Regionalization of Cardiac Services and the Responsiveness of Treatment Choices

Justin G. Trogdon[1]

School of Economics

University of Adelaide[2]

October 2004

[1] *justin.trogdon@adelaide.edu.au*. School of Economics, University of Adelaide, Australia 5005. Phone: 61 8 8303 4821. Fax: 61 8 8223 1460.

[2] I would like to thank Frank Sloan, Peter Arcidiacono, Ahmed Khwaja, and Kevin Schulman for all their help and advice. I would also like to thank Thomas Ahn, Derek Brown, Stephen Ryan and participants in the Applied Microeconomics Lunch Group at Duke University for comments. Lesley Curtis and Judith A. Stafford provided assistance in assembling the data for this research. The contents of this publication do not necessarily reflect the views of the Department of Health and Human Services, nor does mention of trade names, commercial products, or organizations imply endorsement by the US government. The author assumes full responsibility for the accuracy and completeness of the ideas presented. This article is a direct result of the Health Care Quality Improvement Program initiated by the U.S. Health Care Financing Administration, which has encouraged identification of quality improvement projects derived from analysis of patterns of care.

Abstract

Efforts to regionalize cardiac services can increase access costs for patients. This study is the first to quantify this trade off by estimating a demand model for surgery services that is used simulate the effect of centralization of cardiac services on hospital and treatment choices. The model is estimated using a sample of Medicare beneficiaries from the Cooperative Cardiovascular Project. Regulation policies that alter both the quality of providers and access to the providers, such as minimum volume thresholds, need to consider that patients will respond to changes in both dimensions.

KEYWORDS: heart attack, Medicare, volume, discrete choice estimation

JEL CLASSIFICATION: I18, C35

A large medical literature has found that higher volume surgery hospitals have better health outcomes from surgery (for reviews of the literature see [1] and [2]). The volume literature has suggested policies based on these findings, often that hospitals offering surgery services should perform a minimum number of procedures per year. Groups such as the Leapfrog group, a consortium of insurers and providers, have recommended minimum volume thresholds (e.g., 500 coronary artery bypass grafts (CABGs) per year) to be met by surgery providers [3]. These recommendations are the result of a literature that deals almost exclusively with estimating a type of health production function with provider volume as an input. The volume literature does not model the decision-maker's optimization problem and therefore can say little about predicted behavior in the face of changing regulation.

In the case of cardiac facilities, regulators face a trade off between proximity and intensity of use. Prompt treatment of heart attacks can improve health outcomes dramatically. The majority of empirical studies of hospital choice have found that distance/travel time was the primary factor in choice of hospital [4]. While distance is important, there is also evidence that patients are willing to travel a little farther in order to take advantage of facilities at higher quality hospitals [5, 6]. The willingness to trade distance for quality is likely a nonlinear function of health status: patients with extremely mild or severe attacks might not find the additional services worth the cost of travel. Thus, one important issue in the regulation of services is the effect it will have on access costs for patients, costs that might be more likely to be borne for higher quality services and costs that vary by health status [7].

This study is the first to quantify the trade off between distance and volume in estimating the effects of changes in the regulation of hospital services. It does this by estimating a model of demand that accounts for the trade offs between distance and volume at the individual level. It improves on the hospital choice literature by incorporating a unique data set with excellent information about health status. Recent studies in the volume literature have begun to address the trade off by examining the effects of simulated closures of low-volume providers on travel distances to remaining providers [1, 8-10]. This model extends the volume literature by allowing individuals, in conjunction with their health care providers, to respond to changes in regulation policy in their hospital and treatment choices.

The Cooperative Cardiovascular Project (CCP) is a sample of Medicare beneficiaries that had heart attacks in 1994-1995. Collected from medical chart review, it provides extremely detailed information concerning health status at each stage of the treatment process. For example, the data provide information concerning the results of diagnostic tests describing the severity of the heart attack. The CCP data allow preferences for hospitals and treatments to vary by health status at a level previously unavailable to most researchers and are linked to Medicare claims data to allow for transfers between hospitals.

The treatments this study will focus on are catheterization, percutaneous transluminal coronary angioplasty (PTCA), and CABG. Catheterization is used to visualize the blood flow in coronary arteries and serves as a diagnostic tool to determine the necessity of revascularization surgeries such as angioplasty and bypass surgery. Angioplasty uses a small balloon to open up blood flow in a blocked artery. Bypass surgery uses veins from other parts of the body to create an alternate path for blood flow around the blocked artery. In what follows, "surgery" refers to angioplasty or bypass surgery.

The data are used to estimate a model of the demand for high-tech cardiac services. The model's key feature is that individuals take into account the effectiveness of surgery when making treatment decisions. Thus, individuals respond to changes in the effectiveness of treatment in all stages of the treatment process: admitting hospital, diagnostic procedures, and curative treatment. For example, lower hospital surgery volume makes surgery less effective in reducing mortality and, therefore, surgery services less attractive to an individual in his choice of hospital.

The results indicate that individuals respond to both changes in distance and volume. Holding all else constant, a 10% decrease in the distance to the nearest surgery hospital increases the probability of choosing a surgery hospital by 0.9% and increases catheterization and surgery rates by 0.2%. Reductions in volume have the opposite effect. A 10% reduction in volume, holding all else constant, decreases the probability of choosing a surgery hospital by 0.3% and decreases catheterization and surgery rates by 0.1%.

In policy simulations where minimum volume thresholds are enforced for surgery hospitals, even relatively low thresholds lead to substantial decreases in the probability of a patient undergoing surgery. For instance, eliminating all surgery services performing less than 50 Medicare surgeries per year decreases the probability of choosing a surgery hospital by 23%, decreases catheterization rates by 6%, and decreases surgery rates by 8%.

Thus, there is evidence that patients respond to changes in quality in their hospital and treatment decisions. Regulation policies that alter both the quality of providers and access to the providers need to consider that patients will respond to changes in both dimensions, which directly impacts treatment rates and subsequently health outcomes. It is important to note that this is a partial equilibrium result: the demand model in this study does not capture supply-side changes in the market induced by alternative policies.

