physician-owned hospital in 2005 based on link of 20% carrier file with 100% inpatient admissions file using patient identifier and date.

3.1 Mortality and choice patterns: descriptive evidence

In this Section, I provide some descriptive evidence regarding mortality and choice patterns in my sample of markets with physician-owned or specialty cardiac hospitals. Reduced form analysis of the data indicates the presence of optimal matching effects, in that some patients are relatively better-suited to treatment at physician-owned hospitals than others, and that cherry-picking behavior appears small at most. Table 3 displays

Table 3: Reduced form mortality effects ownership and specialization

	Demog Controls		Demog Controls Comorb Controls Primary Diag FEs		Demog Controls Comorb Controls DRG FEs	
HRR FEs	No	Yes	No	Yes	No	Yes
All POH/SSH Markets [N=65,588]						
Non-Phys. Owned SSH	-0.124^{***}	-0.093^{***}	-0.101^{***}	-0.078^{**}	-0.068^{**}	-0.041
	(0.029)	(0.033)	(0.031)	(0.036)	(0.031)	(0.036)
Phys. Owned	-0.149^{***}	-0.157^{***}	-0.109^{***}	-0.125^{***}	-0.090^{***}	-0.107^{***}
	(0.026)	(0.028)	(0.028)	(0.029)	(0.028)	(0.030)
All POH Markets [N=40,930]						
Phys. Owned	-0.139^{***}	-0.133^{***}	-0.109^{***}	-0.115^{***}	-0.086^{***}	-0.099^{***}
	(0.027)	(0.029)	(0.029)	(0.031)	(0.030)	(0.031)
All Cardiac POH Markets [N=37,271]						
Phys. Owned	-0.163^{***}	-0.153^{***}	-0.137^{***}	-0.132^{***}	-0.111^{***}	-0.108^{***}
	(0.029)	(0.030)	(0.031)	(0.032)	(0.031)	(0.032)

Notes: Huber-White robust standard errors in parentheses for specifications without HRR FEs. Specifications with HRR FEs have HRR-clustered standard errors.

the results of a probit regression of 90-day mortality on a dummy for treatment at a physician-owned and/or specialized hospital, separately for different sets of controls for patient characteristics. In the first pair of columns, included patient characteristics are demographics only: age, gender, race, and ZIP code demographics such as income, population, and the percentage of adults with a Bachelor's degree. In the second pair of columns, fixed effects for principal diagnosis and 16 dummies for comorbidities which are commonly used in the health literature, such as congestive heart failure, diabetes, and dementia are included as well.[32] In the third pair of columns, DRG fixed effects and comorbidities are included.[33] For each set of controls, estimates with and without

[32] Included comorbidities are the unweighted comorbidity illness components of the Charlson Index, an index shown to be strongly associated with mortality (Quan, et al., 2005). ICD-9 codes for Charlson index components from http://mchp-appserv.cpe.umanitoba.ca/viewConcept.php?conceptID=1098#a_references.

[33] DRG and procedure codes are in part based on the intensity of treatment chosen by the patient's physician and are thus directly endogenous. Diagnoses and comorbidities are assigned by physician and

HRR fixed effects are shown.

The most striking feature of this table is the significant reduced-form mortality improvement observed at physician-owned hospitals. The magnitude of the improvement decreases as richer controls are included, consistent with the observation that POHs treat an observably healthier patient population on average, but remains large and significant across all specifications. Notably, we see in the specifications including markets with non-physician-owned cardiac specialty hospitals that a mortality improvement is available at those facilities as well, which is generally not statistically different from the POH mortality effect. This fact indicates that the mortality improvement at POHs may be due to specialization rather than physician ownership itself. In markets containing only cardiac POHs and controlling for primary diagnoses, demographics, and comorbidities (the main specification used in this paper), expected mortality is 1.5pp lower for the average patient, which is large relative to sample mortality of 6.35%.

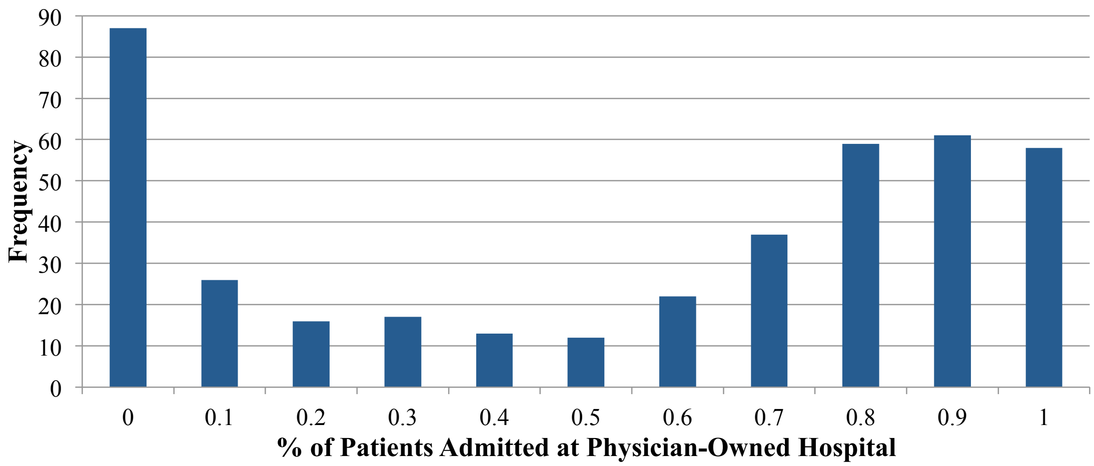
I also investigate the potential for optimal matching using a probit regression of 90-day mortality on all patient controls alone and interacted with a dummy for treatment at POH. Appendix Table C.3 displays the detailed results; the first two columns show the uninteracted estimates and the second two columns show the interactions. Predicted mortality risk for the baseline white, male, mean age patient with zero comorbidities and the modal primary diagnosis of coronary atherosclerosis is 1.8%. A one standard deviation increase in patient age (seven years) implies a 1.4pp increase in expected mortality risk. Among the more common patient comorbidities observed in the data, such as congestive heart failure and chronic pulmonary disease, the presence of such comorbidities increases mortality risk by 67-114%. Patients with primary diagnosis of acute myocardial infarction (AMI) have much higher predicted mortality, up to a factor of 10, than the baseline patient.

Treatment at a physician-owned hospital implies a decrease in mortality risk of about 0.3pp for the baseline patient, an effect size of 18% which is not quite statistically significant for this relatively healthy population. The interaction effects indicate some potential for optimal matching – there are some patient characteristics which alter

may be subject to bias as well as they are a subset of the inputs into the algorithm that determines DRG and thus reimbursement. E.g., if physician-owners "up-code" patient diagnoses/comorbidities in order to target a particular DRG and non-owners do not, mortality estimates could be biased.

the potential mortality effect of treatment at a POH. For example, patients with liver disease, renal disease, or malignancy jointly have significantly higher predicted mortality at physician-owned hospitals than at community hospitals. Treatment at a POH is more beneficial for most patients with more severe cardiac conditions than for the baseline patient. For example, patients with rheumatic heart failure, subendocardial infarct, and chronic systolic heart failure do significantly better at POHs. Most "optimal matching" coefficients are insignificant at this level of disaggregation.

Figure 2: Patterns in potential owner physician referral



Note: Patterns in potential owner physician referral of sample patients to physician-owned hospitals, 2005. Physicians treating fewer than 10 sample patients excluded. Only specialized physician-owned hospital markets included. N=408.

The above reduced form evidence indicates there may be scope for optimal matching of patients to physician-owned hospitals based on underlying health characteristics. There is also evidence of substantial variation across physicians in hospital choice patterns, which may provide evidence of the potential scope for cherry-picking or other differential physician-owner behavior. Figure 2 displays a histogram of the percentage of patients treated at a POH by physicians flagged as potential owners.[34] There is a large mass of physicians treating 70% or more of their patients at the local POH and another mass of physicians treating zero sample patients at the POH. This histogram implies that physicians usually either treat the majority of their patients at the POH or

[34]Potential owner physicians treating 10 or more sample patients are included.

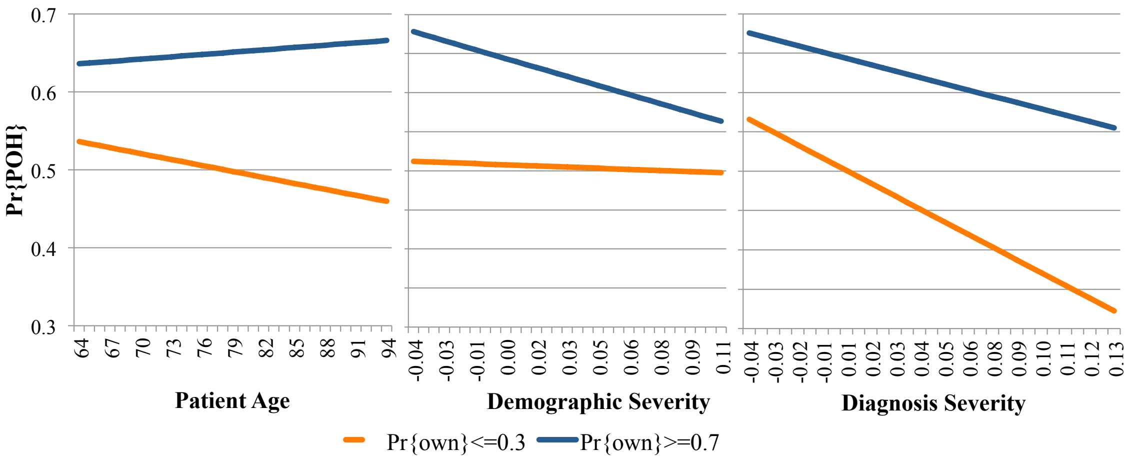
few patients at the POH. Neither behavior allows for a large degree of cherry-picking.

To examine how treatment behavior varies in patient characteristics, Figure 3 provides a coarse characterization of choice model in Section 2, based on a regression of the choice of physician-owned hospital on a sample of physicians who were either very likely (at least 70% probability based on the ratio of actual owners to potential owners) or very unlikely (30% probability or less) to be physician investors. I included in the regression both age and (de-meaned) indexes of patient sickness, one based on demographics and comorbidities and another based on primary diagnosis at admission,[35] alone and interacted with a dummy for likely ownership. As can be seen in the Figure, sample physicians who are not very likely to be owners (but are *potential* owners, and thus have been observed to treat patients at POHs) refer only about 50% of their patients to the local POH, and this probability is decreasing in both age and other patient sickness. In contrast, physicians who are very likely to be owners send more than 65% of their patients to the POH on average, and there is a mixed relationship between referral patterns and patient type – likely owners' referrals to the POH are increasing in patient age and decreasing in other patient sickness. One notable fact is that likely owners' referral slope is less steep for primary diagnosis and more steep for demographics and comorbidities.[36] Using mean probabilities of ownership across the two groups of physicians, Bayes' rule suggests that non-owners who are potential owners send 46% of their patients to POHs, while owners send 70% of their patients to POHs. These estimates do not account for differences in market size and composition across physician probability type (each of which will be factored into the joint model described in Section 2), but are suggestive that physician-owner cherry-picking, to the extent it exists once optimal matching and market characteristics are controlled for, will vary by type of illness characteristic. Indeed, we expect patient profitability to increase in some dimensions of severity, as Medicare reimbursement accounts for severity to some extent.

[35] The index is generated by running a probit of 90-day mortality on all patient demographics, primary diagnosis fixed effects, and comorbidities.

[36] Visible differences observed in the graphs between likely owner and likely non-owner behaviors are statistically significant at the 10% level.

Figure 3: Predicted probability of treatment at a POH: likely owners vs. likely non-owners



Note: Estimates from linear regression of POH treatment dummy on age and indexes of patient sickness excluding age, alone and interacted with dummy for high likelihood of ownership. Indexes of patient sickness generated using coefficient estimates from probit of 90-day mortality on patient demographics, comorbidities, and primary diagnosis fixed effects in full sample of non-emergency cardiac patients in 18 HRRs including specialty cardiac POHs. Physicians not flagged as potential owners excluded. Pr{own} defined as ratio of actual owners to potential owners. See Appendix for description of actual and potential ownership.

4 Joint Model Estimation

In the following Section, I estimate the full joint choice-outcome model using maximum likelihood. Each physician's choice set contains between 3 and 26 hospitals in the local market, as defined by HRR.

As noted in Section 2, the results of the basic joint model estimation may be inconsistent due to unobserved patient heterogeneity across hospitals. To account for this issue, I also perform a two-step estimation procedure using instrumental variables. In the first step, I use patients' distance to the nearest physician-owned hospital to instrument for treatment at a POH.[37] In the second step, I fix the mortality parameters in the joint choice-mortality model at the IV estimates obtained in the first step and allow for an unobserved shock to illness severity to impact both choice and mortality.[38] I integrate the likelihood of the joint choice-outcome probability over the assumed distribution of unobserved illness severity to obtain the expected likelihood of each observation; given

[37]The linear specification is used in all analyses; results are not sensitive to other specifications of the instrument such as log transformation, quadratic or cubic polynomials, or dummies for quantiles of distance.

[38]This additional illness heterogeneity is unobserved to the econometrician, but observed to the decision-maker in the choice model.

the assumption of a unidimensional normal for unobserved illness severity, I improve the speed of the integration by using Gauss-Hermite numerical quadrature.

