THE ROLE OF HOSPITAL COMPETITION ON TREATMENT EXPENDITURE AND OUTCOME: EVIDENCE FROM STROKE AND CARDIAC TREATMENT IN TAIWAN

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This article examines whether market competition affects treatment expenditure and health outcomes of stroke and cardiac treatment in Taiwan. Our measure of treatment expenditure is the hospital expenditure paid at the index admission (short term) and the sum of inpatient and outpatient expenditures paid in the subsequent year (long term). Our measure of health outcome is the probability of death in 1 and 12 months after the hospital's discharge. Our measure of competition follows the method developed by Kessler and McClellan that calculates the Herfindal index based on the predicted patient flows using exogenous variables (e.g., traveling distance to hospitals). Using data of patients hospitalized for new stroke and cardiac treatment between 1997 and 2001 in Taiwan, we find that an increase of market competition results in an insignificant impact on a patient's mortality. In terms of treatment expenditure, our results indicate that hospitals facing more competition incur higher expenditures, either the short- or long-term expenditure. Finally, we find evidence showing that an increase of treatment expenditure at admission is due to a raise of length of stay and treatment intensity per day as well as the usage of expensive equipment. (*JEL* I11, L13, L41)

I. INTRODUCTION

In the past two decades, the landscape of the hospital industry worldwide has undergone a dramatic transformation. In the United States, the number of acute hospital beds fell by 12% between 1988 and 1998, of which 40% was due to the closure of 496 general hospitals over the sample period (Lindrooth, Lo Sasso, and Bazzoli 2003). In Canada, more than 275 hospitals have been closed, merged, or converted to other types of facilities between 1996 and 2001 (Canadian Institute for Health Information 2001). In Taiwan, about one-quarter of the total 700 acute hospitals exited the market in the past 10 years, despite the fact that the total number of hospital beds during the same period grew more than 40%.

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ABBREVIATIONS

AMI: Acute Myocardial Infarction
BNHI: Bureau of National Health Insurance
CABG: Coronary Artery Bypass Grafting
CT: Computed Tomography
CHF: Congestive Heart Failure
HMO: Health Maintenance Organization
IHD: Ischemic Heart Disease
MAR: Medical Arms Race
MC: Marginal Cost
MRI: Magnetic Resonance Imaging
NHI: National Health Insurance
NHID: National Health Insurance Data
PPS: Prospective Payment System
PTCA: Percutaneous Transluminal Coronary Angioplasty

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The dramatic change in the hospital market through exits, ownership conversion, or consolidations has led to substantial research interest in the competitiveness of this industry. The results from empirical research are not consistent. Most of the studies using Medicare patients find a positive impact of competition on quality. However, the results from studies of private markets where prices and quality are chosen by hospitals are much more variable. Some studies, including earlier studies that tested the "medical arms race" (MAR) hypothesis, show increased competition leading to increased quality (measured by outcomes or input intensities), while others show the opposite.

It is not surprising that empirical studies provide mixed evidence because economic theory indeed predicts that quality may either increase or decrease with increased competition depending on the pricing structure (Gaynor 2006). According to economic theories of competition of differentiated products, if prices are regulated, like Medicare in the United States or National Health Insurance (NHI) in Taiwan, competition in hospital industry will unambiguously lead to higher quality as long as regulated prices are above marginal cost (MC). However, if firms are free to choose both price and quality, the impact of market competition is rather ambiguous, depending on the effect of competition on the price and quality elasticity of demand.

Empirical research is even more problematic when applied to U.S. data. First, there are multiple payers; the presence of multiple payers increases the difficulty to collect price information since private payers often negotiate their payments privately with hospitals. Consequently, results of most competition studies are derived based on data of one large public payer (e.g., Medicare or Medicaid). Nonetheless, there have been studies indicating that competition produces different effects for different payers, especially when private payers were involved (Gowrisankaran and Town 2003);[1] findings based on one payer may be difficult to generalize. Moreover, hospitals may shift their costs toward other payers as a result of the price reduction of one payer (e.g., Dranove 1988).[2] In that case, the true impact of hospital competition is likely to be contaminated by the cost-shifting behaviors of hospitals.

The second problem relates to the U.S. payment system. Beginning in 1987, following the practice of Medicare, almost all payers have replaced cost-based payment with a prospective payment system (PPS). Although PPS is effective in containing rising hospital expenditures, it also increases the extent of risk selection since hospitals are paid a fixed amount for each patient based on the patient's diagnosis, not by the hospital's cost of treatment. This is especially prevalent for hospitals under severe competition pressure (Meltzer, Chung, and Basu 2002);[3] the strong incentive for hospitals to select healthy patients at admissions complicates the analysis and distorts findings of hospital competition.

In this article, we analyze the impact of competition among hospitals for patients admitted for stroke, ischemic heart disease (IHD), acute myocardial infarction (AMI), and congestive heart failure (CHF) in Taiwan. We use Taiwan data because Taiwan implemented NHI in 1995, the latest developed country to offer insurance coverage. Because NHI employs the single-payer payment system and pays hospitals on the fee-for-service basis, the data provide an excellent opportunity to investigate the impact of hospital competition. We analyze stroke and heart diseases because of their importance and cost (stroke and heart diseases are leading causes for hospital admission and inpatient expenditures in Taiwan[4]), and they are also one of the most noncommunicable health conditions across the globe. In addition, all four involve procedures and medicines that are performed and used on an emergency basis in many cases; therefore, the severity of the illness is unlikely to be known by an individual before its occurrence. This means the distribution of disease severity is less likely to be correlated with an individual's

1. Gowrisankaran and Town (2003) found that competition for Medicare and HMO patients may have different impacts on hospital quality: the former reduced the welfare, but the latter improves the welfare.

2. Dranove (1988) found that hospitals raised their prices for privately insured patients in response to the reduction of Medicare or Medicaid payments.

3. Meltzer, Chung, and Basu (2002) found that increasing competition in the context of prospective payment is associated with selective reductions of expenditures for the most expensive patients.