The study proceeds as follows. The next section reviews the hospital choice and volume-outcome literature with an emphasis on the contribution of the current research. Section II describes the data and sample used to estimate the model. Section III presents the discrete choice model and empirical specification. Section IV provides estimation results and shows the predicted effects of further regionalization of surgery services. Section V concludes.

I. The Trade Off between Distance and Volume

The primary focus of this study is the trade off many patients and physicians face between choosing a hospital that is close and choosing a hospital that is of high quality. In the treatment of most health events, delays in seeking care lead to worse health outcomes. For this reason, the majority of empirical studies have found that distance/travel was the primary factor in choice of hospital (for a review of this literature, see [4]). These studies included a large variety of choice characteristics that could alter the (indirect) utility from choosing a particular provider but often had little information about the individual; typically only age, gender, and race. Especially in an individual's choice of hospital, health status or the severity of illness could affect preferences for features of the hospitals in the choice set. For instance, preferences for hospitals with cardiac surgery capabilities would likely be highest for those individuals whose health outcomes would benefit the most from surgery. Especially for emergency conditions such as heart attacks, health status at admission may be more important in determining health outcomes than certain aspects of quality of the admitting hospital [11].

Despite the urgent nature of heart attacks, there are reasons to believe that a trade off between distance and quality could still occur. First, ambulance protocols allow discretion in the choice of hospital based on the health status of the patient [12]. Furthermore, paramedics can begin basic treatment before arrival at the hospital, which might provide incentives to seek better quality hospitals when available [13]. Second, many individuals do not use emergency medical services (EMS). Studies have found that only 42 to 45% of heart attack patients used ambulatory services to get to the hospital [13, 14]. Couple this with the fact that most individuals significantly delay seeking care at all [15], and it is possible that once they decide to go to the hospital, they might use discretion. Third, heart attack has been used as the primary diagnosis before in the literature [5, 6, 16]. Evidence concerning the trade off between distance and service offerings is given below.

Three previous studies included health status measures in the models of hospital choices [7, 17, 18]. The results indicated that severity of illness was an important determinant of hospital choice: "Regardless of how the hospital choice equations are used, our results indicate that they are misspecified if relative severity and complexity of illness is not accounted for" [7, p. 609]. However, the health status measures they used were either aggregate measures over many diseases or dichotomous.

This model extends previous work in the hospital choice literature by incorporating detailed information about health status. Focusing on individuals diagnosed with one particular condition, heart attack, allows the use of an index of severity of illness that captures the important features of health status known at the time of the hospital decision; that is comparable across individuals; and that takes on a range of values, which allows a test for a gradient effect of severity on preferences for specialized services.

The primary quality measure considered in this study is hospital surgery volume. A large medical literature has found that larger volume was associated with better health outcomes [1, 11, 19-21]. (Hamilton and Hamilton [22] is an exception looking at hip surgery.) There are three primary explanations for the observed relationship between volume and outcomes [11]. The first explanation posits a direct causal pathway: physicians and hospitals learn how to treat a patient or master a procedure by seeing more patients with the same diagnosis or repeating a procedure (i.e., learning-bydoing). The second explanation is reverse causation: providers with good outcomes attract more patients (i.e., selective referral). The third explanation is that the correlation between outcomes and provider volume is spurious, the result of an omitted variable bias. Thus, some other provider attribute, which is correlated with volume (e.g., teaching status of the hospital), directly affects patient outcomes. Despite caveats raised by the empirical issues above, most researchers agree that a relationship exists between volume and outcomes.

Given that volume relates to better outcomes, many types of policy recommendations have been issued to promote regionalization (or centralization) of services. If increased volume truly causes better health outcomes (and perhaps lower costs), then patients (and tax payers) would benefit from shifting procedures from low-volume providers to high-volume providers. Even if volume is simply correlated with the true mechanism improving outcomes, there is still rationale for policies based on provider volume. Volume is an easily measurable proxy of quality in this case, especially given the difficulty in collecting and disseminating more direct, risk-adjusted data on quality and process mechanisms. Groups such as the Leapfrog group, a consortium of insurers and providers, have recommended minimum volume thresholds (e.g., 500 CABGs per year) to be met by surgery providers [3].

A cost to regionalization is the effects that regionalization has on access to surgery for patients [3, 23]. Centralization of surgery services has the potential of increasing travel times for many patients, especially in rural areas. This implies that proponents of regionalization should consider the distributional effects for patients.

A few studies have attempted to consider such distributional effects [1, 8-10]. These studies simulate closure of low-volume providers and re-calculate the distances that patients would need to travel to reach a remaining (high-volume) surgery provider. These studies provide a starting place for assessing the effects of regionalization as a policy goal on patient access to services. However, these papers cannot make predictions about patient choice of provider and the subsequent treatment choices such as surgery. More studies need to be done to assess patients' willingness to travel to high-volume hospitals; patients might be willing to travel for major procedures [1]. This study estimates just such a model.

II. The Cooperative Cardiovascular Project

Regulation changes that alter the number and location of cardiac services within a market will lead to changes in the demand for those services and hospitals offering those services, as well as potentially affect health outcomes. Large, regional cardiac services may provide benefits through higher procedure volumes, but at the cost of decreased access to care. The data used in this study are excellent for studying the changes in demand that result from such policy changes.

First, the data set used in this study is a large, nation-wide sample of individuals, which provides power to help identify parameters associated with rare health events. The data also contain geographic identifiers that make it possible to trace the effects of changes in the effectiveness of treatment (e.g., changes in hospital surgery volumes) back to the choice of hospital; individuals face a trade off between travel time to a hospital and the presence and effectiveness of cardiac surgery at the hospital and will respond to changes in either dimension.

Second, the data provide extremely detailed information concerning health status at each stage of the treatment process: existing co-morbidities at the time of the heart attack, initial severity of the heart attack at admission to the hospital, and the results of diagnostic tests that provide information about the need for curative treatment. The availability of information concerning co-morbidities at the time of the choice of hospital allows preferences for hospitals to vary by health status in a more detailed way than in previous hospital choice studies. The information about severity of the heart attack is unique to clinical data and not available in administrative discharge records. It provides important information to identify treatment choices. The data also include records of treatments received in the case of transfer to another hospital, allowing the researcher to observe the full set of treatment choices for each individual.