The mortality model in my joint specification is a latent variable model with binary endogenous regressor (treatment at the POH), so I use the multivariate probit model to estimate the first step mortality model. Treatment at a POH is assumed to be a function of all included patient characteristics $\mathbf{X}_i$ and distance $dist_{i,PO}$ to the nearest POH, the latter of which is excluded from the mortality equation:

$$\begin{aligned} m_{ipj} &= 1\left[\alpha_1 + \mathbf{X}_i\beta_1 + d_{ij}^{PO}\nu + s_i > 0\right] \\ d_{ij}^{PO} &= 1\left[\alpha_2 + \mathbf{X_i}\beta_2 + dist_{i,PO}\delta_2 + u_i > 0\right]. \end{aligned}$$

Another distance measure, $dist_{i,hosp}$, the minimum distance from patient i to *any* hospital, is included in $\mathbf{X}_i$ in both equations (i.e., patients located far away from any hospital may be likely to die due to limited availability of care in an emergency situation).

See Angrist and Pischke (2008) for a discussion of this approach. The relevant exclusion restriction requires that the instrument, patients' distance to the nearest POH, is correlated with treatment at a POH, but uncorrelated with unobservable determinants of mortality. Distance to hospitals of different types is a commonly-used instrument in the literature on health care quality (see, e.g., McClellan and Newhouse (1997); Gowrisankaran and Town (1999)), and this restriction seems plausible given that the IV estimation includes a rich set of sickness characteristics including demographic variables that a hospital planning board would take into consideration; Section 6 explores this using pre-entry data and confirms that the exclusion restriction is reasonable.

Table 4 shows estimates of both two-stage least squares (2SLS) and multivariate probit models. The first stage estimates in the second set of columns indicate that distance is a strong negative predictor of treatment at a POH regardless of controls – patients located relatively far from POHs are significantly less likely to be treated at POHs. The reduced form effect of distance on 90-day mortality is shown in the third set of columns – there is a small, but significant, increase in mortality associated with distance from the nearest POH. Results are shown for several different controls – demographics only; demographics, primary diagnoses, and comorbodities; and demographics, DRGs, and comorbidities. The reduced form effect is similar across rows, implying that the IV estimates are unlikely to be contaminated by POH up-coding behavior.

Table 4: Mortality estimation – instrumenting with distance to nearest POH

	OLS		First Stage	Reduced Form	IV	
	Estimate	Marginal Effect	Estimate	Estimate	Estimate	Marginal Effect
Only Demographic Controls						
Linear	-0.018^{***}		-0.0023^{***}	0.0001^{***}	-0.051^{**}	
	(0.003)		(0.00005)	(0.00004)	(0.022)	
Probit	-0.163^{***}	-0.012	-0.0095^{***}	0.0009^{***}	-0.285^{***}	-0.019
	(0.029)		(0.00027)	(0.00030)	(0.073)	
Demographic, Comorbid, Diagnosis Controls						
Linear	-0.015^{***}		-0.0022^{***}	0.0001^{***}	-0.051^{**}	
	(0.003)		(0.00005)	(0.00004)	(0.022)	
Probit	-0.137^{***}	-0.010	-0.0097^{***}	0.0010^{***}	-0.211^{**}	-0.015
	(0.031)		(0.00028)	(0.00032)	(0.084)	
Demographic, Comorbid, DRG Controls						
Linear	-0.012^{***}		-0.0022^{***}	0.0001^{***}	-0.049^{**}	
	(0.003)		(0.00005)	(0.00004)	(0.022)	
Probit	-0.111^{***}	-0.009	-0.0098^{***}	0.0010^{***}	-0.306^{***}	-0.020
	(0.031)		(0.00028)	(0.00033)	(0.084)	

Notes: Instrument for treatment at POH was distance to nearest POH. Driving distance in miles. Linear IV performed using two-stage least squares. Nonlinear IV performed using multivariate probit with 50 simulation draws. Standard errors are Huber-White robust standard errors.

The IV results in all specifications are much less precise than the OLS results, as would be expected. The 2SLS point estimates are excessively large due to this imprecision but are not statistically different from the OLS results. The multivariate probit results indicate an association between POH treatment and an average decrease in mortality of about 1.5-2pp which is not statistically different from the probit results.

In the following Section, I describe the results of the joint model estimation. Estimation of the joint models becomes computationally difficult with the full set of patient characteristics, so I estimate specifications in which I collapse subsets of the patient characteristics into indices of patient sickness using the mortality parameters from the IV estimation results. This approach restricts the pattern of interaction effects across the patient characteristics included in each index, but allows me to illustrate how different types of patient characteristics influence hospital choice behavior both on average and varying with ownership. For the joint model with IV, only binary patient characteristics (quintiles of patient sickness) are included to characterize optimal matching and choice variation, as multivariate probit models can only handle binary regressors.

5 Empirical Results

In this Section, I discuss the results of estimation of my joint models. First, I show mortality and choice results for cardiac POH markets, which are the primary focus of my analysis, using two baseline characterizations of patient type, one continuous and one using quintiles of patient sickness. The estimation sample includes 37,271 patients in 18 markets. I then briefly discuss results of two alternative specifications, one including DRG fixed effects and DRG weight (which determines reimbursement) in order to examine potential cherry-picking based on more direct measures of profitability, and another including additional markets with non-specialized facilities in order to examine cherry-picking behavior at non-specialized POHs. The expanded sample includes 40,930 patients in 22 markets. The results are overall similar across baseline and alternative specification results, indicating there are quality improvements at physician-owned hospitals and no strong evidence of physician-owner cherry-picking.

5.1 Mortality results – base specifications

In this Section, I describe the mortality results of the two estimation approaches – with and without unobservable patient sickness – for the sample of patients treated in markets with cardiac POHs. I first show results for a specification using continuous measures of patient sickness, de-meaned patient age and sickness indexes for other demographic variables, cardiac comorbidities, non-cardiac comorbidities (e.g., end-stage renal disease), and primary diagnoses. Reduced form and IV estimates demonstrate a significant improvement in mortality risk at POHs; IV results do not reject the null of no omitted variables bias. I then show results where patient type is characterized by a set of dummy variables for each quintile of patient sickness, which allows for IV estimation of optimal matching parameters. These results suggest that POH quality is most evident among relatively lower severity patients. The preferred specification, model (2) of Table 5, shows a 90-day mortality improvement of 1.2pp at cardiac POHs.

Model (1) of Table 5 displays the mortality coefficient estimates from the joint model estimation assuming no unobservables, with patient age and sickness indexes entering the model alone and interacted with a dummy for treatment at a POH to allow for optimal matching on observables.[39] In this base specification, I also allow for treatment by a physician-investor to have an effect on mortality, and further allow for that effect to vary by hospital type in order to capture any potential firm specificity of physician performance.[40] The results of the first estimation shown in Table 5 imply a slight decrease in mortality for patients treated by physician investors, which is undone for patients treated at POHs. These effects could be consistent with a number of stories. For example, survey studies discussed in Section 1 indicated that POHs have higher amenities – if physician-owners divert attention to providing amenities at the POH when treating patients at the owned hospital, then this could diminish other dimensions of quality. These estimates are small and insignificant, so I omit the owner effects in subsequent specifications to focus on POH quality.

Model (2) displays the results of the same estimation, excluding the dummy for treatment by an owner. Model (3) displays the results of the IV estimation of the mortality model as a function of patient, hospital, and physician characteristics.[41] A Chi-squared test of the null hypothesis of no endogeneity of hospital choice with respect to mortality, conditional on observables, does not reject at the 10% level of significance.

The results of the mortality model are quite consistent across the two estimation approaches, implying similar effects for patient and non-ownership-related hospital characteristics to those described in the reduced form results in Section 3. Patient age and sickness are strong positive predictors of mortality (the latter by construction), and government and for-profit ownership are associated with an increase in patient mortality.

The estimates from the joint model without instruments in model (2) in Table 5 indicate that treatment in a physician-owned facility entails a 0.6pp reduction in mortality at baseline,[42] an effect which is large in relative terms (the baseline patient's mortality in a nonprofit hospital is predicted to be 2%). The estimated mortality improvement does

[39] Each sickness index was generated by applying the level coefficient estimates from the IV estimation to each patient characteristic included in the index. Coefficients on patient characteristics from the IV estimation are essentially identical to reduced form estimates.

[40] Huckman and Pisano (2006) found evidence that cardiac surgeon performance at a particular hospital was correlated with prior procedural volume at that hospital but not correlated with volume at other hospitals, suggesting that surgeon performance is not fully portable.

[41] In this specification, continuous patient characteristics are used, so no interactions with the POH dummy are estimated as the multivariate probit method allows only for binary endogenous regressors. IV results with interactions are discussed below for the sickness quintiles model.

[42] The sickness indexes are not de-meaned, so that the baseline patient has the modal primary diagnosis and no comorbidities.

Table 5: Mortality results – multiple sickness indexes specification, cardiac POH markets only

	Joint Model No IV (1)		Joint Model No IV (2)		Joint Model IV - Distance (3)	
	Coef.	SE	Coef.	SE	Coef.	SE
Constant	-2.05	(0.04)***	-2.05	(0.04)***	-2.01	(0.05)***
Age	0.03	(0.00)***	0.03	(0.00)***	0.03	(0.00)***
Demographics	0.76	(0.18)***	0.75	(0.18)***	1.00	–
Cardiac Comorbidity	1.01	(0.04)***	1.00	(0.04)***	1.00	–
Non-Cardiac Comorbidity	0.96	(0.02)***	0.96	(0.02)***	1.00	–
Primary Diagnosis	1.00	(0.02)***	1.00	(0.02)***	1.00	–
Government Hosp.	0.07	(0.04)	0.07	(0.05)	0.07	(0.05)
For-Profit Hosp.	0.09	(0.03)***	0.09	(0.03)***	0.09	(0.03)***
Teaching Hosp.	0.00	(0.05)	-0.01	(0.05)	0.00	(0.05)
RNs/Bed	-0.02	(0.02)	-0.02	(0.02)	-0.02	(0.02)
Dist. to Hosp.	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
POH	-0.23	(0.11)**	-0.14	(0.05)***	-0.33	(0.12)***
POH*Age	0.00	(0.00)	0.00	(0.00)		
POH*Demog.	0.57	(0.78)	0.57	(0.80)		
POH*Card.	0.01	(0.15)	0.01	(0.15)		
POH*Non-Card.	0.10	(0.12)	0.10	(0.12)		
POH*Diagnosis	-0.01	(0.07)	-0.01	(0.07)		
Owner	-0.06	(0.05)				
POH*Owner	0.15	(0.12)				

Notes: Mortality results for joint choice-outcome model. Columns (1) and (2) estimated without instrumental variables and without unobserved sickness in the choice model. Column (1) allows treatment by owner to impact mortality. Column (3) instruments for treatment at POH using distance to nearest POH and allows for unobserved sickness in the choice model. Sickness indexes generated using coefficients on patient characteristics from initial estimation of mortality model, separating demographic characteristics, cardiac comorbidities, non-cardiac comorbidities, and primary diagnoses. Standard errors from nonparametric bootstrap of entire two-step procedure, 200 repetitions. N=37,271.

not vary significantly with the included indexes of patient sickness. The coefficient that is largest relative to its standard error is the interaction with non-cardiac comorbidities, its positive sign indicating that patients who are more severely ill in non-cardiac dimensions benefit less from treatment at physician-owned hospitals. This effect is consistent with optimal matching; however, the estimated interactions are quite noisy.

The IV mortality results in the second column of Table 5 imply a larger, noisier quality effect of being treated at a physician-owned hospital – for the average patient, treatment at a POH is estimated to entail a 2.5pp lower mortality risk than treatment at a non-profit community hospital, the excluded hospital category in the mortality model. This effect is larger than the 1.2pp estimated quality effect for the average patient from the non-IV results, and, as we saw in Table 4 the imprecision of the IV estimate suggests that the point estimate is implausibly large. However, the IV estimate is not statistically different from the non-IV estimate, which echoes the finding that the null of no endogeneity of POH treatment was not rejected. Thus, the IV results reinforce the finding higher-quality care at physician-owned hospitals.

The continuous mortality specification considered above is illuminating as to the effect of physician ownership on quality of care for the average patient, but the IV approach had limited ability to characterize optimal matching to physician-owned hospitals due to its focus on binary endogenous regressors. To provide further evidence on the potential for optimal patient-hospital matching, I also estimated a specification in which patient characteristics were limited to sickness quintiles obtained from a probit of 90-day mortality on all available patient characteristics. This provides a set of binary regressors that can be interacted with treatment at the POH to provide evidence of optimal matching while accounting for endogenous hospital choice. The coefficients driving quintile assignment are similar to those found in Table C.3, with primary diagnoses and comorbidities accounting for much of the variation in mortality risk.[43]

Table 6 displays the mortality coefficient estimates from both joint model estimations (with and without IV), where quintiles of sickness enter the model alone and interacted with a dummy for treatment at the POH. The baseline patient in this model has low predicted mortality risk of approximately 0.8-0.9% in non-profit community hospitals. The coefficients on the dummies for other quintiles are sensible – patients in the higher quintiles have increasingly greater mortality risk. The highest quintile patients have an expected mortality rate of 19-20%, which is more than three times the average sample mortality rate.[44] Results for hospital characteristics are similar to both previous specifications and are omitted here for the sake of brevity.

As can be seen by comparing the two pairs of columns of Table 6, the use of the distance IV has a larger impact on the estimation of the effect of treatment at a POH

[43]The majority of patients in the lowest quintile have the modal primary diagnosis of coronary atherosclerosis (the excluded category in Table C.3), while nearly half of patients in the highest quintile have a primary diagnosis of subendocardial infarction or congestive heart failure, unspecified, two severe diagnoses which are common in my sample.

[44]The distribution of predicted latent mortality is heavy-tailed and skewed right; the standard deviation of the index of expected mortality among patients in the highest quintile is more than four times that of patients in the middle quintile.