4. The inpatient expenditure for cerebrovascular disease, namely, stroke, is 4.78% in 2003, next to heart disease (7.18%) and cancers (12.40%).

residence location. As we show below, this feature is important in defining the competition measure used in the analysis.

We use longitudinal hospital claims of NHI receipts diagnosed as new stroke, IHD, AMI, and CHF cases during 1997 and 2001. We include both outcome measures (1-month and 1-year mortality) and input measures (treatment expenditure during the index admission, total expenditures paid in the year following the time of admission, length of stay, per day expenditure, use of expensive surgical procedures, and use of expensive diagnostic equipments) for quality measures.

One major challenge of examining the impact of competition on input intensity and outcomes is to address the endogeneity problem. The relationship between competition and input intensity and outcomes could be attributed to the health policies (such as NHI) or patient selections that determine both the input and outcome measures as well as the extent of market competition. To address these problems, we follow Kessler and McClellan (2000), Town and Vistnes (2001), and Gowrisankaran and Town (2003) and develop measures of competition based on predicted patient flows using relatively exogenous characteristics—travel distances between patients and hospitals. The use of such measures can avoid the endogeneity due to conventionally used competition measures (Hirschman-Herfindahl index [HHI]) since a patient's hospital choice is likely to be correlated with unobserved hospitals' quality or patients' characteristics.

Our findings indicate that higher market competition results in higher treatment expenditures by increasing both length of stay and treatment intensity. Market competition also leads to a higher probability of having expensive surgical procedures, such as percutaneous transluminal coronary angioplasty (PTCA), or using diagnostic technology, such as computer tomography (CT) or magnetic resonance imaging (MRI). Market competition leads to lower mortality rates both in the short run and long run, but the effects are not statistically significant.

This article is organized as follows. We begin in Section II with a discussion of economic theory and previous literature on hospital competition. Section III briefly introduces NHI and the hospital market in Taiwan. Section IV describes the construction of competition measures and the estimation strategy, followed by data and sample descriptions in Section V. In Section VI, we present basic results, robustness checks, and possible mechanisms affecting treatment expenditure. Section VII concludes.

II. THEORETICAL FRAMEWORK AND PREVIOUS LITERATURE ON HOSPITAL COMPETITION

A. Theoretical Framework

As compared to the competitive markets described in the standard economic model, healthcare markets usually differ in a number of important aspects: products are differentiated, information is imperfect, government regulation is extensive, and services are provided by nonprofit organizations (Gaynor and Vogt 2000). Not surprisingly, in the face of various complications, the impact of competition in the healthcare market may not conform to the conventional wisdom that competition leads to lower prices and improved consumer welfare.

Gaynor (2006) discusses theories of competition of differentiated products and reviews their applications on hospital competition. He divides his reviews into analyses where price is set by firms versus those where price is regulated. If firms are free to choose both price and quality, the impact of market competition is rather ambiguous, depending on the effect of competition on the price and quality elasticity of demand.[5] Alternatively, if prices are regulated, like Medicare in the United States or NHI in Taiwan, competition in hospital industry will unambiguously lead to higher quality and consumer welfare as long as prices are above MC, though its impacts on social welfare are still uncertain.

Why is the impact of market competition on quality always higher when prices are regulated? If prices are regulated, hospitals are forced to compete for patients on nonprice dimensions, that is, "quality." In order to gain market share, hospitals will increase quality as

5. Dranove and Satterthwaite (1992, 2000) show that the effect of competition on quality and price depends on the effect of competition on the price and quality elasticity of demand. When the information is imperfect, if competition increases the price elasticity alone, then market competition will decrease quality. If competition increases elasticities of both price and quality, then the effect on quality is ambiguous, depending on the relative magnitudes of elasticities.

long as the regulated price is set above MC at some baseline level of quality. With free entry and exit, the long-run equilibrium will be achieved when all hospitals earn zero profits. However, if the regulated price is above MC at the social optimal quality, then competition can lead to excessive quality. Given that the loss of producer surplus due to excessive quality of care may outweigh the quality benefit to consumers, social welfare may be lower.

The argument that hospitals will engage in an MAR when price competition is weak is similar to the notion of competition with regulated prices described above (Robinson and Luft 1985, 1987). The weak price competition could be due to two reasons. First, as a direct result of insurance, the full burden of healthcare expenses is not borne by consumers, a factor that diminishes the importance of price shopping. In addition, if hospitals were reimbursed on a "cost-plus" basis, they did not bear the marginal costs of intensive treatment decisions. Therefore, hospitals engage in quality competition by providing excessive care or expensive medical technology, adding substantially to overall healthcare costs.

B. Linking Theories with Empirical Analyses

One main difficulty in linking theoretical predictions and empirical findings is how to measure the quality in the hospital market. Although there has been a vast empirical literature examining the consequences of competition in hospital markets,[6] given that theories make no clear indications on how hospitals compete over the dimension of quality, different studies employ different quality measures. If hospitals compete on "true quality," process measures (e.g., prescribing beta blockers to patients after myocardial infarction or monitoring glycosylated hemoglobin levels among diabetics) and outcome measures (e.g., mortality, morbidity, functional status, and pain) are better indicators (Romano and Ryan 2004). Alternatively, if hospitals compete on "appearance of quality," hospitals will exert efforts to demonstrate their commitment to quality to attract patients by enhancing their input intensity or input quality (hereafter termed "input measures") such as investing in new technologies, operating duplicative clinical services, or accommodating patients' preferences for longer stays (i.e., the MAR hypothesis). Notice that more health services do not necessarily improve health; outcomes can still deteriorate if activities to boost input measure involve duplicated services that prohibit health providers from taking advantage of economy of scale or learning effects. In the following, we present empirical evidence on both input measures and outcome measures, but restrict it to the ones where price is regulated or price competition is weak. Therefore, most studies covered here are the ones testing the MAR hypothesis or analyzing Medicare patients as the study sample.