The primary data for the individuals in the study come from the Cooperative Cardiovascular Project (CCP). The CCP was initiated by the Medicare program with the goal of improving quality of treatment received by Medicare patients experiencing heart attack [24, 25]. The CCP collected patient data through medical record review for a nationally representative random sample of Medicare patients.

The original CCP sample consisted of randomly selected patient records for patients admitted to non federal acute care hospitals between February 1994 to July 1995 with a primary diagnosis of AMI (ICD-9-CM 410, excluding a fifth digit of 2; N = 187,007). Some patients in the CCP sample were transferred to other hospitals. The CCP sample is merged with the respective Medicare Part A claims data for these and subsequent admissions. The data are merged by including in an episode of care all of the admissions that occurred consecutively, or within one day of each other. The claims data allow me to construct the remaining treatments received by individuals originally admitted to hospitals participating in the CCP. The claims data are also used to calculate the Medicare surgery volume for each hospital in the sample.

Hospital data come from the American Hospital Association's (AHA) Annual Survey of Hospitals 1994 and 1995. Distances between individuals and hospitals are calculated using zip code data from MapInfo 5.0. Using the latitude and longitude for the centroid of each zip code, straight-line distances in miles are calculated using standard great circle trigonometric formulas. Phibbs and Luft [26] have shown that use of straight-line distance rather than road distance often does not significantly impact hospital choice estimates.

The sample used in estimation meet the following criteria. First, since the CCP is a sample of Medicare beneficiaries, each admission should have Part A claims data available; individuals who had admissions without such data, or admissions to other specialized types of hospitals, are dropped (N = 8,565).

Second, in order to make sure that the complete episode, or sequence of admissions, for a particular heart attack was available, all individuals are dropped who had previous episodes in the data or were first admitted from somewhere other than home (N = 47,432). This sample cut is made for two reasons. First, patients initially transferred from another hospital have had previous and unknown care. Second, the distance calculations were made based on zip code of residence. For patients admitted from other locales these calculations would be incorrect.

Third, individuals who chose hospitals outside of the designated choice set are dropped (N = 45,191). The choice set is the nearest hospital in each of three service categories: no specialized services, catheterization only, and open-heart surgery. Each of these service categories, if chosen by an individual, provides a unique set of treatment choices. At the same time, heart attack victims are not expected to bypass several hospitals for treatment. In addition, this definition of the choice set keeps the size of the decision tree manageable. The remaining sample of patients is more likely to have had their heart attacks close to home, minimizing the error in the distance calculations.

Finally, patients who had unexplained sequences of procedures are dropped from the sample (N = 3,764). For example, these include patients with procedures at hospitals that did not have a record for those facilities, patients who had surgery recorded without a diagnostic procedure, patients who had multiple procedures recorded, and a small set of patients who transferred to hospitals that did not offer heart surgery. This leaves a sample of 82,055 patients for the analysis.

Due to the size of both the sample and the choice set in the empirical model below, the model is estimated using a random sub-sample of one third of the patients (N = 27,083). The results from estimation using the other two sub-samples of one third of the patients were nearly identical to those reported here.

The sub-sample used for estimation closely matches the demographic and health characteristics of the full sample (Table 1). The mean age in both samples is 77. Both samples are evenly divided between men and women, contain similar shares of minorities (9%), and are mostly urban (71%).

The samples exhibit substantial variation in health status and heart attack severity. Nearly half of the samples have significant co-morbidities as measured by the Charlson index [27]. The Charlson score is a weighted sum of co-morbidities, where the weights are proportional to the risk of death from each co-morbidity. Higher values indicate worse health.

Also, approximately half of the samples have evidence of at least moderate congestive heart failure (CHF) at presentation to the hospital (i.e., Killip class greater than I). Killip class, a measure of severity at admission, is used as the initial assessment of the severity of the heart attack. Using a method developed by Killip and Kimbal [28], heart attack patients are classified into one of three classes: those with no evidence of congestive heart failure (CHF) (1), those with mild to moderate CHF (2), and those with overt pulmonary edema and/or cardiogenic shock (3). Thus, a higher classification indicates a more severe heart attack. Killip class has been shown in the medical literature to provide a concise representation of the severity of heart attacks [29, 30]. Finally, the vast majority of those patients who received information concerning systolic function by having catheterization show a moderate reduction; approximately 10% of individuals have severe reduction.

Most patients chose no-service hospitals for the initial admission (38%). Treatment choices are combinations of a choice for procedure and transfer to another hospital. One third of the sample has catheterization and half of those patients go on to have surgery. Approximately 16% of patients are transferred during the treatment process.

Hospital characteristics are reported for each year of the AHA survey (Table 2). No-service hospitals are the most common type of hospital in the sample; catheterization-only hospitals are the most rare type. Medicare surgery volumes typically represent one fourth to one half of the total number of surgeries performed at a hospital [20]. The Medicare surgery volumes in the estimation sample correspond to average overall hospital surgery volumes between 70 and 105 in 1994 and between 115 and 170 in 1995. There is large variation in the size of the hospitals in the sample as measured by the number of beds set up and staffed; the standard deviation is almost as large as the mean in the samples. Approximately 40% of the hospitals have a cardiac intensive care unit (CICU). The majority of hospitals have non-profit ownership status and are non-teaching hospitals.

III. Model of Hospital and Treatment Decisions

It is assumed that individuals and their providers have identical preferences over hospitals and treatments. Equivalently, the provider's role is that of a perfect agent, providing information to the individual, who then has the final decision concerning care. Data limitations preclude any attempt to account for more complex agency relationships (see [31] for a review of the agency literature in health economics). In what follows, “individual” refers both to the patient and to the collection of decision-makers working on behalf of the patient.

Consider the choices available to a heart attack victim as a sequence of treatment decisions. Based on information about his initial health status and his preferences for types of hospitals, some of which are unobserved to the econometrician, the individual then chooses a hospital. Empirically, the choice set includes the nearest hospital in each of three service categories: no specialized services, catheterization only, and open-heart surgery.