Table 6: Mortality results – quintiles specification, cardiac POH markets only

	Joint Model No IV (1)		Joint Model IV - Distance (2)	
	Coef.	SE	Coef.	SE
Constant	-2.40	(0.07)***	-2.36	(0.07)***
Sickness Quintile 2	0.31	(0.08)***	0.26	(0.09)***
Sickness Quintile 3	0.63	(0.07)***	0.56	(0.08)***
Sickness Quintile 4	0.97	(0.07)***	0.90	(0.07)***
Sickness Quintile 5	1.56	(0.06)***	1.49	(0.07)***
POH*Sickness Quintile 1	-0.03	(0.12)	-0.42	(0.27)
POH*Sickness Quintile 2	-0.12	(0.10)	-0.08	(0.27)
POH*Sickness Quintile 3	-0.21	(0.08)**	0.05	(0.21)
POH*Sickness Quintile 4	-0.15	(0.06)**	0.00	(0.18)
POH*Sickness Quintile 5	-0.16	(0.05)***	-0.02	(0.16)

Notes: Mortality results for joint choice-outcome model. Column (1) estimated without instrumental variables and without unobserved sickness in the choice model. Column (2) instruments for treatment at POH using distance to nearest POH and allows for unobserved sickness in the choice model. Results for general hospital characteristics suppressed for brevity. Sickness quintiles generated as quintiles of overall index of patient sickness from initial estimation of mortality model. Standard errors from nonparametric bootstrap of entire two-step procedure, 200 repetitions. N=37,271.

across quintiles of sickness than on the estimated effect for the average patient. The mortality effect of treatment at a POH appears to be nonlinear in patient sickness in the non-IV specification, with the point estimate and relative effect of treatment at a POH largest for patients in the middle quintile of sickness. The effect for this group is a decrease in mortality risk of 1.4pp. In contrast, the estimated effect of treatment at a POH is substantially noisier in the IV specification, and is largest for lower quintiles of sickness – the effect of treatment at a POH is jointly significant at the 5% level among first and second quintile patients but is not individually significant for any group alone. The discrepancy between the two models (with and without IV) is likely driven by POHs treating observably healthier patients within each quintile of sickness, leading to larger estimated effects in the non-IV model, particularly in higher-severity quintiles with larger variation in mortality risk within group.

Taken together, these results suggest that the average mortality result in the previous joint model specifications were primarily driven by quality improvements for low- to moderate-severity cardiac patients. These results are consistent with optimal matching of relatively lower severity patients to POHs; however, standard errors are such that I cannot rank the mortality improvement across groups.

5.2 Choice results – base specifications

Next, I turn to the choice results from the base specifications with and without unobservables. The results indicate that owner physicians prefer to treat the majority of their patients at the physician-owned hospital, and that physician-owner preferences over measures of patient sickness do not diverge substantially from those of non-owners. This is not suggestive of a model of physician-owner cherry-picking of healthier patients. Moreover, estimates on the measure of per-physician ownership share do not suggest that a greater financial stake leads to greater cherry-picking behavior. Finally, the estimated coefficients on unobserved sickness indicate that non-owners, rather than owners, are sending patients with greater unobserved sickness away from POHs, while physician-owners appear to exhibit countervailing behavior, so that on balance there is no substantial selection on unobservables biasing reduced form mortality coefficients. Decomposition of the favorable patient selection observed at POHs into its contributing parts suggests that physician owner behavior has little effect; even the extreme of a 95% confidence interval on owner behavior accounts for less than 30% of the observed differential in the patient population across hospitals.

Models (1) and (2) in Table 7 display the choice coefficient estimates from the joint model estimation using age and indexes of patient sickness characteristics. Model (1) displays the results of the joint model without unobservables; model (2) displays the results fixing mortality parameters at their IV estimates and estimating the choice model allowing for selection on unobservable patient sickness. In each column, we see average preferences over general hospital characteristics, non-owner physician preferences for treating at the physician-owned hospital, differential preferences of owners for treating at the physician-owned hospital, and the effect of ownership share on preferences for treating at one's own hospital.[45] Average preferences of non-owners for treating patients at the POH are separated by whether physicians were flagged as potential owners to account for the mechanical effect of potential owner status on average preferences.

[45] The coefficient on expected latent mortality in the choice equation has been normalized to equal -1, as all terms in the mortality equation also enter linearly into the choice equation and this allows us to interpret the magnitudes of the choice parameters.

Consider the results of model (1), the results of the joint choice-mortality model estimation allowing for optimal matching on continuous patient characteristics (age and sickness indexes) and differential selection by ownership status, but assuming no selection on unobserved patient health. The coefficient on a dummy for a hospital being physician-owned (denoted POH and $POH * PotentialOwner$ for non-potentials and potentials, respectively, in the table), alone and interacted with patient characteristics, represents the preferences of non-owners for treating patients at the local POH, after accounting for the effect of POH treatment on predicted mortality. First, there is a significant negative preference among non-owners for treating patients at the local POH – looking across all sample markets, the average predicted probability of being sent to a POH by a non-owning physician flagged as a potential owner (who by definition considers the POH as part of his or her choice set) is only 13.3%. The coefficients on POH interacted with patient characteristics indicate that non-owners are more likely to treat older patients and patients with greater comorbidities at a community hospital. For example, a standard deviation increase in age or non-cardiac comorbidities implies a 1.8-3pp decrease in the likelihood of treatment at a POH among non-owners. The estimates indicate that non-owners have a preference to treat patients with unfavorable demographics and primary diagnoses at POHs, so that on balance these estimates indicate a slight overall preference, after controlling for optimal matching, among non-owners for treating sicker patients at community hospitals rather than physician-owned hospitals. It should be noted that these baseline preferences may capture the sum of non-owner physician preferences and average patient preferences – e.g., older patients and patients with non-cardiac comorbidities may seek out the general-service environment at a community hospital even beyond what can be accounted for by expected mortality differences across hospitals.

The next six rows of the table tell a somewhat different story. Physician-owners have a strong preference for treating patients at their owned facility. There is a statistically significant coefficient of 4.3 on a dummy for physician owner interacted with a dummy for POH, which represents the differential preference of owners relative to non-owners. Adding in the coefficients that capture baseline preferences for POHs, this estimate indicates that the average predicted probability of a physician-owner sending a patient

Table 7: Choice results – index and quintiles specifications, cardiac POH markets only

Continuous Indexes Specification – Joint Model					Sickness Quintiles Specification – Joint Model				
	No IV; No Unobs. Sickness (1)		IV - Distance Unobs. Sickness (2)			No IV; No Unobs. Sickness (3)		IV - Distance Unobs. Sickness (4)	
	Coef.	SE	Coef.	SE		Coef.	SE	Coef.	SE
POH	-3.30	(0.33)***	-3.53	(0.41)***	POH	-3.23	(0.33)***	-3.91	(0.81)***
POH*Potential Owner	2.74	(0.44)***	2.78	(0.36)***	POH*Potential Owner	2.87	(0.39)***	2.94	(0.51)***
POH*Age	-0.03	(0.01)***	-0.03	(0.01)***	POH*Quintile 2	-0.01	(0.21)	0.36	(0.49)
POH*Demog. Index	6.10	(2.06)***	6.07	(2.37)**	POH*Quintile 3	-0.17	(0.23)	0.48	(0.38)
POH*Card. Comorb. Index	-0.20	(0.41)	-0.07	(0.42)	POH*Quintile 4	-0.08	(0.22)	0.48	(0.42)
POH*Non-Card. Comorb. Index	-0.65	(0.32)**	-0.64	(0.39)*	POH*Quintile 5	-0.43	(0.23)*	0.17	(0.40)
POH*Primary Diag. Index	0.18	(0.21)	0.46	(0.20)**					
POH*Unobserved Sickness			-0.27	(0.40)	POH*Unobserved Sickness			-0.79	(0.73)
POH*Owner	4.34	(0.31)***	5.14	(0.40)***	POH*Owner	4.50	(0.33)***	5.70	(0.59)***
POH*Owner*Age	0.02	(0.01)*	0.03	(0.02)*	POH*Owner*Quintile 2	-0.37	(0.25)	-0.32	(0.37)
POH*Owner*Demog. Index	-1.63	(3.30)	-3.02	(4.67)	POH*Owner*Quintile 3	-0.51	(0.27)*	-0.67	(0.36)*
POH*Owner*Card. Comorb. Index	0.14	(0.67)	-0.64	(0.77)	POH*Owner*Quintile 4	-0.24	(0.29)	-0.18	(0.43)
POH*Owner*Non-Card. Comorb. Index	0.00	(0.47)	-0.85	(0.75)	POH*Owner*Quintile 5	0.03	(0.33)	-0.06	(0.46)
POH*Owner*Primary Diag. Index	0.06	(0.36)	-0.26	(0.40)					
POH*Owner*Unobserved Sickness			1.96	(0.54)***	POH*Owner*Unobserved			2.83	(0.84)***
Share	-0.10	(0.13)	-0.02	(0.19)	Share	-0.21	(0.11)**	-0.04	(0.24)
Share*Age	0.00	(0.01)	-0.01	(0.01)	Share*Quintile 2	0.10	(0.12)	0.16	(0.20)
Share*Demog. Index	0.74	(1.37)	0.64	(2.85)	Share*Quintile 3	0.24	(0.11)**	0.33	(0.18)*
Share*Card. Comorb. Index	0.10	(0.37)	0.30	(0.37)	Share*Quintile 4	0.08	(0.12)	-0.04	(0.23)
Share*Non-Card. Comorb. Index	0.18	(0.17)	0.35	(0.29)	Share*Quintile 5	0.10	(0.16)	0.02	(0.23)
Share*Primary Diag. Index	-0.18	(0.18)	-0.31	(0.25)					
Share*Unobserved Sickness			0.29	(0.16)*	Share*Unobserved Sickness			0.39	(0.20)**
Distance	-1.42	(0.03)***	-1.52	(0.04)***	Distance	-1.42	(0.04)***	-1.53	(0.04)***
Government	-1.37	(0.13)***	-1.40	(0.14)***	Government	-1.37	(0.14)***	-1.39	(0.14)***
For-Profit	-0.53	(0.08)***	-0.56	(0.09)***	For-Profit	-0.53	(0.09)***	-0.56	(0.10)***
Teaching	0.30	(0.11)***	0.35	(0.12)***	Teaching	0.28	(0.13)**	0.35	(0.12)***
RNs/Bed	0.24	(0.08)***	0.19	(0.09)**	RNs/Bed	0.24	(0.09)***	0.18	(0.08)**

Notes: Choice results for joint choice-outcome model without unobservables and joint choice-outcome model with mortality parameters on observables fixed at their IV estimates. Sickness indexes generated using coefficients from initial estimation of mortality model, separating demographic characteristics, cardiac comorbidities, non-cardiac comorbidities, and primary diagnoses. Sickness quintiles generated as quintiles of overall index of patient sickness from initial estimation of mortality model. Standard errors from nonparametric bootstrap of entire two-step procedure, 200 repetitions. N=37,271.

of average health to their owned hospital is 82%. Selection behavior is surely variable across physicians and markets, but this estimate is similar to the 88% POH market share observed for Oklahoma Heart Hospital physician-owners in this sample.[46] Patient age, cardiac comorbidity index, and primary diagnosis index each have a positive, noisy effect on owner preferences over hospitals. None of these effects suggest a significant preference of owners to treat healthier patients at the POH. Moreover, the standard errors on the estimates are sufficiently small that the finding of no effect is meaningful. For example, I find a noisy negative effect of unfavorable demographics and small positive effects of cardiac comorbidity, non-cardiac comorbidity, and primary diagnosis on differential referrals to the owned POH by owners; however, even at the bottom ends of the 95% confidence intervals for the estimated effects, a standard deviation increase in any characteristic implies only a 2.2-4.9pp decrease in the POH referral probability. These "most extreme" effect sizes are still small in both absolute and relative terms, and do not suggest strong evidence of physician-owner cherry-picking.

Per-physician ownership share directly affects the reimbursement a physician can expect for a given patient, so the final six estimates in the model (1) examine the effect of increasing estimated per-physician ownership share on average preferences as well as cherry-picking behavior. The point estimate on average per-physician ownership share, which ranges from 0.2 - 5.3%, is essentially zero in this specification, indicating that physician-owners with greater ownership shares do not have more or less of a home-base preference than owners with lower than average ownership shares. This estimate may provide evidence that ownership *per se* drives physician choice patterns much more than a physician's actual financial stake in the hospital. There is no significant evidence in this model of physician stake driving cherry-picking behavior, either. The interactions between ownership share and patient characteristics exhibit no clear pattern with regard to greater physician share and patient sickness altering preferences.

Model (2) of Table 7 displays the estimates of the choice model holding mortality parameters fixed at their IV estimates and allowing for selection across POHs and community hospitals based on unobservable patient sickness. The estimated choice coefficients regarding preferences of owners and non-owners for the POH on average and

[46] Oklahoma Heart Hospital is the single cardiac POH for which individual owner data has been obtained; see Appendix B for details.

varying with observable characteristics are not statistically different from the estimates in the model (1), except that the joint model with IV predicts a slightly higher baseline preference of owners for treating patients at the POH.

Specification (2) of Table 7 also includes estimates of how owner and non-owner preferences across hospitals vary with unobserved patient sickness. The coefficient on the POH indicator interacted with unobserved patient sickness is negative for non-owners and positive for owners (the latter effect is reinforced for larger ownership share, though the share effect is only marginally significant). These results are consistent with non-owners generally sending sicker patients to the community hospital, though the countervailing effect of physician-owner preferences is consistent with there being no selection of unobservably healthy patients into POHs on balance – recall that I did not reject the null hypothesis of no endogeneity of treatment at a POH.