The early empirical studies evaluating the impact of competition on hospital quality concentrate on the input measures. Many of those studies find results consistent with the predictions from the MAR hypothesis. Joskow (1980) finds that a higher market concentration leads to a lower reservation quality in hospitals, while studies based on 1972 data (Robinson and Luft 1985) and 1982 data (Robinson and Luft 1987) find that average costs per admission and costs per patient day were substantially higher in hospitals operating in more competitive markets. Held and Pauly (1983) examine the competition and quality in the dialysis market and find that there are more dialysis machines per patient in less concentrated areas. In addition, studies have also revealed that hospitals located in more competitive markets were more likely to offer PTCA and coronary artery bypass grafting (CABG) (Robinson, Garnick, and McPhee 1987) as well as employ a substantially higher number of employees (Robinson 1988). Dranove, Shanley, and Simon (1992) find that market competition leads more hospitals to adopt particular technologies, although the effect is weak. Noether (1988) finds that more competitive markets have lower prices and higher expenses, but again the effect is weak and small.

Recent studies, however, switch the focus to quality in terms of outcome measures.[7] Kessler and McClellan (2000) find that competition lead to lower mortality rates for Medicare heart disease patients—the effect was particularly substantial after 1991 while the health maintenance organization (HMO) penetration was prevailing. Shen (2003)

6. For comprehensive reviews, see Gaynor and Vogt (2000), Dranove and White (1994), and Dranove and Satterthwaite (2000).

7. Gaynor (2006) has summarized those studies in his Table 3.

investigates the impact of financial pressure from reduced Medicare payments and HMO penetration on mortality from AMI and finds that hospitals respond to an increase in the regulated price by increasing quality; the response is augmented when hospitals face more competitors. The findings from these two studies are consistent with the theory. On the contrary, Gowrisankaran and Town (2003) find that an increase in competition for Medicare enrollees is associated with an increase in risk-adjusted mortality rates, a finding that contradicts the theory. One way that their results could be consistent with the theory is if the Medicare margins are indeed negative (i.e., price < marginal cost). However, Gaynor (2006) casts doubt on this possibility because heart treatments for Medicare patients are widely regarded to be profitable. Finally, an earlier study by Shortell and Hughes (1988) finds no statistically significant association between market concentration and in-hospital mortality among Medicare patients.

Since there are no clear suggestions about quality measures that may be particularly sensitive to the impact of competition, in our analysis we include both outcomes measures (1-month and 1-year mortality) as well as several input measures (treatment expenditure during the index admission, total expenditures paid in the year following the time of admission, length of stay, per day expenditure, use of expensive surgical procedures, and use of expensive diagnostic equipments) for quality measures. All of them were widely used in previous studies to evaluate the market competition.

III. BACKGROUND

This section provides some institutional background for NHI and the healthcare market in Taiwan. We first briefly outline the universal health insurance implemented in 1995. We then describe the Taiwan hospital market between 1992 and 2002.

A. Brief Introduction of NHI

In March 1995, Taiwan implemented NHI that provides insurance coverage to the entire population. Before the implementation, the health insurance coverage was primarily provided through three social insurance programs serving different populations: labor insurance for employees in the private sector, government employee insurance for workers in the public sector, and farmer insurance for farmers. In total, these programs covered the health insurance of 12.3 million or 57% of the total population in 1994. Since nearly half of the total population was still uninsured, of which the majority were children younger than 14 or elderly older than 65, the Bureau of National Health Insurance (BNHI) was established in January 1995, and 2 months later universal health insurance was inaugurated.[8]

The NHI is designed to accomplish two objectives: to provide equal access to health care for all citizens and control total health spending to reasonable levels (Council of Economic Planning and Development 1990). To achieve the first goal, the insurance premium is shared among three parties: enrollees, employers, and governments; enrollees of lower income pay a smaller share.[9] In addition, NHI provides a comprehensive benefit package—ranging from preventive and medical services, prescription drugs, dental services, Chinese medicine, and home nurse visits—as well as a modest cost sharing: $5 copayment for each outpatient visit to clinics, $8 for every visit to hospital outpatient clinics, and 10% coinsurance rate for inpatient care, but capped at 10% of the average national income per person. The poor are exempted from all cost sharing. Furthermore, every enrollee is free to go to almost all health providers.[10] Not surprisingly, with a generous benefit package and low cost sharing, the insured rate has grown at an astonishing speed—the rate jumped to 92% within less than a year and has stayed above 97% since 1997.

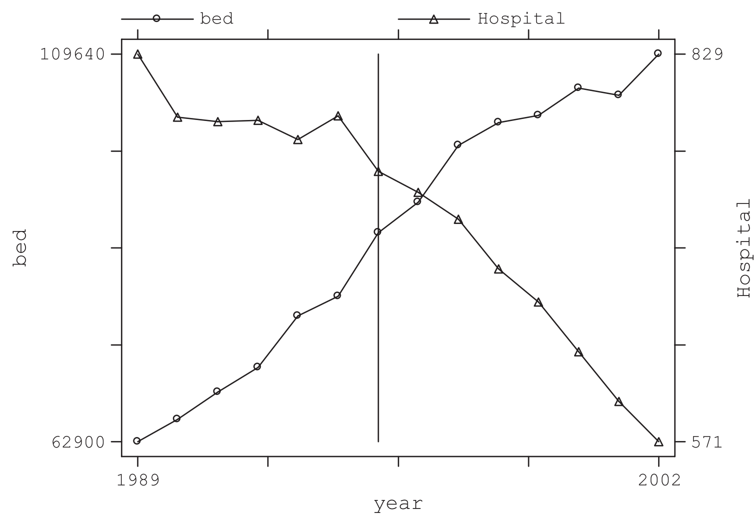
NHI has been less successful in achieving the second objective. Before the NHI's inception,

8. The inauguration of NHI was to a large extent initiated by the pressure of a looming legislation election in the next year (1996). For more discussions, see Cheng (2003).

9. For instance, workers in the private sector pay 30% of the premium, while their employers and the government pay 60% and 10%, respectively. Farmers, on average a lower income group, pay 30% while the rest is covered by the government. The lowest income households do not have to pay an insurance premium. See Lu and Hsiao (2003) for a detailed description.