Afterward, the individual receives initial information about the severity of the heart attack. With this new information he chooses whether or not to undergo catheterization, which could include transfer to another hospital. Empirically, the choices include no transfer/no catheterization, no transfer/catheterization, transfer/no catheterization, and transfer/catheterization, respectively. The catheterization choice set is restricted in some cases by the choice of hospital. For example, if a no-service hospital is chosen, then the catheterization choices are limited; no transfer/catheterization is not an option.

Finally, conditional on choosing catheterization, the individual receives information about the systolic functioning of their heart. He then chooses a surgery option, which could include a transfer. The surgery options available to individuals in the third period are no transfer/no surgery, no transfer/surgery, transfer/no surgery, and transfer/surgery. The surgery choice set is also conditional on previous decisions. Specifically, surgery is only available to individuals who received catheterization. Table 3 shows the decision tree facing an individual having a heart attack in the model. Each individual chooses one of the 14 combinations of hospitals and treatments in order to maximize utility.

The nature of the decision process presented above leads naturally to a nested logit (NL) estimation strategy. Consider characterizing the treatment regiment for a patient as choosing from the complete set of choices observed at the end of the process (e.g., no-service hospital, transfer/catheterization, and no transfer/surgery as one outcome). In many applications the nesting of choices is rather ad hoc but here the sequential nature of the decision leads to natural branches in the decision tree (see Table 3). Thus, the NL model can be viewed as a static version of a dynamic model, a version in which the individual chooses the complete path of treatment simultaneously.

For the nested logit model, consider a linearized version of the utility function for the hospital choice j, catheterization choice c, and surgery choice s:

$$(1) \qquad U_{scj} = \beta' X_j + \theta' Y_{cj} + \alpha' Z_{scj} + \varepsilon_{scj}$$

Here $\beta' X_j$ represents the utility that varies with choice of hospital. X_j includes: initial health status as measured by the Charlson index interacted with hospital service indicators, distance from the patient to the hospital, distance interacted with a MSA dummy, and distance interacted with initial health status. This specification allows preferences for types of hospitals to vary by the health of the individual and the (dis) utility of travel costs to also differ by health status in a more detailed way than in previous studies.

X_j also includes demographic characteristics interacted with hospital service indicators (i.e., age, gender, and race); hospital Medicare surgery volume; the number of beds; and indicators for whether the hospital has a CICU, ownership (for-profit, government, and non-profit omitted), and teaching status (major teaching hospital, minor teaching hospital, and non-teaching hospital omitted). In the nested logit model each level of nests must have variation in the data that belongs only to that nest. Since demographic and hospital information is known at the beginning of the decision process, these variables are assigned to the first nest of hospital choices. However, the utility derived from these characteristics most likely derives from their expected impact on health outcomes.

Y_{cj} captures the information about initial severity that is revealed at admission to a hospital and varies only within catheterization choice. Specifically, Y_{cj} includes Killip class interacted with catheterization choice indicators. The coefficients specific to each of the catheterization choices are constrained to be the same across the types of hospitals. Thus, catheterization involves the same level of discomfort at surgery hospitals as at catheterization-only hospitals.

Z_{scj} includes variables specific to the surgery decision: the information on systolic function revealed by the catheterization interacted with surgery choice indicators. Again, the coefficients specific to each surgery choice are constrained to be equal across catheterization branches. Those patients with missing blockage status are considered the reference category in the interactions.

Assuming the stochastic utility components, ε_{scj}, are i.i.d. generalized extreme value (GEV) gives choice probabilities

$$(2) \qquad P_{scj} = \frac{\exp(U_{scj})}{\sum_{l=1}^{J}\sum_{m=1}^{C}\sum_{n=1}^{S}\exp(U_{nml})}$$

where P_{scj} is the probability of observing choice $\{j,c,s\}$. The GEV assumption allows the variance of the unobserved tastes components to vary across groups of choices (nests). Estimation of the NL model consists of breaking the joint probability of observing each combination of choices into smaller conditional probabilities:

$$(3) \qquad P_{scj} = P_{s|cj} \cdot P_{c|j} \cdot P_j$$

$P_{s|cj}$, the probability of observing surgery choice s conditional on hospital and catheterization choices j and c, depends only on the blockage information revealed by catheterization:

$$(4) \qquad P_{s|cj} = \frac{\exp(\alpha' Z_{scj})}{\sum_{n=1}^{S|cj} \exp(\alpha' Z_{ncj})}$$

Thus it is possible to estimate α using just this information.

Now, to estimate θ, define the inclusive value

$$(5) \qquad I_{cj} \equiv \log\left(\sum_{n=1}^{S|cj} \exp(\alpha' Z_{ncj})\right)$$

which means the probability of catheterization conditional on hospital choice can be written

$$(6) \qquad P_{c|j} = \frac{\exp\left(\theta' Y_{cj} + \left(1/\mu_{c|j}\right) I_{cj}\right)}{\sum_{m=1}^{C|j} \exp\left(\theta' Y_{mj} + \left(1/\mu_{m|j}\right) I_{mj}\right)}$$

$\mu_{c|j}$ is the scale parameter associated with the level of surgery choices and measures the similarity of observed choices at that level.

An analogous procedure is used to construct the probability of hospital type:

$$(7) \qquad P_j = \frac{\exp\left(\beta' X_j + \left(1/\rho_j\right) I_j\right)}{\sum_{l=1}^{J} \exp\left(\beta' X_l + \left(1/\rho_l\right) I_l\right)}$$

where

$$(8) \qquad I_j \equiv \log\left(\sum_{m=1}^{C|j} \exp\left(\theta' Y_{mj} + \left(1/\mu_{m|j}\right) I_{mj}\right)\right)$$

ρ_j is the scale parameter associated with the sets of choices at the catheterization level. In this framework, α is identified up to a scale factor of $\mu_{c|j}$ and θ to a scale factor of ρ_j.

The parameters are estimated jointly using full information maximum likelihood of the form

$$(9) \qquad \ln L = \sum_{n=1}^{N} \ln\left[P_{s|cj} \cdot P_{c|j} \cdot P_j\right]_i$$

IV. Regionalization of Cardiac Services

The primary trade off that this study focuses on can be seen in the coefficients on the distance variables and volume for choice of hospital (Table 4). An increase in the distance to a hospital lowers the utility from choosing that hospital and the disutility is larger in urban areas where travel time for any given distance is likely to be greater. This result is consistent with findings in most previous hospital choice studies. At the same time, hospitals with higher surgery volumes are more attractive to heart attack victims, holding all else constant.