Looking across the remaining rows in the table, it appears that physicians have strong preferences over general hospital characteristics aside from their effects on mortality. The coefficient on distance is negative and precise. A standard deviation increase in driving distance (29 miles) to the chosen hospital decreases the choice probability by 11.3pp for that hospital, all else equal. In my sample of patients in cardiac POH markets, there is a significantly negative preference for government and non-physician-owned for-profits, and a significant positive preference for teaching hospitals and greater RNs per bed, above and beyond the effects of those characteristics on mortality.

Models (3) and (4) of Table 7 displays the choice coefficient estimates from the joint model estimations using sickness quintiles as a stand-in for patient characteristics. Consider first the estimates in model (3). Overall, the results for non-owner preferences exhibit a similar pattern to those in the previous specification – non-owners overall prefer not to treat at the POH, and greater observable patient sickness decreases their preference for the owned facility. The latter preferences are only significant for the highest quintile of sickness and entail small changes overall – a patient in the highest quintile of sickness is about 2.2pp less likely to be treated by a non-owner at a POH than a patient in the lowest quintile, all else equal.

Model (3) shows a similar pattern to the previous specification regarding owners' average preferences and selection of patients across hospitals based on sickness. Owners are very likely to send all patients to the owned hospital, and there is not a clear pattern of owner preferences varying in patient sickness characteristics that would be expected in a model of cherry-picking. Several of the point estimates on the POH*Owner interactions are negative, but the estimates show countervailing effects for ownership share. The average share for a potential owner is 0.92%, so these estimates show, for the average owner, a slight negative preference (coefficient of -0.17 to -0.29) for treating second-fourth quintile patients at the POH, and a small positive preference (coefficient of 0.13) for treating the sickest patients at the POH. Given the substantial increase in severity between quintiles four and five, on balance physician-owner preferences do not alter the patient severity at POHs in these results.[47] The results of model (4) are substantially noisier than (3) but not statistically different regarding preferences of owners and non-owners over patient characteristics. As in model (2), model (4) shows that unobservably sick patients are selected by non-owners away from the POH and that there is a countervailing effect for patients of owner physicians.

To understand the implications of these results, I performed the following decomposition exercise. Holding physicians' average preferences over hospital characteristics fixed, I set all variation with patient characteristics to zero, then added them back in to see how the predicted patient population across POHs and non-POHs differed.[48] Setting all patient characteristic choice preferences to zero, latent mortality at POHs would be -0.048 lower than at competitor hospitals (implying a mortality differential of 0.4pp). Optimal matching is expected to have a tiny effect; matching based on age and diagnosis (negative interactions in Table 6) decreases this differential by 0.0007, while matching based on demographics and comorbidities increases the differential by 0.0012. Preferences of non-owners' patients have a large, significant effect, increasing the patient population differential by 0.0178 as sicker patients tend to prefer community hospitals at baseline. Finally, physician-owner behavior is expected to *decrease* favorable selection at POHs on balance. Physician-owner preference parameters are noisy, but the lower bound of a 95% confidence interval accounts for less than one-third of the total patient sickness differential across facilities (-0.065 mortality index, or -0.5pp mortality risk).

[47] These estimates imply that the expected sickness index at POHs decreases by 0.004, from a mean of -1.7, based on differential physician-owner preferences over patient characteristics.

[48] I used the preferred specification results in model (1) of Table 7

5.3 Alternative specifications

In this Section, I estimate two alternative specifications in order to further explore the patterns found in the baseline estimation results.

First, columns (1) and (3) of Table 8 show the results of expanding the estimation to include all markets, including those with non-specialized POHs providing intensive cardiac care. Non-specialized POHs differ in at least two dimensions. First, they provide more general medical and surgical care than cardiac hospitals. I found in Section 3 that non-physician-owned cardiac hospitals provide comparable care to the cardiac POHs in my main sample; to the extent that specialization rather than integration is the source of quality improvements, we may expect to see mortality improvements dampened in the expanded sample. Second, ownership in non-cardiac POHs is shared by more physicians, so that referral patterns of owners may differ materially from cardiac POH owners. Previous results indicated no omitted variables bias with a coarser set of controls, so IV results allowing for unobservables are suppressed in this Section.

Column (1) of Table 8 displays the mortality estimates from the continuous index joint model estimation assuming no unobservables. The mortality results on patient and non-ownership hospital characteristics are nearly identical to the results from the restricted sample (see column (2) of Table 5). Again, there is a large and significant mortality improvement at POHs, which does not vary significantly with patient characteristics. The additional sample size in the four non-specialized POH markets is small, but the results do not suggest that results for POHs generally are significantly different than results for specialized POHs. Column (3) shows that inclusion of the expanded sample similarly does not change the choice estimates significantly – we see a large home base preference of owners, with little evidence of cherry-picking behavior.

Second, the results thus far demonstrated that physician-owners' preference for treating at POHs is not substantially affected by greater patient sickness, but did not consider how preferences vary with reimbursement, which also affects patient profitability; in order to explore the determinants of cherry-picking behavior more closely, I also estimated a specification including an index based on DRG fixed effects as well as the DRG "weight" that determines reimbursement.[49] This modification allows me to explore the

[49]Medicare classifies inpatient treatment into diagnosis-related groups and reimburses hospitals a fixed

effect of patient reimbursement on hospital choice, holding fixed expected sickness.

Column (2) of Table 8 displays the mortality estimates.[50] Average quality effects are quite similar to the base specification in Table 5. Mean expected mortality risk of 3.94% is reduced by 0.8% for the average patient treated in a POH. As before, no statistically significant matching effects are detected using these indexes of patient sickness.

Column (4) of Table 8 displays the choice coefficient estimates with DRG controls. As in the base model, non-owners have a negative preference for treating patients at the POH and tend to send sicker patients away from POHs, and the magnitudes of the effects are similar to the base model.

As before, owners have a strong positive preference for treating at the owned facility, and the differential preferences of owner physicians exhibit a similar pattern to that seen in previous specifications with respect to age, demographics and comorbidities. The effect of DRG severity on choice is stronger than that of primary diagnosis severity on choice for owners; owners appear to be more likely than non-owners to treat patients in more severe DRGs and with lower DRG weights in POHs, but the differences are not statistically significant. The estimates of how physician preferences vary in ownership share are again for the most part zeros or sufficiently noisy to be uninformative.

This alternative specification was intended to examine whether including DRG weight (a proxy for patient reimbursement), while controlling for DRG sickness, would provide evidence of cherry-picking not seen in the previous specifications, which just controlled for sickness. There is no evidence of such behavior using these controls. On the contrary, the effects tend to go in the opposite direction. DRG assignment is likely to be endogenous to physician treatment behavior (moreso than simple diagnosis) and DRG weights are not direct measures of profitability, so I will not interpret these effects as evidence of physician-owner altruism. However, they do provide further evidence that physician-owners are not cherry-picking based on patient characteristics.

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fee for each DRG. Each DRG has a payment "weight" assigned to it, based on the average resources used to treat Medicare patients in that DRG. Subject to some adjustments for local wages, disproportionate share of low-income patients treated, and teaching status, the DRG weight is a multiple of the payment a hospital receives for a given admission. DRG is partly a choice, as physicians may prefer to treat patients more intensively – for this reason, primary diagnosis rather than DRG was used in the main specification.

[50] In this specification, the baseline patient is in DRG 527 (percutaneous cardiovascular procedure with drug-eluting stent). The coefficients on DRG index in Table 8 are expressed in standard deviations of the index, as the index is heavier-tailed than the other indexes used in these analyses.

Table 8: Alternative specification results – all markets and DRGs

Mortality Results				
	All Markets Base Spec. (1)		Cardiac Markets DRG Spec. (2)	
	Coef.	SE	Coef.	SE
Constant	-2.07	(0.04)***	-2.63	(0.08)***
Age	0.03	(0.00)***	0.03	(0.00)***
Demog. Index	0.86	(0.18)***	0.75	(0.15)***
Card. Comorb. Index	1.01	(0.03)***	0.97	(0.03)***
Non-Card. Comorb. Index	0.96	(0.02)***	0.97	(0.03)***
Primary Diag./DRG	1.00	(0.02)***	2.16	(0.16)***
DRG Weight			-1.21	(0.10)***
Government	0.06	(0.04)	0.05	(0.05)
For-Profit	0.09	(0.03)***	0.09	(0.03)***
Teaching	0.00	(0.06)	0.00	(0.05)
RNs/Bed	-0.02	(0.02)	-0.02	(0.02)
Dist. to Hosp.	0.00	(0.00)	0.00	(0.00)**
POH	-0.12	(0.05)**	-0.10	(0.07)
POH*Age	0.00	(0.00)	0.00	(0.00)
POH*Demog.	0.33	(0.76)	0.67	(0.62)
POH*Card.	-0.01	(0.14)	0.12	(0.14)
POH*Non-Card.	0.12	(0.12)	0.10	(0.14)
POH*Primary Diag./DRG	-0.01	(0.07)	-0.05	(0.16)
DRG Weight			0.03	(0.09)

Choice Results				
	All Markets Base Spec. (3)		Cardiac Markets DRG Spec. (4)	
	Coef.	SE	Coef.	SE
POH	-3.35	(0.32)***	-3.31	(0.41)***
POH*Potential Owner	1.53	(0.41)***	2.74	(0.40)***
POH*Age	-0.02	(0.01)**	-0.02	(0.01)**
POH*Demog. Index	9.36	(2.64)***	7.00	(1.83)***
POH*Card. Comorb. Index	-0.41	(0.40)	-0.31	(0.40)
POH*Non-Card. Comorb. Index	-0.61	(0.34)*	-0.57	(0.34)*
POH*Primary Diag./DRG	0.14	(0.19)	0.16	(0.53)
POH*DRG Weight			0.09	(0.30)
POH*Owner	5.50	(0.36)***	4.22	(0.43)***
POH*Owner*Age	0.02	(0.01)	0.01	(0.01)
POH*Owner*Demog. Index	-3.93	(3.11)	-3.66	(2.44)
POH*Owner*Card. Comorb.	0.42	(0.55)	0.37	(0.67)
POH*Owner*Non-Card. Comorb.	-0.09	(0.45)	-0.35	(0.50)
POH*Owner*Primary Diag./DRG	0.10	(0.34)	0.52	(0.71)
POH*Owner*DRG Weight			-0.48	(0.40)
Share	-0.12	(0.12)	-0.04	(0.17)
Share*Age	0.00	(0.01)	0.00	(0.01)
Share*Demog. Index	0.16	(1.30)	1.04	(1.15)
Share*Card. Comorb.	0.09	(0.26)	0.05	(0.28)
Share*Non-Card. Comorb.	0.22	(0.14)	0.24	(0.18)
Share*Primary Diag./DRG	-0.16	(0.19)	-0.19	(0.36)
Share*DRG Weight			0.09	(0.19)

Notes: Results (1) and (3) expand sample to include non-specialized POHs (N=40,930); (2) and (4) uses DRG dummies rather than primary diagnosis dummies and adds DRG weight to the mortality and choice models (N=37,271). Sickness indexes generated using coefficients on patient characteristics from initial estimation of mortality model, separating demographic characteristics, cardiac comorbidities, non-cardiac comorbidities, primary diagnoses, and DRGs. Standard errors from nonparametric bootstrap of entire two-step procedure, 200 repetitions. The choice results on general hospital characteristics and distance are similar to the base model and are omitted.

6 Robustness

My approach relies on several assumptions regarding the distribution of unobserved patient illness severity; further, I use a probabilistic method to distinguish the behavior of owners from non-owners. I now examine the validity of these approaches.

6.1 Distribution of unobservable patient sickness across physicians

Because patient characteristics may not be perfectly observed, my choice-outcome analysis takes a structural approach to dealing with unobserved illness severity. I assume that unobserved patient sickness is normally distributed and independent of patient observable characteristics and physician type. If physician-owners attract an unobservably different patient population, my results for cherry-picking on unobservables would be biased. In order to explore this issue, I examine whether ownership variables are correlated with 1) unexplained patient mortality prior to POH entry; or 2) changes in observed patient severity upon POH entry. This allows me to explore the extent to which unobserved severity is likely to differ across owners and non-owners post-entry. To that end, I constructed a panel of inpatient cardiac admissions for 2000-2005 in exactly the same manner as described in Section 3, but selecting only the admissions for physicians appearing in my 2005 sample. The full panel in markets with pre-entry data includes 177,356 patients treated by 2,246 physicians at 141 hospitals.

First, I ran a regression for the pre-entry period ($N = 61,327$) of 90-day mortality on the usual patient and hospital controls, plus some proxies for physician ownership:

$$m_{ipt} = \alpha + \mathbf{X}_{it}\beta + \mathbf{Z}_j\delta + \mu OwnerVar_p + e_{ipt}$$

I used three different proxy variables: the probability that the physician is an owner, an index equalling the probability of ownership times aggregate physician ownership share, and a dummy for potential owners. The first row of Table 9 shows that there is no detectable relationship between ownership and unaccounted-for mortality risk ($\hat{\mu}^{Pr\{own\}} = 0.0028$, $\hat{\mu}^{Index} = -0.00028$ and $\hat{\mu}^{potential} = 0.00075$, respectively).[51]

[51] Results displayed are for linear regression of mortality on included characteristics; probit regression results were similarly small and insignificant. If physician-owner quality effects and unobserved patient type have countervailing effects on mortality, e.g., if physician-owners treat sicker patients but provide higher-quality care, then this specification would not detect differences in patient population in the pre-period.