10. The NHI contracted rate for hospitals is 96.72% and 96.90% in 1996 and 2002, respectively; the rate for clinics is 92.49% in 1996 and 92.90% in 2002 (data source: http://www.doh.gov.tw/statistic).

FIGURE 1
Total Number of Beds and Hospitals



the health spending per capita rose at the average rate of 6–8% in real terms, about 2–3% higher than gross domestic product's growth. One explanation for the rapid spending growth is that the multiple payer system forces health providers to increase administrative work and allows them to shift service costs among different payers. The implementation of NHI is intended to ease the extent of cost shifting and decrease unnecessary administration costs through standardized payments. Moreover, the single-payer system is regarded as an effective tool to identify fraudulent claims and overcharges since better information can be used to build hospital and patient profiles. In spite of these ambitious aims, the average health spending still grows at a rate higher than originally planned. In response to the rising health spending, BNHI adopted several new reforms on reimbursement schemes[11,12] and raised the insurance premium rate for the first time since its inception in 2003.[13]

11. Selective procedures such as vaginal delivery, cesarean section, or artery bypass surgery are reimbursed on case-payment basis (similar to diagnostic related group [DRG] system in the U.S.). There are in total fifty case payment procedures up to 2002, of which stroke is not included.

12. Beginning in 2002 for clinics and 2003 for hospitals, in order to contain the medical expenditures, NHI introduced Global Budgeting—the maximum cap that a government imposes on the increase of medical spending.

13. The insurance rate was set as 4.25% from the inauguration of NHI and raised to 4.55% beginning in 2003.

B. Hospital Market in Taiwan

Consistent with experiences from other countries, the contribution of hospitals in supplying health care has increased over time in Taiwan. Its importance manifested from two aspects. First, the hospital share of NHI payment has gained over time, rising from 2.14% of gross national product in 1997 to 2.46% in 2002.[14] Moreover, the number of hospital beds (acute care), as displayed in Figure 1, has increased over the years, rising from about 70,000 in 1991 to over 110,000 in 2002, over a 50% increase in 10 years.

In spite of the consistent growth of hospital beds, the hospital industry has experienced a structural change. Most notable is the *decline* of the number of hospitals—more than 150, approximately one-fifth of the total 700 hospitals, exited the market between 1991 and 2002. Additionally, the declining pattern accelerated after the implementation of NHI. To closely examine the change of hospital market, Table 1 lists the number of general hospitals by bed size (0–100, 100–300, and above 300) and ownership (public, nonprofit, and private) between

14. Payment for outpatient and inpatient care to hospitals in 2002 is about $3.5 billion and $3.1 billion, respectively. The hospital share of medical expenditures is calculated from the Financial Resource and Allocation of National Health Expenditure, Year 1997 and Year 2002 obtained from the Ministry of Health (data source: http://www.doh.gov.tw/statistic).

TABLE 1
Summary of Characteristics of General Hospitals Between 1992 and 2002

Year	1992	1994	1996	1998	2000	2002
Bed number						
0–100	577	567	509	465	421	376
100–300	77	73	86	93	92	93
300+	39	49	59	64	70	71
Ownership						
Private	548	538	497	459	418	372
Nonprofit	64	63	67	71	72	76
Public	81	88	90	92	93	92
Accreditation						
Medical centers	13	13	14	17	22	22
Regional hospitals	44	44	44	50	63	71
District hospitals	527	508	479	469	387	384
None	109	124	117	86	111	63
Total observations	693	689	654	622	583	540

1992 and 2002. Two distinct trends can be observed from the table. First, approximately one-fourth of small hospitals, of which almost all are privately owned, exited the market; this trend to a large extent explains the decline of hospital number in Figure 1. Second, there is an increase in the number of large-sized hospitals, either from the expansion of medium-sized ones or entries of new hospitals; this explains why the total number of hospital beds continues to rise though many small hospitals exited the market. Consistent with Figure 1, these two trends manifest after 1995. Obviously, the hospital market has undergone a significant change after the implementation of NHI.

What are the reasons for these two distinct trends? Why have smaller hospitals exited and large hospitals prospered? How does the introduction of NHI affect the hospital market? Although these are important questions to address, due to the data limitations (no reliable data were collected before NHI), so far there are no clear answers, but several plausible explanations. One explanation is that universal coverage substantially squeezes the room for hospitals to engage in price competition. Before NHI, about half of the population did not have health insurance. Smaller hospitals, largely privately owned, can thus attract these patients by offering the limited services at a discount price. The introduction of NHI, however, adversely affects small hospitals since they now can only compete through the quality of care. Another explanation is that universal health insurance increases the demand of health care, which benefits medium-sized or above hospitals due to the economy of scale.

The last, and perhaps the most important argument, is that these trends reflect the reimbursement schemes of NHI. In Taiwan, hospitals are categorized into several levels of accreditation: medical center, regional hospital, district hospital, and unaccredited hospital. To reflect differences in admitted severity mix and supplied quality of care, BNHI pays better accredited hospitals higher rates for the same service.[15] For example, the daily rate for a hospital stay in an ordinary bed (four occupancies in a room) is NT 512 for medical centers, NT 456 for regional hospitals, and NT 395 for the rest. Therefore, it is possible that the higher reimbursed rate helps better accredited hospitals prosper;[16] the increasing trend in the number of large hospitals over time is simply the reflection that better accredited hospitals happen to be large ones. As Table 1 shows, there is an increase in the number of medical centers and regional hospitals compared to a sharp decline in the number of area and unaccredited hospitals over the years[17]. Of course, a careful analysis

15. The practice—paying better accredited hospitals higher rates for the same service—was first used by the Bureau for Labor Insurance where hospitals were categorized into three levels: A, B, and C; BNHI subsequently adopts this practice in designing the reimbursement scheme of NHI.