Parameter estimates of nested logit models are difficult to interpret due to the normalizations required and the nonlinearity of the model. The marginal effects of interacted variables in nonlinear models are not indicated by the estimated coefficients and can differ in sign [32]. Reductions in distance increase the probability that an individual will choose a surgery hospital. This means that fewer patients will need to transfer in order to have catheterization and surgery, which increases surgery rates. A 10% decrease in distance to the nearest surgery hospital, holding all else constant, increases the probability of an individual choosing a surgery hospital by 0.9% and increases surgery rates by 0.2%.

Changes in surgery volume have the opposite effect on choice probabilities. Reductions in surgery volume make surgery hospitals, catheterization, and surgery less attractive. A 10% decrease in Medicare surgery volume at the nearest surgery hospital, holding all else constant, decreases the probability of choosing a surgery hospital by 0.3% and decreases the probability of surgery by 0.1%.

The estimates for the effect of other hospital characteristics on hospital choice in the first nest are the most straightforward to interpret. Conditional on other features like distance, heart attack victims appear to prefer larger hospitals with specialized services like a CICU. They also tend to prefer non-profit hospitals that are typically larger and offer a larger range of services not measured here. It appears minor teaching hospitals are the preferred type of teaching hospital, but it should be emphasized that this result is conditional on other measures of the scope of the hospital such as size and surgery volume.

The estimates suggest that preferences for hospital surgery services vary by health status. All of the demographic and health status parameters are relative to choosing a hospital with no specialized services. The interactions between initial health status as measured by the Charlson index and the hospital service categories are all significant at the 95% confidence level. Moving from the lowest Charlson category to the highest category increases the probability of choosing a surgery hospital by 7.1% on average. There do not appear to be any significant differences in preferences for hospital services across age and gender but minorities do have significantly different preferences for hospital services.

The parameters for the catheterization choice are relative to choosing no transfer/no catheterization. All of the interactions of more severe Killip class with transfer and catheterization choices are negative and significant. The benefits to these choices are in improved health outcomes, which do not appear explicitly in the nested logit model.

The results for the surgery nest are also difficult to interpret due to the nature of the normalization. Within each set of choice interactions the reference group is the patients with unknown blockage status, which consists of two groups: patients that transferred to a non-CCP hospital for catheterization and patients who did not have catheterization. The first group of patients could go on to have surgery, but the (larger) second group of patients could not have surgery. Thus, the positive coefficients for no transfer/surgery indicate that patients with known blockage statuses, who have had catheterization, are more likely to undergo surgery. The policy simulations using the nested logit results will allow changes in the distance to the nearest surgery hospital and the surgery volume at that hospital to affect decisions at all periods.

Note that some of the inclusive values are identically one. This occurs for the catheterization branches that only have one choice available for surgery, namely the branches that include no catheterization (see Table 3).

The policy recommendations that have resulted from the medical literature have largely focused around the setting of volume thresholds below which hospitals providing the surgery services should reconsider their provision. Grumbach et al. [8] and Birkmeyer et al. [10] were the first to address the trade off between distance and volume in the presence of existing thresholds. They simulate elimination of low-volume surgery services and re-calculate the travel times to the remaining high-volume surgery hospitals. Using the estimates from the model presented above, it is possible not only to replicate their policy experiments, but to extend the results to predict what would happen to the choice of hospital and treatments.

The following policy simulations use the estimation results to eliminate low-volume surgery services from the choice set and predict the optimal choices for individuals. The simulations use threshold levels of 50, 100, and 200 procedures per year. In 1995, 50 procedures was roughly the 60th percentile, 100 procedures was roughly the 80th percentile, and 200 procedures was roughly the 95th percentile of surgery hospitals. If Medicare patients make up one fourth to one half of total procedures, then this corresponds to thresholds from 100 to 800 angioplasties and bypass surgeries per year. The Leapfrog group recommends 500 CABGs per year.

Table 5 shows how elimination of low-volume surgery services affects distance to the nearest surgery hospital. It shows the share of patients from the estimation sample that live within given distances of a surgery hospital. There are rather dramatic changes in distance to surgery providers when low-volume services are removed. When surgery services with less than 50 procedures a year are eliminated, the share of patients living within 5 miles of a surgery hospital falls from 36% to 22%. In addition, the share of patients at least 50 miles from a surgery hospital more than doubles from 7% to 18%. Under the policy with the highest threshold (200 procedures per year), 71% of individuals would have to travel over 50 miles to reach the nearest surgery hospital.

Where previous studies of centralization end here, the model estimated in this study allows analysis of the effect of enforcement of volume thresholds on treatment decisions. Table 6 shows the results of removing the low-volume services and predicting hospital and treatment choices. The first two rows of Table 6 show the fit of the nested logit model. The first row shows the mean distance in miles to the nearest surgery hospital, the mean Medicare surgery volume, and the frequencies of choices in the estimation sample. The second row shows the predicted choice frequencies from the nested logit model. The model fits the data reasonably well. The choices of surgery hospital and surgery predictions are very close to the frequencies in the data. The nested logit model slightly under predicts catheterization rates and over predicts transfer rates. There are many branches of the decision tree involving transfer that have very few observations in the data (e.g., see Table 1). The logit form assigns positive probability to each outcome for each person. When summed over all the branches this leads to an over estimate of the probability of transfer.

The next rows of Table 6 show the new mean distances to the nearest surgery hospital; mean Medicare surgery volume; and predicted choice probabilities, with percentage changes from the baseline prediction in parentheses, under the different volume threshold policies. When surgery services with less than 50 procedures per year are eliminated, the fraction of individuals choosing surgery hospitals falls by 23% (from 36% to 28%). Thus, in order to receive surgery, more patients have to transfer (29% vs. 26%). The net effect of the large decrease in admissions to surgery hospitals and the smaller increase in transfers is that surgery rates fall by 8% (15% vs. 16%).