Table 9: Robustness check for association between patient sickness and physician ownership

	Pre-Entry			DD Interaction		
LHS Variable	Pr{own}	Own Index	Pot. Owner	Pr{own}	Own Index	Pot. Owner
90-Day Mortality	0.003	−0.000	0.001			
	(0.002)	(0.001)	(0.001)			
Mortality Index	-0.017^{***}	-0.009^{***}	-0.012^{***}	0.000	−0.002	0.001
	(0.001)	(0.001)	(0.000)	(0.001)	(0.002)	(0.001)
N	61,327	61,327	61,327	177,356	177,356	177,356

Notes: First three columns display estimated coefficients from pre-entry regressions of left-hand-side variables on three proxies for ownership. Second three columns display interaction term estimates from differences-in-differences regressions of observables on a dummy for post-entry period, alone and interacted with three proxies for ownership. Standard errors clustered by year in parentheses.

Physician owners and non-owners did not have unobservably different patient populations prior to POH entry, but it may be the case that entry induced a change in referral patterns to owners. To examine this possibility, I ran a regression of patient illness (captured by an index of latent mortality $\hat{m}$ estimated in a first step regression of mortality on all patient characteristics) separately on each proxy for potential ownership, an indicator for the period after POH entry, and an interaction between the ownership proxy and the post-entry dummy, on the full panel of 177,356 patients:

$$\hat{m}_{it} = \alpha + \mu_1 OwnerVar_p + \mu_2 AfterEntry_{it} + \mu_3 OwnerVar_p * AfterEntry_{it} + u_{ipt}$$

where $\hat{m}_{ipt}$ is the index of latent mortality.[52] In the second row of Table 9, the right three columns show at most a small and insignificant negative effect of POH entry on the relationship between ownership and observable patient sickness.

The association between observable sickness and ownership appears to be much larger in magnitude than that between unobserved sickness and ownership in the pre-entry period; the lower-left results in Table 9 show that the association between eventual physician ownership and the sickness index is small but significantly negative (one-fifth of a standard deviation in the most extreme case, $\hat{\mu}^{Pr\{own\}}$). These results are an order of magnitude larger than the results for unexplained illness in the top row, so that the lack of an association between POH entry and favorable selection by owners implies that the the effect of ownership on unobserved sickness upon entry is likely to be similarly

[52]Since POH entry affects the quality of treatment, I cannot use mortality to examine unexplained patient illness; instead I focus on *observed* patient illness here and speculate about the implied association for unobserved illness.

small and insignificant.

6.2 Relationship between unobserved sickness and POH entry

Using panel data, I also examine the relationship between unobserved patient type and POH entry. I perform this check for two reasons. First, in my choice model, I assume that per-physician ownership shares are not endogenous with respect to unobserved patient type. Second, my instrumental variables approach requires that the distance instrument not be correlated with mortality except through its effect on hospital choice.

If physician-owned hospitals enter with different per-physician ownership shares as a function of unobservable patient health (e.g., if POHs enter with a larger per-physician ownership share in areas with unobservably healthier patients), then my estimates on each term with ownership share in the choice equation may be biased. To examine this association, I perform a similar exercise as in the above and regress mortality on all patient characteristics and eventual physician ownership share:

$$m_{it} = \alpha + X_{it}\beta + \mu\tau_i + e_{it}$$

where τ_i is the maximum physician ownership share as of 2005 in patient i's market. The estimate is $\hat{\mu} = -9.60e^{-06}$ – there is no evidence of a problematic association.

Second, my instrumental variables strategy assumes that the excluded instrument, distance from the patient to the nearest POH, is not correlated with the outcome of interest, 90-day mortality, except through the endogenous variable, treatment at the POH. Distance to hospital is commonly used in the literature on hospital quality (see, e.g., McClellan and Newhouse (1997); Gowrisankaran and Town (1999)), but this instrument may be suspect for this application as POHs are relatively new and may have entered in areas close to unobservably healthy patients. To explore this relationship, I regressed 90-day mortality on all patient and hospital characteristics and distance to the eventual site of the nearest physician-owned hospital, using only pre-entry data. The coefficient on distance to the site of the nearest POH is -0.000251 and has a standard error of 0.0003978. Patients located relatively far away from the eventual site of the nearest POH had no difference in mortality outcomes, conditional on observables.

6.3 Ownership data and identification of potential physician-owners

Finally, I explore robustness of my use of ownership data. This study uses self-collected data on physician ownership from mostly public sources, and one may be concerned that these data are reported with error. I also employ a probabilistic approach to identification of the treatment patterns of physician-owners relative to non-owners, which assumes that all physicians filing claims on at least two admissions at POHs in 2005 are equally likely to be physician-owners. This has the advantage of not privileging procedure-based specialists such as interventional cardiologists and cardiac surgeons in the assignment of ownership. However, it may be too restrictive. To examine the sensitivity of my results to each of these factors, I present results of two analyses, the first using only ownership data from the most credible sources (hospitals for which data were sourced from peer-reviewed articles and interviews and/or which were confirmed independently in two or more sources were considered to have highest credibility; see Appendix B for detail), and the second using an alternative method in which I "pick" owners based on treatment patterns as in Mitchell (2005).

In the latter approach, I rank physicians by the total number of cardiac admissions, then by the total number of all admissions, on which they were present at the POH.[53] For hospitals with P owners, I assign ownership to the top-ranked P physicians. Because only admissions data contains hospital identifiers, this criterion has the disadvantage of potentially over-assigning ownership to physicians treating admitted patients and thus favors surgeons and interventional cardiologists over cardiologists who tend to treat on an outpatient basis (e.g., non-invasive cardiologists perform stress tests, EKGs, echocardiograms and see patients in a clinical setting; invasive cardiologists who are not ICs do everything non-invasive cardiologists do plus diagnostic angiography, which can be done on an inpatient or outpatient basis (Johnson, 2009)). Hence, this approach assigns ownership to a greater number of the decision-making physicians in my sample; under the probabilistic approach, 404 sample physicians are expected to have been owners, while the "pick" owners approach assigns ownership to 481 sample physicians.

The results are displayed in Table 10. In column (1), we see that the choice pat-

[53] This procedure was performed by linking the 20% carrier (physician) claims file with the 100% inpatient admissions file by patient identifier and date in order to identify the hospital of admission.

terns of physicians in the markets with the most credible data are not statistically or qualitatively different from our baseline results, the exception being on the preferences of owners over treating older or demographically more severe patients at POHs. In each of these cases, the baseline owner prefers to treat more severe patients at the POH while the owner with greater imputed per-physician ownership share has a countervailing effect – these effects counteract each other on balance so that we again conclude that there is no evidence of cherry-picking behavior for the average owner. As expected given the sample size reduction, standard errors are larger.

Column (2) shows physician choice behavior under the "pick owners" method. Here, the preferences of non-owners and owners are somewhat different at baseline. Non-owners have a stronger negative preference for treating patients at the POH, consistent with the fact that non-owners by this algorithm by definition have at most a small number of POH referrals. They still have a preference for treating younger patients with less favorable demographics and fewer comorbidities at the POH rather than the community hospital – estimates are not statistically distinct from previous estimates.

The preferences of physician owners on average and varying with overall patient sickness are similar to the main specification. Now, there is a larger difference between the preferences of owners and non-owners than in the main specification and the average predicted probability of a physician owner sending a patient of average health to the physician-owned hospital is 75%. The results on ownership and share interacted with patient characteristics are also similar to the estimates from the main specification, with the exception that owners have a slightly stronger negative preference for treating patients with non-cardiac comorbidities at the POH.[54]

In sum, more restrictive approaches to data collection on ownership or identification of owner behavior do not impact my overall conclusion. Physician-owner behavior involves a diversion of the overall patient population to POHs which does not vary by patient characteristics as in a model of cherry-picking.

[54] The lower bound of the 95% confidence interval indicates that a standard deviation increase in non-cardiac comorbidities results in a 1.2pp decrease in probability of referral to the POH.

Table 10: Choice model – "most credible" sample and alternative owner identification results

	Joint Model "Best" Owners (1)		Joint Model "Pick" Owners (2)	
	Coef.	SE	Coef.	SE
POH	-4.08	(0.41)***	-1.79	(0.21)***
POH*Potential Owner	3.94	(0.43)***	0.88	(1.37)
POH*Age	-0.03	(0.01)***	-0.02	(0.01)**
POH*Demographic Index	4.03	(1.23)***	5.21	(2.31)**
POH*Cardiac Comorbidity Index	0.01	(0.35)	-0.65	(0.47)
POH*Non-Cardiac Comorbidity Index	-0.76	(0.40)*	-0.24	(0.31)
POH*Primary Diagnosis Index	-0.15	(0.22)	-0.16	(0.24)
POH*Owner	4.38	(0.57)***	4.16	(1.42)***
POH*Owner*Age	0.08	(0.02)***	0.01	(0.01)
POH*Owner*Demographic Index	14.37	(4.30)***	-0.27	(3.11)
POH*Owner*Cardiac Comorbidity Index	-0.75	(1.11)	0.78	(0.58)
POH*Owner*Non-Cardiac Comorbidity Index	-0.20	(0.90)	-0.54	(0.44)
POH*Owner*Primary Diagnosis Index	0.95	(0.60)	0.39	(0.38)
Share	0.33	(0.51)	-0.20	(0.15)
Share*Age	-0.04	(0.02)*	0.01	(0.00)
Share*Demographic Index	-11.74	(4.13)***	-1.25	(1.51)
Share*Cardiac Comorbidity Index	0.33	(1.08)	0.06	(0.19)
Share*Non-Cardiac Comorbidity Index	0.12	(0.74)	0.35	(0.16)**
Share*Primary Diagnosis Index	-0.41	(0.55)	-0.21	(0.18)
N	23,672		37,277	

Notes: Choice results for joint choice-outcome model. Columns (1) restricts sample to markets with "best" owner data; (2) uses owners chosen as top-ranked physicians by total number of admissions at POH (admissions count based on link of 20% carrier file with 100% inpatient admissions file using patient identifier and date). See Appendix B for detail. Results for general hospital characteristics suppressed for brevity. Standard errors from nonparametric bootstrap of entire two-step procedure, 200 repetitions.

7 Conclusion

The welfare implications of physician ownership of hospitals involve several economic forces. Physicians have a hand in choosing where patients are treated, so physician-owners have an incentive to send the high-margin, low cost patients to their own hospitals, cream-skimming their competitors. On the other hand, physician-owned hospitals may provide better care to certain types of patients. The key insight of this paper is that, on their own, differences in patient population across hospitals are no more a smoking gun for cherry-picking than differences in mortality rates are for quality. Estimates of quality at physician-owned hospitals must account for favorable selection of healthier patients, but at the same time, estimates of cherry-picking must account for patient-hospital matching and baseline patient preferences for specialized facilities.

The results of this study indicate that treatment at a physician-owned hospital can lead to substantial improvements in mortality risk for cardiac patients – for the average severity patient, treatment at a POH leads to a 1.2pp decrease in expected mortality risk, which is large relative to average mortality of 6.3%. Relative quality appears somewhat attenuated for patients who are sicker along some dimensions, but differential effects are small and imprecise. Estimates are qualitatively similar with and without instrumental variables and generally indicate that selection on unobservables is not a substantial driver of the reduced form quality differences across hospital type. Further, quality benefits appear to be comparable to those available at non-physician-owned cardiac hospitals, indicating that specialization may drive quality effects rather than ownership.

Physician-owners treat the majority of their patients at their owned facilities, but I find limited evidence of cherry-picking on patient health by owners. Point estimates regarding owner selection on patient health indicate the opposite of cherry-picking behavior, and standard errors are small enough to exclude cherry-picking being a substantial driver of the favorable selection observed at POHs. Interestingly, neither preferences for the average patient nor preferences for relatively sicker patients are exacerbated by physicians having a greater personal ownership share in the owned facility. This may be due to physician owners maximizing total hospital surplus rather than personal surplus when deciding on treatment location.

Taken together, the results of my model indicate that, for cardiac care, the hospital choice incentives of physician-investors in POHs are not distorted, while quality improvements at POHs are large, particularly for moderate-severity patients. The results are robust to alternative specifications and several checks of my assumptions regarding both unobserved patient illness and physician ownership. The results suggest that the banning of further physician ownership as part of the ACA may have detrimental effects on patient health.

8 References

109 Cong. Rec. S1, 109-38 (2005, May 12) (statement of Alan Pierrot). Retrieved from http://www.gpo.gov/fdsys/pkg/CHRG-109hhrg21636/html/CHRG-109hhrg21636.htm.

Angrist, J. and J. Pischke (2008). *Mostly Harmless Econometrics: An Empiricist's Companion.* Princeton, NJ: Princeton University Press.

Barro, J. R., R. S. Huckman, and D. P. Kessler (2006). The effects of cardiac specialty hospitals on the cost and quality of medical care. *Journal of Health Economics 25*(4), 702-721.

Casalino, L. P., K. J. Devers, and L. R. Brewster (2003). Focused factories? Physician-owned specialty facilities. *Health Affairs 22*(6), 57-67.

Centers for Medicare and Medicaid Services, Department of Health and Human Services (2005). *Study of Physician-Owned Specialty Hospitals Required in Section 507(c) (2) of the Medicare Prescription Drug, Improvement, and Modernization Act of 2003*, Baltimore: CMS.

Chollet, D., et al. (2006). *Analysis of Niche Hospitals in Texas and the Financial Impact on General Hospitals: Final Report to the Texas Department of State Health Services*, Mathematica Policy Research, Inc.

Cram, P. C., G. E. Rosenthal, and M. S. Vaughan-Sarrazin (2005). Cardiac revascularization in specialty and general hospitals. *New England Journal of Medicine 352*(14), 1454-62.