16. In 2002, during a formal investigation by Control Yuan, BNHI claims this payment scheme not only can adjust for the severity mix of patients among hospitals, but also offers an incentive for hospitals to improve their service quality (becoming a better accredited one). However, this practice has been seriously criticized by many health professionals for several reasons. First, this practice unfairly limits the potential for smaller hospitals to survive, given they are paid less for the same work. Second, to obtain higher accreditations, hospitals often need to purchase expensive equipments, resulting in unnecessary and often duplicate investments. Furthermore, this practice creates an incentive for large hospitals to compete with smaller ones in attracting minor ill patients.

17. The sharp decline in the number of community hospitals over recent years has transformed into large political pressure on BNHI. In 2002, the Control Yuan started a formal investigation and advised BNHI to consider adjusting the scheme to meet the standard of "equal job, equal pay." In October 2004, in the face of strong opposition from community hospitals and clinics regarding the payment scheme and global budgeting, the CEO of BNHI was forced to resign. Nonetheless, due to strong support from medical centers and regional hospitals, this payment practice continues to be used as the standard for NHI's reimbursement scheme.

is necessary to separate the relationship between hospital size and accreditations.

IV. ESTIMATION

We assess the impact of hospital competition on treatment expenditure and health outcomes using longitudinal data of NHI beneficiaries hospitalized for new occurrences of strokes and cardiac diseases between 1997 and 2001. For reasons listed below, in the analysis we decide not to use the conventional HHI as the competition measure to avoid endogenous bias. First, as noted by Kessler and McClellan (2000), hospitals with distinctive services often attract unobservable high-cost patients. Without accounting for the possible correlations between patient's severity and hospital choice, employing the conventional HHI based on patient's actual choice is likely to overstate the effect of market competition. This is especially true in our study because many small hospitals exited the market due to the change of payment structure after the implementation of NHI. If patients who were treated in small hospitals, but transferred to the surviving hospitals, were comparably healthier, our estimated results are likely to interpret that market concentration leads to lower expenditures and better outcomes. Alternatively, the introduction of NHI in 1995 may have lead to higher growth in medical expenditures and better health outcomes over time. Consequently, we may attribute higher expenditures or better health outcomes to market concentration that are fundamentally caused by the changes of health policy. In other words, if market concentration leads to lower expenditures and higher mortality rates, we will overstate the impact of market concentration in the first case. In the second case, we will understate the impact of market concentration on health expenditures but overstate the impact on health outcomes.

To overcome these problems, we follow Gowrisankaran and Town (2003), Kessler and McClellan (2000), and Town and Vistnes (2001), to construct the measure of market competitiveness. First, we estimate patient-level hospital choice models as a function of exogenous variables (e.g., travel distances between patients and hospitals), which are not correlated with unobserved patient or hospital characteristics. Then, we calculate the predicted market share for each hospital using the estimates from the choice model. Next, we calculate Herfindahl indices based on these predicted patient flows (rather than actual patient flows)[18] and assign them to patients based on their zip code of residence (rather than their actual hospital of admission). Finally, we use these exogenous measures of market competitiveness to examine the effect of hospital competition on input and outcome measures.

A. Model of Patient's Hospital Choice

We posit that the individual i with stroke or cardiac illness makes a hospital choice j among the J hospitals in her area by maximizing an indirect utility function of the form

$$U_{ij} = V_{ij} + \varepsilon_{ij}, \tag{1}$$

where V_{ij} denotes the deterministic component of the utility function, which is a function of the hospital characteristics as well as the patient's characteristics, and ε_{ij} is patient i's unobserved, idiosyncratic preference admitted to hospital j. We assume that ε_{ij} follows the generalized extreme value distribution.

We follow the literature on discrete choice and assume that V in Equation (1) is a linear and additively separable function of patient and hospital characteristics. Specifically,

$$V_{ij} = \boldsymbol{H}_j\beta_h + \boldsymbol{D}(d_{ij})\beta_D + H_j\boldsymbol{\gamma}(d_{ij})\beta_{hj} + Ill_i\boldsymbol{\gamma}(d_{ij})\beta_{pi}, \tag{2}$$

where $\boldsymbol{H}_j$ is a vector of hospital j's characteristics, including ownership (public, nonprofit, and for-profit), accreditation (medical center, regional hospital, and others), and the number of beds and its square; d_{ij} is the distance from patient i's residence zip code to hospital j's zip code relative to patient i's distance to the nearest hospital. To allow that the distance may

18. The most widely used measure of competition in the literature is HHI; the index is defined as: $\text{HHI}_k = \sum_j s_j^2 I(d_{jk} \leq R_k)$, where d_{jk} is the distance between hospital j and k, R_k is the distance boundary that defines the hospital k's market, and I is an indicator equaling one if hospital j were located within the distance boundary. Once the relevant competitors in the market are defined, the HHI index for hospital k simply equals to the sum of squares of each competitor's share in the market.

influence the hospital choice nonlinearly, we consider two distance vectors $\boldsymbol{D}(d_{ij})$ and $\boldsymbol{\gamma}(d_{ij})$. The first vector, $\boldsymbol{D}(d_{ij})$, consists of d_{ij} and its square, two dummies indicating if hospital j is the nearest medical center or the nearest regional hospital, and five other dummies d_{ij} is categorized into five categories, with category boundaries at every 20th percentile of the distribution of the relative distance of that zip code. The second vector is $\boldsymbol{\gamma}(d_{ij})$, which consists of three dummies categorized into three groups: 0–20th, 20th–40th, and 40th and above of the distribution of the relative distance in that zip code; they are used to capture the interaction effect between the relative distance and $\boldsymbol{H}_j$ as well as those with various illness dummies.