Eliminating surgery services with less than 100 procedures per year decreases the fraction of patients admitted initially to surgery hospitals to 19%. Consequently, transfers increase by 25%. Catheterization rates decrease by 13% and surgery rates decrease 18% from the baseline predictions. The more stringent threshold of 200 procedures per year shows the same patterns as above except the magnitude of the effects is much larger. This policy effectively eliminates almost all existing surgery services and leaves the average heart attack victim hundreds of miles from a surgery hospital.

In general, enforcement of threshold volume levels leads to a decrease in the share of individuals choosing surgery hospitals initially, an increase in transfer rates, leading to a net decrease in surgery rates. This provides empirical evidence for the trade off between distance and volume: policies intended to capitalize on the benefits of increased volumes will lead to some patients no longer receiving catheterization and surgery.

V. Conclusion

State regulators face a trade off between concentrating the number of procedures performed at hospitals and reducing the access to cardiac services by increasing the travel time to these services. A large literature has shown that increased surgery volume at a hospital reduces patient mortality. Thus, as patients and physicians weigh the costs and benefits of surgery, regionalizing cardiac service hospitals may increase or decrease both surgery rates and mortality. This study models the hospital and treatment decisions of heart attack victims. It accounts for detailed health status of the patient and the ability of patients to transfer to surgery hospitals during their treatment episode. The model provides predictions of the changes in hospital choices and procedure rates resulting from changes in the distance to the nearest surgery hospital and surgery volume at those hospitals.

The results indicate that heart attack patients consider quality in their hospital decisions: increases in hospital surgery volume, which improve the benefit to surgery, increase not only surgery rates, but also catheterization rates and the probability of choosing a surgery hospital for treatment. At the same time, increases in the distance to the nearest surgery hospital have the opposite effect—they decrease procedure rates and the likelihood of choosing a surgery hospital. Thus, the model quantifies the trade off faced by regulators considering changes in the supply of cardiac services in a market. The results indicate that policy makers need to consider the responsiveness of patients to changes in quality and access when considering regulations in the hospital market.

This study has limitations. First, up to 50% of all heart attack deaths occur before the individual reaches the hospital [15]. Thus, the CCP sample suffers from a form of selection; the patients with reported health status and hospital choices are systematically different than those heart attack victims not observed. In order to implement corrections for selection, some information about the selected sample would be necessary. This information is not available for hospital-based samples. If the sample of heart attack victims that were not admitted to a hospital had (ex ante) higher preferences for service offerings (e.g., if they died in transit to surgery hospitals), then the policy simulations above underestimate the costs of centralization, which would place surgery hospitals farther from these patients.

Second, this study assumes a direct relationship between volume and improved health outcomes. The volume literature has not reached a consensus as to the magnitude of this relationship. The CCP is rich enough to potentially estimate the effect of hospital surgery volume on health outcomes and formally incorporate patients' expectations of this effect in the model.

Finally, these results capture only the demand-side response to changes in the market for cardiac services. Due to substantial deviations from the competitive model in the hospital industry [33], the theoretical implications of increased competition are often ambiguous in this context (see [34] and [35] for reviews of this literature). Under cost-based reimbursement, the presence of insurance can lead hospitals to compete on the basis of quality, which can lead to increases in costs.

However, since Medicare converted to a prospective payment system, there is some evidence that competition lowers costs [36]. If this were indeed the case, the effects of centralization of cardiac services described above (decreased surgery rates and associated costs) would be partially offset by the decrease in competition. A full analysis of the welfare gains from centralization would have to take this into consideration.

References

1. Dudley RA, Johansen KL, Brand R *et al*. Selective referral to high-volume hospitals: estimating potentially avoidable deaths. *JAMA* 2000; 283: 1159-1166.
2. Halm EA, Lee C, Chassin MR. Is volume related to outcome in health care? A systematic review and methodologic critique of the literature. *Ann Intern Med* 2002; 137: 511-520.
3. Shahian DM, Normand ST. The volume-outcome relationship: from Luft to Leapfrog. *Ann Thorac Surg* 2003; 75: 1048-1058.
4. Porell FW, Adams EK. Hospital choice models: a review and assessment of their utility for policy impact analysis. *Med Care Res Rev* 1995; 52: 158-195.
5. Hodgkin D. Specialized service offerings and patients' choice of hospital: the case of cardiac catheterization. *J Health Econ* 1996; 15: 305-332.
6. Tay A. What can patient outcomes tell us about the difference in hospital quality? Working paper: Columbia University, 2002.
7. Adams EK, Houchens R, Wright GE *et al*. Predicting hospital choice for rural Medicare beneficiaries: the role of severity of illness. *Health Serv Res* 1991; 26(5): 583-612.
8. Grumbach K, Anderson GM, Luft HS *et al*. Regionalization of cardiac surgery in the United States and Canada: geographic access, choice, and outcomes. *JAMA* 1995; 274: 1282-1288.
9. Chang RK, Klitzner TS. Can regionalization decrease the number of deaths for children who undergo cardiac surgery? A theoretical analysis. *Pediatrics* 2002; 109(2): 173-181.
10. Birkmeyer JD, Siewers AE, Marth NJ *et al*. Regionalization of high-risk surgery and implications for patient travel times. *JAMA* 2003; 290(20): 2703-2708.
11. Luft HS, Garnick DW, Mark DH *et al*. *Hospital Volume, Physician Volume, and Patient Outcomes*. Health Administration Press Perspectives: Ann Arbor, 1990.
12. Athey S, Stern S. The adoption and impact of advanced emergency response services. In *The Changing Hospital Industry: Comparing Not-for-Profit and For-Profit Institutions*, Cutler DM (ed.). University of Chicago Press: Chicago, 2000; 113-168.
13. Meischke H, Ho MT, Eisenberg MS *et al*. Reasons patients with chest pain delay or do not call 911. *Ann Emerg Med* 1995; 25: 193-197.