David, G. (2009). The convergence between for-profit and nonprofit hospitals in the United States. *International Journal of Health Care Finance Economics 9*(4), 403-428.

Dranove, D., et al. (2003). Is more information better? The effects of "report cards" on health care providers. *Journal of Political Economy 111*(3), 555-588.

Gowrisankaran, G. and R. J. Town (1999). Estimating the quality of care in hospitals using instrumental variables. *Journal of Health Economics 18*(6), 747-767.

Greenwald, L., J. Cromwell, W. Adamache, S. Bernard, E. Drozd, E. Root, and K. Devers (2006). Specialty versus community hospitals: referrals, quality, and community benefits. *Health Affairs 25*(1), 106-118.

Huckman, R. S. and G. P. Pisano (2006, April). The firm specificity of individual performance: evidence from cardiac surgery. *Management Science 52*(4), 473-488.

Johnson, E. M. (2011). Ability, learning, and the career path of cardiac specialists. *Working paper.*

Kimbol, A. S. (2005). The debate over specialty hospitals: how physician-hospital relationships have reached a new fault line over these "focused Factories". *Journal of Health Law 38*(4), 633-672.

Limitation on certain physician referrals. 42 U.S.C. §1395nn.

McClellan, M. and J. P. Newhouse (1997). The marginal cost-effectiveness of medical technology: a panel instrumental-variables approach. *Journal of Econometrics 77*, 39-64.

Medicare Payment Advisory Commission (MedPAC) (2005, March). *Report to the Congress: Physician-Owned Specialty Hospitals.* Washington, DC: MedPAC.

Mitchell, J. M. (2005). Effects of physician-owned limited service hospitals: evidence from Arizona. *Health Affairs W5*, 481-90.

Nakamura, S., C. Capps, and D. Dranove (2007). Patient admission patterns and acquisition of "feeder" hospitals. *Journal of Economics & Management Strategy 16*(4), 995-1030.

Nallamothu, B., et al. (2007). Acute myocardial infarction and congestive heart failure outcomes at specialty cardiac hospitals. *Circulation 116*(20), 2280-7.

Quan H., V. Sundararajan, P. Halfon, A. Fong, B. Burnand, J. C. Luthi, L. D. Saunders, C. A. Beck, T. E. Feasby, and W. A. Ghali (2005). Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Medical Care 43*(11), p. 1130-1139.

Schneider, J. E., P. Li, and R. L. Ohsfeldt (2011, April). The effects of endogenous market entry of physician-owned hospitals on Medicare expenditures: an instrumental variables approach. *Contemporary Economic Policy 29*(2), 151-62.

Sorrel, A. (2007, January 22). Arkansas cardiologists accuse hospital of collusion. *American Medical News.*

Train, K. (2009). *Discrete choice methods with simulation*, 2nd. ed. New York, NY: Cambridge University Press.

A Appendix A: Model Details *For Online Publication*

In this study, I consider Medicare patients, for which the reimbursement structure is well-known, so it is straightforward to model physician profit explicitly. For physician p with ownership stake τ_{pj} in hospital j, I assume that physician profit is

$$\pi_{ipj} = R^P_{pj}(\mathbf{X_i}) - c^P_{pj}(\mathbf{X_i}) + \tau_{pj}\left(R^H(\mathbf{X_i}) - mc^H(\mathbf{X_i})\right).$$

Here, R^P and c^P are the revenue and cost of *physician services* for a patient with characteristics $\mathbf{X_i}$; the choice of hospital may affect the provision of physicians' services through, for example, capacity constraints, so generally these terms may depend on j. Although I refer to this as "profit," these expressions capture both financial and non-financial preferences. For example, physicians may prefer physician-owned hospitals because they may be more pleasant workplaces, and further may prefer treating sicker patients at physician-owned hospitals because they require longer bed stays and greater physician presence at the POH. Each of these effects could be interpreted as a lower "cost" of physician services at the POH. R^H is the Medicare reimbursement for *hospital services* ordered by physician p, and mc^H is the hospital's cost of treatment; a physician with ownership share τ_{pj} will receive that percentage of hospital profits $R^H - mc^H$.

The cost terms c^P and c^H are not known, so I impose a simple partially-separable functional form for each profitability term:

$$\begin{aligned} R^P_{pj}(\mathbf{X_i}) - c^P_{pj}(\mathbf{X_i}) &= \mu_1 + \mu_2 * \mathbf{X_i} + \mu_3 * d_j^{PO} + \mu_4 * d_j^{PO}\mathbf{X_i} + \mu_5 * d_p^{own} \\ &\quad + \mu_6 * d_p^{own}\mathbf{X_i} + \mu_7 * d_p^{own} * d_j^{PO} + \mu_8 * d_p^{own} * d_j^{PO}\mathbf{X_i} \\ R^H(\mathbf{X_i}) - mc^H(\mathbf{X_i}) &= \lambda_1 + \lambda_2 * \mathbf{X_i}. \end{aligned}$$

Here, the profit on physician services depends on patient characteristics, both alone and interacted with physician and hospital type. The quite simple form for $R^H - mc^H$ is used because hospital reimbursements will only be received when $\tau_{pj} > 0$, which implies $d_j^{PO} = d_p^{own} = 1$. When I replace the revenue less cost terms in π_{ipj} with these specifications, combine terms that enter multiple times, and drop terms which are invariant to hospital and which thus may not impact choice, I obtain the following simple specification:

$$\pi_{ipj} = d_j^{PO}\omega_1 + \mathbf{X_i} * d_j^{PO}\omega_2 + d_j^{PO} * d_p^{own}\omega_3 + \mathbf{X_i} * d_j^{PO} * d_p^{own}\omega_4 + \tau_{pj}(\lambda_1 + \mathbf{X}_i\lambda_2).$$

Using the above functional form for physician profit, the choice model can be rewritten as[55]

$$\begin{aligned} u_{ipj} &= d_j^{PO}\omega_1 + \mathbf{X_i} * d_j^{PO}\omega_2 + d_j^{PO} * d_p^{own}\omega_3 + \mathbf{X_i} * d_j^{PO} * d_p^{own}\omega_4 + \tau_{pj}(\lambda_1 + \mathbf{X_i}\lambda_2) \\ &\quad + \rho_1\hat{m}_{ipj} + \rho_2 dist_{ij} + \epsilon_{ipj}. \end{aligned}$$

[55]Note that, although I have modeled "patient concerns" in the physician's utility function as determined by expected mortality and travel distance only, it is possible that other hospital characteristics (e.g., nurse staffing) affect both physician and patient utility so that ω is a sum of physician and patient coefficients. I consider a single decision-maker, so I am unable to measure the extent to which each characteristic affects the physician vs. the patient population and speak of them as "physician profit" only for the sake of exposition. This issue is less likely to pertain for the patient profitability term $\tau_{pj}(\lambda_1 + \mathbf{X}_i\lambda_2)$ unless hospital choice is the outcome of a Nash bargaining process where total surplus is split between the physician and patient; I ignore this issue now and return to it in the discussion of welfare.

To sum up, hospital choice is determined by non-owner physician preferences for POHs (ω_1), the effect of patient characteristics $\mathbf{X_i}$ on non-owner physician preferences for POHs (ω_2), the additional preference of a physician-investor of treating a patient at a physician-owned facility, on average (ω_3, λ_1)[56] and varying with patient characteristics (ω_4, λ_2), physician preferences over patient mortality (ρ_1), and physician preferences for patient travel distance (ρ_2). Cherry-picking behavior is captured by ω_4 and λ_2.

[56]The terms ω_3 and λ_1 may also capture a "home base" preference for physician-investors to treat at their owned hospital.

B Appendix B: Details on Physician-Owned Hospital Dataset *For Online Publication*

In order to construct a dataset of physician-owned hospital characteristics, I began with a list of all physician-owned hospitals from the membership rolls of the industry group Physician Hospitals of America (PHA) in 2009 (Physician's hospitals, 2009) and from the annual reports of MedCath, Inc., a public for-profit company whose business model is partnership with physicians to develop physician-owned hospitals. A Lexis Nexis news search and close examination of the websites of cardiac specialty hospitals identified in the inpatient claims data (using the measure of specialization defined in Section 3) uncovered no physician-owned hospitals not already in PHA's member list or MedCath's archives. Each hospital in the PHA member list or MedCath's financial reports was initially classified as providing cardiac services if such services were listed on its website. Hospitals listing no cardiac services were excluded from my sample. Table B.1 displays the ownership and specialization of all physician-owned facilities identified using this procedure.

All of the above facilities can be linked to the inpatient admissions data except for Heartland Memorial Hospital. In order to focus on hospitals which are sufficiently comparable to the physician-owned cardiac hospitals that are the primary subject of my analysis, I further limit the set of physician-owned hospitals to those with at least thirty admissions in surgical cardiac DRGs in 2005. This refinement eliminates Coast Plaza Doctors Hospital, Dupont Hospital, and Olympia Medical Center from my sample of physician-owned hospitals. For the remaining hospitals, I performed a search of public corporation annual reports to shareholders, news articles, and press releases. I also compared the resulting data with a spreadsheet received from PHA dated March 2011 and with conversations with Dr. John Harvey, President and CEO of Oklahoma Heart Hospital, and Mr. Lynn Jeane, COO of Kansas Heart Hospital. I was able to identify, for each sample hospital, the following characteristics: ownership type (fully physician-owned, joint venture with non-profit hospital, joint venture with private corporation), date hospital opened, aggregate physician ownership share, and number of physician owners. Where possible, data on physician ownership share and number of physician owners were determined for 2005. Hospitals for which data were sourced from peer-reviewed articles and interviews and/or which were confirmed independently in two or more sources were considered to have highest credibility; in robustness analysis, only those POH markets with the most credible sources are included (see Section 6). Sources are displayed in Table B.2.

After linking carrier claims to hospitals using beneficiary identifiers and dates in the inpatient database, I flag as potential owners at each physician-owned hospital those physicians in appropriate specialties present on at least two inpatient admissions in the 20% carrier claims sample in 2005. This criterion was developed to identify potential owners without assuming specific referral behavior for physician-investors.[57] Two of the

[57]The carrier claims file was used in conjunction with the inpatient admission file because the carrier claims identify all physicians present on each admission, while the inpatient file displays only up to three physician identifiers and may therefore exclude many physicians present on each admission. In particular, the "operating physician" field in the inpatient file naturally favors cardiac surgeons

Table B.1: Entry, all physician-owned hospitals providing cardiac services

Hospital	Market	Opened	Specialized?
Arizona Heart Hospital	Phoenix, AZ	Jun-98	Yes
Arkansas Heart Hospital	Little Rock, AR	Mar-97	Yes
Aurora BayCare Medical Center	Green Bay, WI	2001	No
Avera Heart Hospital	Sioux Falls, SD	Mar-01	Yes
Bakersfield Heart Hospital	Bakersfield, CA	Oct-99	Yes
Baylor Heart and Vascular	Dallas, TX	2002	Yes
Coast Plaza Doctors Hospital	Norwalk, CA	1957	No
Crestwood Medical Center	Huntsville, AL	1965	No
Dayton Heart Hospital	Dayton, OH	Sep-99	Yes
Doctors Hospital at Renaissance	Edinburg, TX	1997	No
Dupont Hospital	Fort Wayne, IN	2001	No
Fresno Heart Hospital	Fresno, CA	Oct-03	Yes
Galichia Heart Hospital	Wichita, KS	Dec-01	Yes
Harlingen Medical Center	Harlingen, TX	Oct-02	No
Heart Hospital of Austin	Austin, TX	Jan-99	Yes
Heart Hospital of Lafayette	Lafayette, LA	Mar-04	Yes
Heart Hospital New Mexico	Albuquerque, NM	Oct-99	Yes
Heartland Memorial Hospital	Munster, IN	1994	No
Indiana Heart Hospital	Indianapolis, IN	Feb-03	Yes
Kansas Heart Hospital	Wichita, KS	1999	Yes
Louisiana Heart Hospital	St. Tammany Parish, LA	Feb-03	Yes
Lubbock Heart Hospital	Lubbock, TX	Jan-04	Yes
NEA Medical Center	Jonesboro, AR	1998	No
Nebraska Heart Institute	Lincoln, NE	May-03	Yes
Oklahoma Heart Hospital	Oklahoma City, OK	Aug-02	Yes
Olympia Medical Center	Los Angeles, CA	Dec-04	No
St. Francis Heart Hospital	Tulsa, OK	Apr-04	Yes
St. Vincent Heart Center	Indianapolis, IN	Dec-02	Yes
TexSAn Heart Hospital	San Antonio, TX	Jan-04	Yes
Tucson Heart Hospital	Tucson, AZ	Oct-97	Yes
Wisconsin Heart Hospital	Wauwatosa, WI	Jan-04	Yes

and interventional cardiologists (ICs) over other types of cardiologists, as it identifies the performing physician if a procedure was performed during the admission. 83% of the non-emergency patients in my sample had a procedure performed, 37% of which were for percutaneous transluminal coronary angioplasty (PTCA), a procedure performed by ICs, and a further 16% of which were for CABG, a procedure performed by surgeons. There are three major sub-specialties of cardiology: non-invasive cardiologists, invasive cardiologists, and interventional cardiologists (Johnson, 2011). POHs are owned by both cardiologists and surgeons, so that using the inpatient file to identify potential owners might overstate the probability that physicians in procedural specialties in my sample are owners. The merged

Table B.2: Sources, physician-owned hospitals providing high-acuity cardiac services