Patient i will choose to go to hospital j, if $U_{ij} > U_{ik}, \forall j \neq k$. As shown in McFadden (1978, 1981), the assumption of the generalized extreme value distribution implies that the conditional choice probability will be given by multinomial logit formulas that have the following general form:

$$\hat{\pi}_{ij} = \frac{e^{\hat{V}_{ij}}}{\sum_{j \in J} e^{\hat{V}_{ij}}}. \tag{3}$$

To estimate a patient-level hospital choice model (Equation (1)), we allow each patient's potentially relevant geographic hospital market to include all hospitals within 40 km of the patient's residence with at least 20 admissions for stroke or cardiac diseases. Then, we estimate Equation (1) separately for different years and counties to account for different effects of distances and other hospital and patient characteristics across counties and over time.[19]

B. Measures of Market Concentration

We use the estimated parameters of Equation (2) to calculate predicted probabilities Equation (3) of admission for every patient i to every hospital j in his or her potentially relevant geographic market. Following Kessler and McClellan (2000), we construct the revised HHI based on predicted patient flows. First, we calculate the predicted share of patients from zip k going to hospital j as the ratio of predicted number of patients from zip k that go to hospital j to total number of patients from zip k, such that

$$\hat{\alpha}_{jk} = \frac{\sum_{i=1}^{N_k} \hat{\pi}_{ij}(\text{Predicted number of patients from zip } k \text{ that go to hospital } j)}{\sum_{j=1}^{J}\sum_{i=1}^{N_k} \hat{\pi}_{ij}(\text{Total number of patients from zip } k).} \tag{4}$$

In this framework, the HHI for patients in zip k is:

$$\text{HHI}_k^{\text{pat}} = \sum_{j=1}^{J} \hat{\alpha}_{jk}^2. \tag{5}$$

A given hospital j will concern itself with the nature of competition from all nearby areas. Thus, the competitiveness of hospital j's market is weighted by the relative probability that a patient in zip k will be admitted to hospital j. For a given zip k, the likelihood of admission to hospital j is

$$\hat{\beta}_{kj} = \frac{\sum_{i=1}^{N_k} \hat{\pi}_{ij}(\text{Predicted number of patients from zip } k \text{ that go to hospital } j)}{\sum_{i=1}^{N} \hat{\pi}_{ij}(\text{Predicted number of patients that go to hospital } j)}, \tag{6}$$

Where $\hat{\beta}_{kj}$ is the is the ratio of predicted number of patients from zip k that go to hospital j over the predicted number of patients that go to hospital j.

19. To be more precise, we estimate 138 equations separately for 6 year and 23 cities/counties.

Therefore, the HHI for hospital j is

$$(7)\quad \mathrm{HHI}_j^{\mathrm{hosp}} = \sum_{k=1}^{K} \hat{\beta}_{kj} \mathrm{HHI}_k^{\mathrm{pat}} = \sum_{k=1}^{K} \hat{\beta}_{kj} \sum_{j=1}^{j} \hat{\alpha}_{jk}^2.$$

$\mathrm{HHI}_j^{\mathrm{hosp}}$ is the HHI employed in Town and Vistnes (2001) and Gowrisankaran and Town (2003), but not the HHI used in Kessler and McClellan (2000). We would like to briefly discuss the advantages and disadvantages of using $\mathrm{HHI}_j^{\mathrm{hosp}}$ here. First, it uses predicted market shares based on exogenous determinants (such as distance) of patient flows (Equations (3)–(5)), rather than potentially endogenous measures such as actual patient flows. For instance, high-quality hospitals may be more likely to survive after the NHI and high-quality hospitals may attract more patients from further away. In these cases, estimates of the effect of market competitiveness (measured based on actual patient flow) on costs or quality will be confounded by the unobserved hospital quality. Second, $\mathrm{HHI}_j^{\mathrm{hosp}}$ is calculated based on the patient HHI from all relevant geographic areas (Equations 5 and (6)). Therefore, it does not rely on any arbitrary definition of the market.[20] It also considers all potential competitors from any relevant geographic market.

One problem of using $\mathrm{HHI}_j^{\mathrm{hosp}}$ is that it is assigned to patients according to each patient's actual hospital of admission (Gowrisankaran and Town 2003; Town and Vistnes 2001). However, the selection of hospital may depend on a patient's unobserved health status. For instance, if high-quality hospitals are more likely to be selected by sick patients, estimates of the effect of market competitiveness on quality will be biased. To address this problem, we follow Kessler and McClellan (2000) and assign $\mathrm{HHI}_k^{\mathrm{pat}*}$, a weighted average of the competition indices for hospitals expected to treat patients in zip k of residence, to patients according to each patient's zip of residence:

$$(8)\quad \mathrm{HHI}_k^{\mathrm{pat}*} = \sum_{j=1}^{J} \hat{\alpha}_{jk} \sum_{k=1}^{K} \hat{\beta}_{kj} \mathrm{HHI}_k^{\mathrm{pat}} = \sum_{j=1}^{J} \hat{\alpha}_{jk} \mathrm{HHI}_j^{\mathrm{hosp}}.$$

That is, this index is weighted by the predicted probability of patients from zip k going to hospital j. The variation of $\mathrm{HHI}_k^{\mathrm{pat}*}$ will come from changes over time in hospital markets across areas (e.g., openings of large hospitals and closures of small hospitals) and changes over time of patient's hospital choice in response to the travel distance.

C. Estimation Strategy

Let i be the patient residing in county/city m and zip k and hospitalized for stroke or cardiac treatment at hospital j in year t. Let Exp_{ijkmt} be the dependent variable that measures a patient's treatment expenditure. Likewise, let $\mathrm{Outcome}_{ijkmt}$ be the variable measuring i's health outcome. Because stroke or cardiac disease is likely to generate a lasting effect on a patient's health, the treatment expenditure is measured by the hospital expenditure paid at the index admission (short term) and the sum of inpatient and outpatient expenditures paid in the year following the time of admission (long term). Similarly, we use 1-month and 1-year mortality to evaluate a patient's short- and long-term health outcome, respectively. Our basic model can be described as the following:

20. Conventionally, there are three ways to define a market boundary: service area, fixed-radius, and variable-radius (see Dranove and White 1994, Baker 2001, and Wong, Zhan, and Mutter 2005 for more detailed comparisons of alternative definitions of market concentration). The first is the service area method that defines the market ad hoc using political or census divisions such as counties, metropolitan statistical areas (Joskow 1980), health service areas, or urbanized areas (e.g., Dranove, Shanley, and Simon 1992; Dranove, Shanley, and White 1993). The second and third approaches define the market using the distance between two hospitals. The fixed-radius approach defines a hospital's market boundary as a fixed-radius, such as 5, 10, or 15 miles (e.g., Robinson 1988; Robinson and Luft 1985, 1987;). The variable-radius approach moves even one step forward: defining the market radius that contains 75% or 90% of a hospital's actual patient flow (e.g., Gresenz et al. 2004; Phibbs and Robinson 1993) or defining the market as the collection of geographic areas that collectively account for 40–95% of a hospital's discharges (e.g., Gruber 1994; Zwanziger and Melnick 1988). As a result, each hospital has a flexible and specific distance radius. No single measure of a hospital's market is ideal for all research questions (Baker 2001). In general, the service area is more problematic since it defines the boundary subjectively. For two methods using the distance as the measure, variable-radius method is considered to be superior for most research questions (Gresenz, Rogowski, and Escarce 2004). Nonetheless, variable-radius method is still criticized since any measure based on the actual patient flow is not immune from endogenous bias.

$$(9)\quad \text{Exp}_{ijkmt} = \boldsymbol{H}_{jt}\alpha + \boldsymbol{X}_{it}\beta + \text{Comp}_{jkt}\gamma + \mu_j + \nu_t \times \varsigma_m + \varepsilon_{ijkmt}$$

$$\text{Outcome}_{ijkmt} = \boldsymbol{H}_{jt}\alpha + \boldsymbol{X}_{it}\beta + N_j + \text{Comp}_{jkt}\gamma + \mu_j + \nu_t \times \varsigma_m + \varepsilon_{ijkmt},$$

(10)

where $\boldsymbol{X}_{it}$ is a vector of variables describing patient i's severity at the admission year t; $\boldsymbol{H}_{\text{jt}}$ is a vector of admitted hospital's observed features; Comp_{jkt} is the HHI index for zip k (or hospital j) at year t; μ_j is the unobserved hospital's specific error, ν_t is the year effect, ς_m is the county/city fixed effect, and ε_{ijkmt} is the random error assumed to be independent of all other error terms. Since the time effect is likely to differ with respect to city or rural areas, we further allow the year dummy (ν_t) to interact with county/city dummies (ς_m). Finally, given the well-known volume-outcome relationship, in the outcome equation we separately include N_j, the number of cases performed by hospital j.[21] Since the actual volume is likely to introduce endogenous bias, in the analysis we replace N_j with the predicted volume ($\hat{N}_j$) calculated from the hospital choice model (i.e., $\hat{N}_j = \sum_{i=1}^{N} \hat{\pi}_{ij}$).

To carefully investigate the effect of hospital competition, the estimation first controls a detailed set of observables of patients ($\boldsymbol{X}_{it}$) and hospitals ($\boldsymbol{H}_{jt}$). Aside from age and sex, we exploit a patient's utilizations in the preceding year before the hospital admission, including the sum of total inpatient expenditures and outpatient expenditures, as well as the Charlson index and the DxCG risk score to account for patient's severity at admission. The Charlson index is a risk index ranging between 0 and 6 that indicates a patient's comorbidity conditions (Goldstein et al. 2004). The DxCG risk score is a risk index based on patient age and gender to account for patient risk at the time of admission (Zhao et al. 2005). We also include disease dummies indicating whether the patient has IHD, AMI, ischemic stroke, or hemorrhage stroke with CHF as the reference group. For the hospital's features, we include a hospital's ownership status (public, private, and nonprofit) and accreditation (medical center, regional hospital, and area hospital), along with the number of beds in a hospital.

We estimate two variants of Equations (9) and (10). First, for purposes of comparison with different measures of HHI — $\text{HHI}_k^{\text{pat*}}$ and conventional 75% variable-radius HHI ($\text{HHI}_j^{75\%}$), we use linear and quadratic terms of HHI in Equation (9). Because $\text{HHI}_k^{\text{pat*}}$ are varied by zip codes and $\text{HHI}_j^{75\%}$ are varied by hospitals, it is difficult to define the comparable categorical variables based on different distribution assumptions. Second, to investigate how different levels of market competition affect expenditures and health outcomes, we estimate a nonparametric model of the effect of $\text{HHI}_k^{\text{pat*}}$. We follow Kessler and McClellan (2000) by categorizing $\text{HHI}_k^{\text{pat*}}$ into four levels (very low, low, high, and very high HHI) according to the $\text{HHI}_k^{\text{pat*}}$ distribution across 5 years.

V. DATA

A. Sources

We use four data sources in the study; all, except the last one, are obtained from the National Health Insurance Data (NHID), maintained by the National Health Research Institute. The first is longitudinal medical claims (inpatient and outpatient) of NHI enrollees between 1996 and 2002. Because NHI covers almost the entire population, we essentially have every stroke and cardiac patient in Taiwan. These claims record diagnoses of diseases, admission dates, and discharge dates (for inpatient services), along with a detailed description of medical expenses (food, room, diagnoses, surgery, etc.) before and after copayment. Since NHI covers almost all treatment on stroke and heart diseases,[22] and few adjustments were made between claims and reimbursement, the

21. A majority of studies finds evidence of a correlation between higher volumes and better patient health outcomes (Halm, Lee, and Chassin 2002). It may be that higher volumes lead to better patient outcomes, and thus there is learning by doing (Luft, Bunker, and Enthoven 1979). An alternative theory is there exists some potentially outcome improving characteristic, unobservable to the researcher, which attracts higher volumes of patients. This alternate theory is referred to as selective referral (Luft, Hunt, and Maerki 1987). Recent work by economists focuses on disentangling this endogenous relationship. Thus, we use expected volume to shy away from the problem of endogeneity.