14. Gurwitz JH, McLaughlin TJ, Willison DJ *et al*. Delayed hospital presentation in patients who have had acute myocardial infarction. *Ann Intern Med* 1997; 126(8): 593-599.
15. Dracup K, Moser DK, Eisenberg M *et al*. Causes of delay in seeking treatment for heart attack symptoms. *Soc Sci Med* 1995; 40(3): 379-392.
16. Tay A. Assessing competition in hospital care markets: the importance of accounting for quality differentiation. *Rand J Econ* 2003; 34(4): 786-814.
17. Phibbs CS, Mark DH, Luft HS *et al*. Choice of hospital for delivery: a comparison of high-risk and low-risk women. *Health Serv Res* 1993; 28: 201-222.
18. Dranove D, White WD, Wu L. Segmentation in local hospital markets. *Med Care* 1993; 31: 52-64.
19. Hannan EL, Racz M, Ryan TJ *et al*. Coronary angioplasty volume-outcome relationships for hospitals and cardiologists. *JAMA* 1997; 277: 892-898.
20. Jollis JG, Peterson ED, Nelson CL *et al*. Relationship between physician and hospital coronary angioplasty volume and outcome in elderly patients. *Circulation* 1997; 95: 2485-2491.
21. Canto JG, Every NR, Magid DM *et al*. The volume of primary angioplasty procedures and survival after acute myocardial infarction. *N Engl J Med* 2000; 342: 1573-1580.
22. Hamilton BH, Hamilton VH. Estimating surgical volume-outcome relationships applying survival models: accounting for frailty and hospital fixed effects. *Health Econ* 1997; 6: 383-395.
23. Norton EC, Garfinkel SA, McQuay LJ *et al*. The effect of hospital volume on the in-hospital complication rate in knee replacement patients. *Health Serv Res* 1998; 33(5): 1191-1210.
24. Jencks SF, Wilensky GR. The health care quality improvement initiative: a new approach to quality assurance in Medicare. *JAMA* 1992; 268: 900-903.
25. Ellerbeck EF, Jencks SF, Radford MJ *et al*. Quality of care for Medicare patients with acute myocardial infarction: a four-state pilot study from the Cooperative Cardiovascular Project. *JAMA* 1995; 273: 1509-1514.

26. Phibbs CS, Luft HS. Correlation of travel time on roads versus straight line distance. *Med Care Res Rev* 1995; 52(4): 532-542.

27. Charlson ME, Pompei P, Ales KL *et al*. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987; 40: 373-383.

28. Killip T III, Kimbal JT. Treatment of myocardial infarction in a coronary care unit. *Am J Cardiol* 1967; 20: 457-464.

29. Rott D, Behar S, Gottlieb S *et al*. Usefulness of the Killip Classification for early risk stratification of patients with acute myocardial infarction in the 1990s compared with those treated in the 1980s. *Am J Cardiol* 1997; 80(7): 859-864.

30. DeGeare VS, Boura JA, Grines LL *et al*. Predictive value of the Killip Classification in patients undergoing primary percutaneous coronary intervention for acute myocardial infarction. *Am J Cardiol* 2001; 87(9): 1035-1038.

31. McGuire TG. Physician agency. In *Handbook of Health Economics*, Culyer A, Newhouse JP (eds), vol. 1. Elsevier Science: Amsterdam, 2000; 461-536.

32. Ai C, Norton EC. Interaction terms in logit and probit models. *Econ Lett* 2003; 80: 123-129.

33. Arrow K. Uncertainty and the welfare economics of medical care. *Am Econ Rev* 1963; 53: 941-973.

34. Dranove D, White WD. Recent theory and evidence on competition in hospital markets. *J Econ Manage Strat* 1994; 3(1): 169-209.

35. Dranove D and Satterthwaite MA. The industrial organization of health care markets. In *Handbook of Health Economics*, Culyer A, Newhouse JP (eds), vol. 1. Elsevier Science: Amsterdam, 2000; 1093-1140.

36. Kessler DP, McClellan MB. Is hospital competition socially wasteful? *Quart J Econ* 2000; 115(2): 577-615.

37. Taylor DH Jr, Whellan DJ, Sloan FA. Effects of admission to a teaching hospital on the cost and quality of care for Medicare beneficiaries. *N Engl J Med* 1999; 340: 293-299.

Table 1. Individual Characteristics

Variable	Full Freq.	%	Estimation[1] Freq.	%
Hospital Choice				
Age (mean, sd)	76.89	7.32	76.89	7.33
Female	40,670	49.56	13,350	49.29
Minority race	7,270	8.86	2,350	8.68
MSA	58,122	70.83	19,153	70.72
Charlson index = 0 or 1	41,693	50.81	13,717	50.61
Charlson index = 2 or 3	29,070	35.43	9,622	35.53
Charlson index > 3	11,292	13.76	3,754	13.86
No-service hospital	31,236	38.07	10,363	38.26
Cath-only hospital	21,622	26.35	7,088	26.17
Surgery hospital	29,197	35.58	9,632	35.57
Cath choice				
Killip I	40,264	49.07	13,244	48.83
Killip II	9,647	11.76	3,148	11.62
Killip III or IV	32,144	39.17	10,711	39.55
No transfer/no cath	53,396	65.07	17,611	65.03
No transfer/cath	17,163	20.92	5,627	20.78
Transfer/no cath	1,381	1.68	455	1.68
Transfer/cath	10,115	12.33	3,390	12.52
Surgery choice				
Systolic: normal[2]	3,295	19.20	1,016	18.06
Systolic: moderate reduction	12,269	71.49	4,070	72.33
Systolic: severe reduction	1,599	9.32	541	9.61
No transfer/no surgery	67,921	82.77	22,390	82.67
No transfer/surgery	11,766	14.34	3,919	14.47
Transfer/no surgery	1,006	1.23	335	1.24
Transfer/surgery	1,362	1.66	439	1.62
Sample size	82,055		27,083	

1. A 33% random sample of individuals is used for estimation.
2. 17,163 individuals have information on blockage status in the full sample and 5,627 in the estimation sample.