Hospital	Most Credible?	Source(s)
Arkansas Heart Hospital	Yes	MedCath 10-K (2005); Casalino, et al. (2003); PHA spreadsheet (2011)
Aurora BayCare Medical Center		Reilly (2002); Stern (2002)
Avera Heart Hospital	Yes	MedCath 10-K (2005); Soderholm (2005); PHA spreadsheet (2011)
Bakersfield Heart Hospital	Yes	MedCath 10-K (2005); Bedell (1998); PHA spreadsheet (2011)
Baylor Heart and Vascular		Ornstein (1999); Gordon (2006)
Coast Plaza Doctors Hospital		Our Services (2013)
Crestwood Medical Center		Crestwood CEO (2008); About Us (2013)
Dayton Heart Hospital	Yes	MedCath 10-K (2005); Lamb (1999); Neal (2003)
Doctors Hospital at Renaissance		Kirchheimer (2010); Sack and Herszenhorn (2009)
Dupont Hospital		Triad 10-K (2006); Leduc (2000)
Fresno Heart Hospital	Yes	Correa (2004, 2006); "In the Spotlight" (2004)
Galichia Heart Hospital		Robeznieks (2011); Siebenmark (2010); McChesney (2003)
Harlingen Medical Center		MedCath 10-K (2005); Smith (2005)
Heart Hospital of Austin		MedCath 10-K (2005); Rodgers and Laird (2007); Park (1998)
Heart Hospital of Lafayette	Yes	MedCath 10-K (2005); Specialty Hospitals (2005); Lourdes, Heart Hospital Join Forces (2008); Welcome to Heart Hospital of Lafayette (2013); Medical Roster (2013); PHA spreadsheet (2011)
Heart Hospital of New Mexico	Yes	MedCath 10-K (2005); Two of New Mexico's largest cardiology groups merge (2002); Quigley (2002); PHA spreadsheet (2011)
Heartland Memorial Hospital		Erler (2006)
Indiana Heart Hospital	Yes	Swiatek (2003); Morrison (2001); Doctors joining hospital payrolls (2009); Casalino, et al. (2003)
Kansas Heart Hospital		Agovino (2003); conversation with Lynn Jeane (2011); PHA spreadsheet (2011)
Louisiana Medical Center and Heart Hospital	Yes	MedCath 10-K (2005); Chapple (2003); PHA spreadsheet (2011)
Lubbock Heart Hospital		Senator planning legislation (2003); Lubbock Heart Hospital (2009); Indeed (2001); PHA spreadsheet (2011)
NEA Medical Center		NEA Clinic and Baptist Memorial (2007); NEA Clinic Selects Touchworks (2003); Tenet to sell four Arkansas hospitals (2003); Triad 10-K (2004)
Nebraska Heart Institute Heart Hospital		Vogeler (2004); Anderson (2002); Anderson (2011)
Oklahoma Heart Hospital	Yes	Conversation with John Harvey (2011); Oklahoma Heart Hospital Achieves Paperless (2003); Flynn (2003)
Olympia Medical Center		Briefly (2006); Hospital renaming (2005); Olympia Medical Center - About Us (2012)
Saint Francis Heart Hospital	Yes	Rogoski (2006); Billington (2006); Kelly (2004)
Saint Vincent Heart Center of Indiana	Yes	Fogel and Campbell (2003); Conn (2003); Gaines (2012); PHA spreadsheet (2011)
TexSAn Heart Hospital	Yes	MedCath 10-K (2005); Danner (2011); Methodist Texsan Hospital (2011)
Tucson Heart Hospital	Yes	MedCath 10-K (2005); Dobson and Haught (2005); Erikson (2001)
Wisconsin Heart Hospital		Flynn (2003); Romano (2007); Boulton (2005); Manning (2003); Dang (2002)

physician-owned hospitals in my dataset, the Oklahoma Heart Hospital and the Aurora

inpatient-carrier file identifies any physician who had an office visit, performed a test, consulted with, or otherwise treated the patient, giving me a more comprehensive list of physician IDs even though the carrier file is only a 20% sample.

BayCare Medical Center, have made current lists of their physician investors available on their websites.[58] I examined these lists to aid in identification of potential physician-investors based on referral patterns and specialization.[59] Flagging as potentials those physicians in the appropriate specialties present on at least two inpatient admissions in 2005 (the primary algorithm used) identified all 34 of the 34 physician-investors at Oklahoma Heart Hospital, while "picking" the top admitting physicians as investors identified only 24 physician-investors correctly. Neither method identified a substantial proportion of current physician-investors at the non-specialized Aurora BayCare (the two methods identified 50 and 33 current investors, respectively), potentially due to non-specialized physician-owners' lower involvement in inpatient admissions or to higher turnover in ownership. I focus on patients treated at cardiac POHs in the majority of my analyses. Physicians treating patients at multiple physician-owned hospitals were only flagged as potential owners at the hospital for which they were present on more admissions, under the assumption that physician-owners have an average preference for treating patients at their owned hospital over another physician-owned hospital.

I also eliminate from my sample the Arkansas Heart Hospital, whose doctors were subject to economic credentialing by competing hospitals during the sample period (Sorrel, 2007), the Wisconsin Heart Hospital, which competed with the physician-owned Heart Hospital of Milwaukee that closed in late 2004 (Boulton, 2005), and Doctors Hospital at Renaissance, which had far more physician-investors (over 300) than ever practiced substantially at the facility. For each hospital eliminated from the sample, all other hospitals in the hospital's HRR are eliminated as well so that the competitive environment for each included market is represented in full.

After making these restrictions, I obtain a sample of 20 physician-owned cardiac hospitals and 4 physician-owned non-specialty hospitals.

[58]BayCare Clinic (2011); Oklahoma Heart Hospital (2011).

[59]Oklahoma Heart Hospital's physician-investors have the following specializations: cardiology, internal medicine, pulmonary disease, thoracic surgery, peripheral vascular disease, vascular surgery, cardiac surgery, and emergency medicine. Aurora BayCare's physician-investors have a wide range of specializations, the majority being anesthesiology, emergency medicine, and ophthalmology.

C Appendix C: Additional Tables and Figures *For Online Publication*

Table C.1: Sample hospital characteristics

	Non-Phys-Owned General Hospitals	Non-Phys-Owned Cardiac Hospitals	Phys-Owned General Hospitals	Phys-Owned Cardiac Hospitals
Government	0.132	0.000	0.000	0.000
	(0.339)	(0.000)	(0.000)	(0.000)
For-profit	0.223	0.300	1.000	1.000
	(0.417)	(0.483)	(0.000)	(0.000)
Teaching	0.109	0.200	0.000	0.000
	(0.313)	(0.422)	(0.000)	(0.000)
Cardiac catheterization	0.866	0.875	1.000	0.941
	(0.342)	(0.354)	(0.000)	(0.243)
Cardiac ICU	0.623	0.875	0.750	0.765
	(0.486)	(0.354)	(0.500)	(0.437)
Angioplasty	0.745	0.875	1.000	0.882
	(0.437)	(0.354)	(0.000)	(0.332)
Adult cardiac surgery	0.584	1.000	0.750	0.882
	(0.494)	(0.000)	(0.500)	(0.332)
Heart transplant	0.069	0.250	0.000	0.000
	(0.254)	(0.463)	(0.000)	(0.000)
Ultrasound	0.987	1.000	1.000	0.941
	(0.113)	(0.000)	(0.000)	(0.243)
CT scan	0.983	0.875	1.000	0.824
	(0.131)	(0.354)	(0.000)	(0.393)
MRI	0.931	0.875	1.000	0.118
	(0.254)	(0.354)	(0.000)	(0.332)
SPECT	0.641	0.750	0.500	0.176
	(0.481)	(0.463)	(0.577)	(0.393)
PET	0.251	0.125	0.000	0.000
	(0.435)	(0.354)	(0.000)	(0.000)
Emergency department	0.983	0.875	1.000	0.765
	(0.131)	(0.354)	(0.000)	(0.437)
Beds	304.302	203.889	107.500	54.650
	(216.090)	(119.915)	(20.551)	(18.027)
Cardiac ICU Beds	7.511	19.375	5.000	15.765
	(10.312)	(13.212)	(7.572)	(18.318)
RNs/bed	1.432	1.745	2.215	1.829
	(0.515)	(0.831)	(0.832)	(0.801)
N	265	10	4	20
HRRs	30	9	4	18

Notes: All hospitals providing high-acuity cardiac care in 30 HRRs including either a physician-owned hospital or cardiac specialty hospital. See Section 3 for definition of high-acuity cardiac care. Standard deviations in parentheses.

Table C.2: Sample patient characteristics

	All POH Markets		Cardiac POH Markets	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Demographic variables:				
Age	75.222	7.091	75.190	7.069
Female	0.446	0.497	0.443	0.497
Black	0.037	0.188	0.038	0.191
Asian	0.004	0.064	0.004	0.065
Hispanic	0.027	0.162	0.024	0.153
% Bachelor's (ZIP)	0.136	0.083	0.138	0.083
Population (ZIP)	21,605	15,847	21,556	15,456
Median Income (ZIP)	$39,419	$13,470	$39,890	$13,664
Primary diagnosis: 41401	0.369	0.483	0.378	0.485
Comorbid conditions:				
End stage renal disease	0.017	0.128	0.017	0.129
Congestive heart failure	0.235	0.424	0.232	0.422
Peripheral vascular disease	0.109	0.312	0.110	0.313
Dementia	0.009	0.097	0.009	0.092
Chronic pulmonary disease	0.220	0.414	0.219	0.414
Rheumatic disease	0.016	0.126	0.015	0.123
Mild liver disease	0.006	0.078	0.006	0.077
Diabetes with chronic complication	0.020	0.138	0.019	0.135
Hemiplegia or paraplegia	0.002	0.042	0.002	0.041
Renal disease	0.056	0.231	0.055	0.228
Malignancy	0.024	0.152	0.024	0.152
Moderate or severe liver disease	0.001	0.024	0.001	0.023
Metastatic solid tumor	0.004	0.063	0.004	0.063
Treatment/outcome characteristics:				
Treated at POH	0.283	0.450	0.294	0.455
90-day mortality	0.064	0.245	0.063	0.244
# Hosps	12.077	7.456	12.867	7.341
Distance	22.460	23.112	22.935	23.613
N	40,930		37,271	

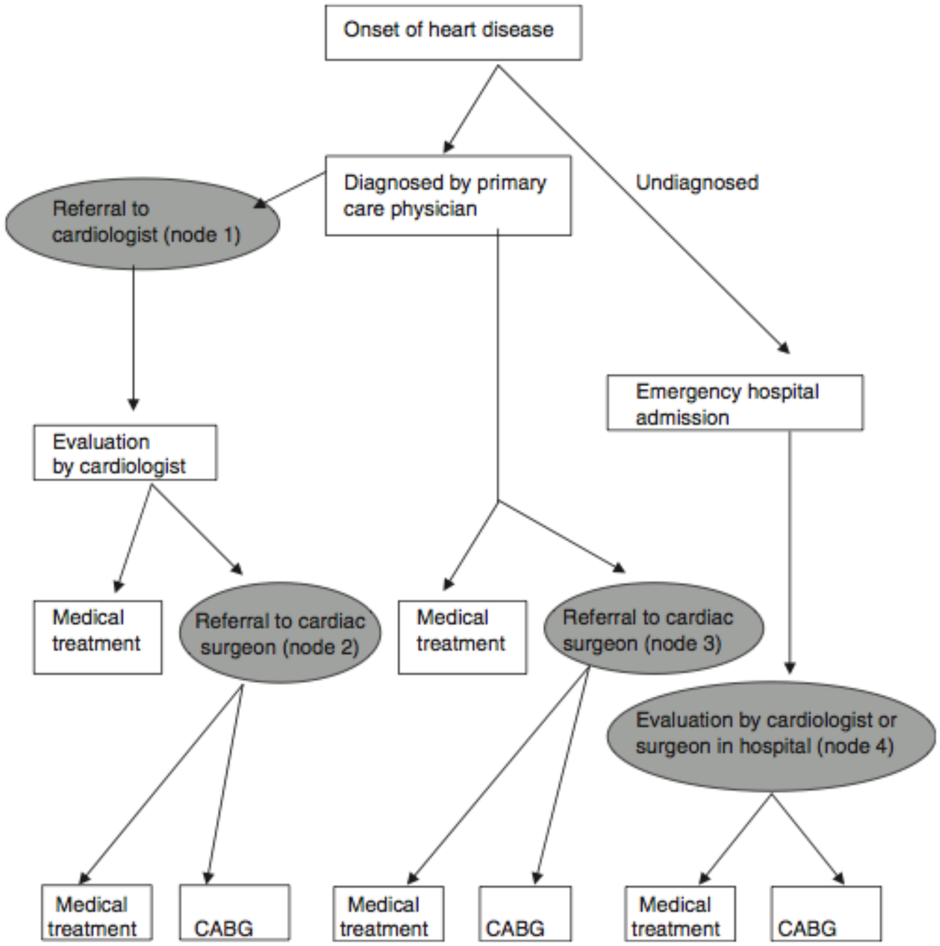
Notes: Non-emergency cardiac patients in HRRs with physician-owned hospitals. Distance is driving distance from centroid of patient's ZIP code to treatment hospital. ICD-9 codes for comorbidities from http://mchp-appserv.cpe.umanitoba.ca/viewConcept.php?conceptID=1098#a_references.