Table 2. Hospital Characteristics

	Full		Estimation[1]	
Variable	Freq.	%	Freq.	%
1994				
No-service hospital	1,672	56.32	1,327	52.85
Cath-only hospital	523	17.62	487	19.39
Surgery hospital	774	26.07	697	27.76
Surgery volume (mean, sd)[1]	28.52	37.90	30.12	38.89
Beds (mean, sd)	198.31	179.05	208.83	181.14
CICU	1,212	40.82	1,073	42.73
For-profit	401	13.51	343	13.66
Government	662	22.30	511	20.35
Non-profit	1,906	64.20	1,657	65.99
Major teaching[2]	302	10.17	271	10.79
Minor teaching	373	12.56	330	13.14
Non-teaching	2,294	77.27	1,910	76.07
Sample size	2,969		2,511	
1995				
No-service hospital	2,429	61.76	2,142	59.27
Cath-only hospital	576	14.65	576	15.94
Surgery hospital	928	23.60	896	24.79
Surgery volume (mean, sd)	53.49	64.95	54.15	65.44
Beds (mean, sd)	177.88	171.06	185.56	172.58
CICU	1,501	38.16	1,437	39.76
For-profit	562	14.29	534	14.78
Government	995	25.30	846	23.41
Non-profit	2,376	60.41	2,234	61.82
Major teaching	366	9.31	354	9.80
Minor teaching	516	13.12	497	13.75
Non-teaching	3,051	77.57	2,763	76.45
Sample size	3,933		3,614	

1. The surgery volume statistics are for surgery hospitals only.
2. Major teaching facilities have a resident-to-bed ratio above the national median of hospitals with residents. The remaining hospitals with residents are classified minor teaching [37].

Table 3. Decision Tree

Nest 1	Nest 2	Nest 3
No-service hospital	No tran/no cath	No tran/no surgery
	Tran/no cath	No tran/no surgery
	Tran/cath	No tran/no surgery
		No tran/surgery
Cath-only hospital	No tran/no cath	No tran/no surgery
	No tran/cath	No tran/no surgery
		Tran/no surgery
		Tran/surgery
	Tran/no cath	No tran/no surgery
	Tran/cath	No tran/no surgery
		No tran/surgery
Surgery hospital	No tran/no cath	No tran/no surgery
	No tran/cath	No tran/no surgery
		No tran/surgery

Table 4. Nested Logit Estimates

Variable	Coefficient		Std. Error
Hospital Choice [1]			
Volume	0.015	*	0.003
Distance	-0.163	*	0.004
Dist*MSA	-0.182	*	0.005
Dist*Charlson 2-3	0.007		0.005
Dist*Charlson >3	0.007		0.007
Beds	0.006	*	0.001
CICU	0.240	*	0.027
For-profit	-0.487	*	0.043
Government	-0.596	*	0.043
Major teaching	-0.287	*	0.039
Minor teaching	0.075	*	0.033
Catheterization-only			
Age	0.034	*	0.002
Female	-0.035		0.050
Minority	-0.238	*	0.085
Charlson 2-3	0.148	*	0.056
Charlson >3	0.301	*	0.078
Surgery			
Age	-0.002		0.003
Female	-0.047		0.048
Minority	-0.166	*	0.077
Charlson 2-3	0.188	*	0.055
Charlson >3	0.408	*	0.076
Catheterization Choice [2]			
No Transfer/Catheterization			
Killip II	-1.273	*	0.036
Killip III or IV	-1.559	*	0.029
Transfer/No Catheterization			
Killip II	-2.251	*	0.119
Killip III or IV	-2.967	*	0.074
Transfer/Catheterization			
Killip II	-0.714	*	0.039
Killip III or IV	-0.917	*	0.034

Table 4. *cont.*

Variable	Coefficient		Std. Error
Surgery choice [3]			
No Transfer/Surgery			
Normal	0.806	*	0.031
Moderate reduction	0.810	*	0.027
Severe reduction	0.773	*	0.036
Transfer/No surgery			
Normal	-2.820	*	0.140
Moderate reduction	-2.708	*	0.071
Severe reduction	-2.479	*	0.177
Transfer/Surgery			
Normal	-2.298	*	0.110
Moderate reduction	-2.456	*	0.064
Severe reduction	-2.608	*	0.188
Inclusive Values			
Hospital Nest			
No surgery	27.086	*	2.296
Catheterization only	27.092	*	2.247
Surgery	28.838	*	2.448
Catheterization Nest			
None/No Tran/No Cath	1.000		-
None/Tran/No Cath	1.000		-
None/Tran/Cath	-0.543	*	0.034
Cath/No Tran/No Cath	1.000		-
Cath/No Tran/Cath	-2.013	*	0.074
Cath/Tran/No Cath	1.000		-
Cath/Tran/Cath	-1.491	*	0.081
Surg/No Tran/No Cath	1.000		-
Surg/No Tran/Cath	0.618	*	0.022
N	27,083		
ln L	-40,714.52		

* indicates significance at the 95% confidence level.
1. No-service hospitals are the reference category.
2. No transfer/no catheterization is the reference category.
3. No transfer/no surgery is the reference category.

Table 5. Share of Patients Within Given Radius of Surgery Hospital (%)

		Eliminate surgery services with <:		
Distance	Observed	50 proc/yr	100 proc/yr	200 proc/yr
0 to 5 miles	36.28	22.18	13.49	3.37
6 to 25 miles	38.35	37.65	30.66	15.00
26 to 50 miles	18.20	22.06	19.88	10.78
51 to 100 miles	6.08	13.00	18.42	17.46
100+ miles	1.09	5.11	17.56	53.38
Sample size	27,083			

Table 6. Elimination of Low Volume Hospitals--frequency (% change)

Dist.[1]	Vol.[2]	Surgery Hospital	Transfer	Cath.	Surgery
Observed					
17.49	43.63	35.57	17.05	33.29	16.08
Predicted					
		35.83	26.11	29.86	15.89
No surgery hospitals < 50 proc/yr					
36.47	101.56	27.53	29.30	28.03	14.63
		(-23.16)	(12.22)	(-6.14)	(-7.93)
No surgery hospitals < 100 proc/yr					
76.79	148.45	18.63	32.64	25.96	13.05
		(-48.02)	(25.00)	(-13.06)	(-17.90)
No surgery hospitals < 200 proc/yr					
216.98	257.47	6.55	36.90	23.20	10.82
		(-81.71)	(41.34)	(-22.32)	(-31.89)

1. Mean distance to nearest surgery hospital in miles.
2. Mean Medicare surgery volume at nearest surgery hospital.