Table C.3: Reduced form mortality model results for cardiac POH markets

	Level Term		POH Interaction	
	Coef.	SE	Coef.	SE
Treated at POH	-0.082	(0.067)		
Age	0.035^{***}	(0.002)	0.001	(0.004)
ESRD	0.240^{***}	(0.081)	0.001	(0.213)
Population (ZIP)	0.028^{**}	(0.013)	-0.041^{*}	(0.025)
Congestive heart failure	0.329^{***}	(0.029)	0.007	(0.060)
Cerebrovascular disease	0.281^{***}	(0.054)	0.058	(0.095)
Dementia	0.273^{***}	(0.103)	-0.197	(0.276)
Chronic pulmonary disease	0.217^{***}	(0.029)	-0.001	(0.060)
Mild liver disease	0.813^{***}	(0.113)	0.085	(0.247)
Renal disease	0.341^{***}	(0.048)	0.111	(0.102)
Malignancy	0.342^{***}	(0.068)	0.181	(0.160)
Moderate/severe liver disease	0.724^{**}	(0.347)	0.921	(0.663)
Metastatic solid tumor	0.969^{***}	(0.133)	-0.359	(0.365)
Mitral insufficiency/aortic stenosis	0.611^{***}	(0.229)	-0.085	(0.343)
Rheumatic heart failure	0.861^{***}	(0.139)	-0.542^{**}	(0.244)
Hypertensive chronic heart failure and kidney disease	0.440^{**}	(0.221)	0.000	n/a
AMI anterolateral wall, initial	1.281^{***}	(0.187)	-0.295	(0.306)
AMI anterior wall, initial	0.867^{***}	(0.100)	-0.057	(0.180)
AMI inferolateral wall, initial	1.041^{***}	(0.231)	-0.954^{*}	(0.550)
AMI inferoposterior wall, initial	0.710^{***}	(0.266)	0.583	(0.402)
AMI inferior wall, initial	0.653^{***}	(0.107)	0.237	(0.162)
AMI other lateral wall, initial	0.830^{***}	(0.226)	-0.003	(0.393)
Subendocardial infarct, initial	0.614^{***}	(0.050)	-0.202^{**}	(0.095)
AMI, other site, initial	0.820^{***}	(0.208)	-0.083	(0.365)
AMI, not otherwise specified, initial	1.312^{***}	(0.114)	-0.529^{**}	(0.265)
CABG	0.488^{*}	(0.285)	0.000	n/a
Other chronic pulmonary heart disease	0.607^{***}	(0.220)	0.000	n/a
Mitral valve disorder	0.450^{***}	(0.127)	-0.064	(0.244)
Aortic valve disorder	0.473^{***}	(0.081)	-0.183	(0.165)
Paroxysmal supraventricular tachycardia	0.266^{**}	(0.114)	-0.245	(0.235)
Atrial fibrillation	0.201^{***}	(0.056)	-0.272^{**}	(0.127)
Sinoatrial node dysfunction	-0.155^{**}	(0.077)	-0.044	(0.171)
Congestive heart failure, not otherwise specified	0.638^{***}	(0.041)	-0.004	(0.087)
Chronic systolic heart failure	0.600^{***}	(0.231)	-0.952^{**}	(0.482)
Acute on chronic systolic heart failure	0.613^{**}	(0.252)	0.381	(0.366)
Abdominal aortic aneurysm	0.202^{**}	(0.084)	-0.252	(0.179)
Chest pain	-0.397^{***}	(0.132)	-0.299	(0.390)
Infection and inflammatory reaction to cardiac device/implant/graft	0.757^{***}	(0.203)	0.000	n/a
Other primary diagnosis	0.565^{***}	(0.062)	0.043	(0.119)
Constant	-2.094^{***}	(0.037)		
N	37,043			
R-squared	0.1645			

Notes: All patient characteristics included alone and interacted with dummy for treatment at POH. Only characteristics with statistically significant level effect on mortality included. Huber-White robust standard errors in parentheses.

Figure C.1: Mukamel, et al. (2006) model of CABG treatment



D Appendix D: Appendix References *For Online Publication*

About us. (2013). Crestwood Medical Center. Available at http://www.crestwoodmedcenter.com/About/Pages/About%20Us.aspx (retrieved 4/18/2013).

Agovino, T. (2003, July 29). Specialty hospitals give general institutions heart ache. *The Associated Press*.

Anderson, M. (2002). Beyond spotlight of publicity, Heart Institute's creation was contentious. *Lincoln Journal Star (Nebraska)*, p. A8.

Anderson, M. (2011). Heart hospital sale in talks; Sale of Nebraska Heart Hospital to owner of Saint Elizabeth could be final by July 1. *Lincoln Journal Star (Nebraska)*, p. A1.

BayCare Clinic (2011). Aurora BayCare Medical Center physician/non-physician shareholders. Retrieved from http://www.baycare.net/about-us/corporate-information/baycare-aurora-relationship.

Bedell, C. (1998, September 13). Investment firms sign deal to buy parent of Bakersfield, Calif., hospital. *The Bakersfield Californian*.

Billington, J. (2006). Heart hospital to change its location. *Tulsa World (Oklahoma)*, p. A11.

Briefly (2006, July 1). *Modern Physician*.

Boulton, G. (2005, July 3). Hospital predicts healthier finances. *The Milwaukee Journal Sentinel*.

Casalino, L. P., K. J. Devers, and L. R. Brewster (2003). Focused factories? Physician-owned specialty facilities. *Health Affairs 22*(6), 57-67.

Chapple, C. (2003, February 20). Heart center nearly ready to open its doors; other hospitals may feel pinch. *Times-Picayune (New Orleans, LA)*, p. 1.

Conn, J. (2003). The list. *Modern Physician*, p. 24.

Correa, T. (2004, March 20). Heart hospital's ills aired CEO Carr's firing upsets physician investors. *Fresno Bee (California)*, p. A1.

Correa, T. (2006, August 20). Code green; Community Medical Centers hopes this year for its first black ink since 2003. *Fresno Bee (California)*, p. A1.

Crestwood CEO oversees growth spurt (2008, February 24). *Huntsville Times (Alabama)*, p. 1C.

Dang, S. (2002, August 16). Heart hospital breaks ground in Wauwatosa, Wis. *The Milwaukee Journal Sentinel*.

Danner, P. (2011, January 3). Methodist Healthcare closes deal on TexSan. *Express-News*. Retrieved from http://www.mysanantonio.com/business/article/Methodist-Healthcare-closes-deal-on-Texsan-934969.php.

Dobson, A. and R. Haught (2005, October). The rise of the entrepreneurial physician. *Health Affairs*, 494-497.

Doctors joining hospital payrolls; Specialists reacting to major changes in reimbursement. (2009, May 11). *The Indiana Business Journal.*

Erikson, J. (2001, July 21). Hospital owner in Tucson, Ariz., plans to raise money for business expansion. *The Arizona Daily Star.*

Erler, S. (2006, November 2). Heartland Hospital assets sold. *nwitimes.com.*

Flynn, L. (2003, February 1). Matters of the heart; cardiac-care hospitals are finding their niche in the specialty hospital market with facilities designed to improve patient outcomes and caregiver efficiency. *Building Design and Construction*, p. 38.

Fogel, R. I. and G. S. Campbell (2003). The Heart Center of Indiana: changing the way hearts are treated. *American Heart Hospital Journal 1*(4) 304-308.

Gaines, A. (2012). St. Vincent Heart Center of Indiana. *Inside Healthcare.* Available at http://www.inside-healthcare.com/index.php/featured-reports/1103-st-vincent-heart-center-of-indiana (retrieved 4/18/2013).

Gordon, J. (2006, May 21). HCA rips Baylor-Hamilton deal. *Dallas Business Journal.*

Hospital renaming (2005, April 21). *City News Service.*

In the Spotlight. (2004, March 29). *Modern Healthcare*, p. 32.

Indeed (2001). Company information: Lubbock Heart. Retrieved from http://www.indeed.com/cm-p/Lubbock-Heart.

Kelly, N. (2004, March 25). Heart hospital to come on line. *Tulsa World (Oklahoma)*, p. A10.

Kirchheimer, B. (2010, April 20). Physician-owned doctors hospital in Texas attributes success to community focus. *Becker's Hospital Review.*

Lamb, K. (1999, September 5). A battle for broken hearts; Dayton Heart Hospital on Tuesday goes after a lucrative slice of the area heart-care market. *Dayton Daily News (Ohio)*, p. 1A.

Leduc, D (2000). Health network expands hospital fulfills old plan. *Fort Wayne News Sentinel*, p. 1A.

Lourdes, heart hospital join forces. (2008). *Louisiana Medical News.* Available at http://www.louisianamedicalnews.com/in-the-news-january-cms-1059.

Lubbock Heart Hospital (2009, January 11). Focusing on the past, present and future of Lubbock Heart Hospital. Retrieved from http://www.lubbockheart.com/imgs/logos/5th%20Anniversary%2-0Tabloid.pdf.

Manning, J. (2003, May 26). Heart hospital debate raises Milwaukee officials' blood pressure. *The Milwaukee Journal Sentinel.*

McChesney, C. (2003). Boutique cardiovascular hospitals. *Endovascular Today*, February.

MedCath Corporation (2005). *Annual Report Pursuant to Section 13 or 15(d) of the Securities Exchange Act of 1934, for the fiscal year ended September 30, 2005.*

Medical roster (2013). Heart Hospital of Lafayette. Available at http://hearthospitallaf.net/doctors.php (accessed 4/17/13).

Methodist Texsan Hospital. (2011). Methodist Healthcare. Available at http://www.sasalud.com/files/mhs-facilities/MHS-Texsan.pdf (retrieved 4/18/2013).

Morrison, P. (2001). Could a stand-alone bone hospital be next?; Orthopedics facility is subject of study, rumor. *Indiana Business Journal 22*(15), p. 5A.

Mukamel, D. B., D. L. Weimer, and A. I. Mushlin (2006, August). Referrals to high-quality cardiac surgeons: patients' race and characteristics of their physicians. *HSR: Health Services Research 41*(4), 1276-1295.

NEA Clinic and Baptist Memorial make partnership official (2007, November 6). *U.S. Newswire*.

NEA Clinic selects TouchWorks from Allscripts Healthcare Solutions (2003, April 24). *PRNewswire*.

Neal, S. J. (2003, September 14). Dayton Heart Hospital; after four years, how is the Miami Valley medical scene different? *Dayton Daily News (Ohio)*, p. D1.

Oklahoma Heart Hospital (2011). Physician owners of Oklahoma Heart Hospital. Retrieved from http://www.okheart.com/about-ohh.

Oklahoma Heart Hospital achieves paperless vision with Cerner CPOE; JCAHO awards accreditation to all-digital hospital (2003, February 6). *PRNewswire*.

Olympia Medical Center - About Us (2012). Available at http://www.olympiamc.com/AboutUs/ (retrieved 4/18/2013).

Ornstein, C. (1999, October 27). Baylor University starts work on new heart center in downtown Dallas. *The Dallas Morning News*.

Our services. (2013). Coast Plaza Hospital. Available at http://www.coastplaza.com (retrieved 4/18/2013).

Park, A. (1998, December 5). New hospital puts bet on hearts; Austin center tries to draw cardiac. *Austin American-Statesman (Texas)*, p. A1.

Physician's hospitals are a model of true health Care reform; industry looks forward to working with Obama Administration (2009, February 27). *PRNewswire*.

Quigley, W. (2002, May 22). New Mexico medical practices merge, creating largest heart group in state. *Albuquerque Journal*.

Reilly, P. (2002, September 30). Caught in the middle; a booming specialty hospital market has the AHA and state hospital associations working to balance competing interests. *Modern Healthcare 32*(39), 26-28.

Robeznieks, A. (2011). Fight and flight; Some physician investors getting out of hospital ownership while others stay their course. *Modern Healthcare 41*(14), p. 28.

Rodgers, G. P. and D. Laird. (2007). Heart hospitals with physician investors: a successful model. *American Heart Hospital Journal 5*(2), 68-72.

Rogoski, R. (2006, February). 2 + 2 = benefits by the dozen. *Health Management Technology*, p. 12.

Romano, M. (2007, January 1). Hitting resistance: two doc-owned hospitals sell to not-for-profits. *Healthcare Business News*. Retrieved from http://www.modernhealthcare.com/article/20070101/MAGAZINE/61229020.

Sack, K. and D. M. Herszenhorn (2009, July 30). Texas hospital flexing muscle in health fight. *The New York Times*.

Senator planning legislation regarding new hospital (2003, March 6). *The Associated Press State and Local Wire*.

Siebenmark, J. (2010). Wesley parent HCA to buy Galichia Heart Hospital. *Wichita Business Journal*.

Single source from day one (2002, August). *Health Data Management 10*(8), 34.

Smith, J. C. (2005, April 15). Texas legislature passes bill to force physicians to disclose ownership. *The Monitor*.

Soderholm, J. (2005). Partners for success: Avera Heart Hospital of South Dakota. *American Heart Hospital Journal 3*(2) 128-131.

Sorrel, A. (2007, January 22). Arkansas cardiologists accuse hospital of collusion. *American Medical News*.

Specialty hospitals (2005, May 15). *The Advocate (Baton Rouge, Louisiana)*, p. 1-I.

Stern, A. (2002, February 27). Health system looks to bolster position in Appleton, Wis., area. *The Post-Crescent (Appleton, WI)*.

Swiatek, J. (2003, February 14). New Indianapolis heart center offers latest in high-tech healthcare. *The Indianapolis Star*.

Tenet to sell four Arkansas hospitals, slash costs to boost profits. (2003, March 18). *The Associated Press State & Local Wire*.

Two of New Mexico's largest cardiology groups merge. (2002, May 22). *The Associated Press State & Local Wire*.

Vogeler, S. (2004, December). The heart of efficiency. *Health Management Technology 25*(12), 20-25.

Welcome to Heart Hospital of Lafayette (2013). Heart Hospital of Lafayette. Available at hearthospitallaf.net/files/Patient_Handbook.pdf (accessed 4/17/2013).