22. The only treatment not fully covered is stent for cardiac patients. Nonetheless, the use of this procedure was still not prevalent at the sample time (1997–2002) in Taiwan.

actual NHI amount was very close to expenditures recorded on these claims.[23] Most importantly, each claim record consists of three scrambled but unique IDs: patient ID, doctor ID, and provider ID; these unique IDs enable us to link information about patients and providers from other sources.

The second source combines several different NHID health provider (hospital and clinics) data sets spanning from 1996 to 2002.[24] From these data sets, we obtain a health provider's location, accreditation, ownership, and teaching status (for hospitals) as well as its facilities (e.g., departments and beds) and manpower (e.g., doctors, nurses, and technicians). Because accreditation and teaching status are highly correlated, we combine these two variables and categorize hospitals into three groups by their teaching status: major teaching hospitals, minor teaching hospitals, and community hospitals. Moreover, we merge the provider's location with a file containing the latitude and longitude of each zip code in Taiwan. As shown below, this information is the key to defining a hospital's "market" in our analysis.

The third source is the eligibility file of all NHI enrollees covering between 1996 and 2002. The eligibility file reports an enrollee's ID, basic demographics (sex and age), group of enrollment, as well as zip code of enrollment location. With the help of the unique patient ID, we are able to merge the eligibility file with medical claims and extract two pieces of information: sex/age and zip code of enrollment; the latter piece of information allows us to derive the distance between a patient's residence and admitted hospital. Because the eligibility file is kept in the log format—a new entry is added once there is a change in zip code or group of enrollment—a covering period (starting and ending dates) is also included for each entry. For convenience, we match a patient's claim with the last entry of eligibility file in the admitted year if multiple entries are found in that year. Finally, we merge the data with death certificate files obtained from the Ministry of Health; the certificates record information such as place and cause of death and, most importantly, date of death; the time of death after health shock is used as an indicator of quality of care.

23. The difference between the actual reimbursement and the amount from these claims is less than 3% and 5% for inpatient and outpatient services, respectively, over the sample years.

24. Specifically, we use "Registry for Contracted Medical Facilities," "Supplementary Registry for Contracted Medical Facilities," "Registry for Contracted Beds," "Registry for Medical Personnel," and "Registry for Contracted Specialty Services." For hospitals with incomplete or missing information in the data, we supplement with Hospital Registry Files and Hospital Service Files obtained from the Ministry of Health.

B. Sample

Our study uses data of stroke and cardiac patients who were over 35 years old and admitted during 1997 and 2001. We dropped the sample of 1996 for the convenience of calculating each patient's outpatient and inpatient expenditures in the preceding year. We excluded patients admitted in 2002 to calculate the 1-year mortality. We also use only cases of patients who stayed less than 91 d at short-term general hospitals and had health expenditures less than NT500,000. Furthermore, we restrict to cases admitted to accredited hospitals with at least 20 stroke and cardiac cases in that year. Longer stays or higher expenditures are extreme cases. Hospitals with fewer cases are dropped because their performances are likely to be distorted by extreme cases. In addition, given that our subjects are patients suffering severe illnesses, smaller hospitals are unlikely to be relevant competitors in our analysis.

About half of the sample is dropped to ascertain a patient's residence information. While the eligibility file records information on the zip code of enrollment, there are several practical difficulties in the direct application of this information. Most problematic is that the zip code of enrollment indicates the location from which an enrollee obtains his or her coverage, not that of a patient's household registry. The discrepancy is especially prevalent for those who do not coreside with the ones who pay their insurance premiums (e.g., college students or the elderly). In addition, even for enrollees whose residences are identical to household registries, a substantial portion of them actually choose to live at places different from their household registries.[25]

We take three steps to ensure a patient's residence information. First, we select enrollees whose premiums are self-paid or paid by spouses only, excluding the ones covered by

25. The discrepancy rate is estimated to be around 17%, that is, 17% of the families do not live at their household registries. See Shih et al. (2003) for details.

TABLE 2

Patients and Hospitals Used in the Analysis (Table Entries are Number of Hospitals Meeting Selection Criteria)

Year	New cases with valid hospital and patient information	and enrolled into accredited hospitals with 20 cases a year	with reliable residence information	and who lived within 30 km of the index hospital
Number of hospitals				
1997	515	409	409	409
1998	489	381	381	381
1999	480	369	369	369
2000	480	357	357	357
2001	444	331	331	331
Year	**New cases with valid hospital and patient information**	**and enrolled into accredited hospitals with 20 cases a year**	**with reliable residence information**	**and who lived within 30 km of the index hospital**
Number of patients				
1997	127,623	126,628	74,788	61,490
1998	137,086	136,085	79,952	65,979
1999	145,577	144,795	84,308	69,093
2000	149,160	148,211	85,855	69,953
2001	156,647	155,734	90,209	73,941
	New cases with valid hospital and patient information	**and enrolled into accredited hospitals with 20 cases a year**	**with reliable residence information**	**and who lived within 30 km of the index hospital**
Characteristics of patients				
Patients (%)				
AMI	5.76	5.76	5.67	5.55
CHF	17.34	17.33	17.41	17.39
IHD	45.96	45.88	46.84	47.64
Hemorrhage stroke	7.58	7.61	7.16	6.66
Ischemic stroke	23.36	23.43	22.92	22.76
Male	56.02	56.06	59.64	60.41
Age	69.02	69.02	69.72	69.80
DxCG risk Score[a]	2.659	2.659	2.733	2.739

[a]DxCG risk index is derived from patient's age and sex using commercial concurrent model (Zhao et al. 2005).

third parties (children or relatives).[26] Second, we choose enrollees of three enrollment groups: obtaining coverage from the office of household registry, farmer associations, and private employers. Zip codes of enrollment for those enrollees are identical to that of their household registries or places of employment.[27] To further ensure that patients reside at places close to household registries, we drop the ones whose traveling distances

26. The restriction can ensure that an enrollee co-resides with the one who pays his or her insurance premium.

27. Enrollees obtaining coverage from farmers' associations or household registry offices in general have identical zip codes of enrollment and household registries. For those obtaining insurance from private employers, their zip codes of enrollment are largely identical to those of their place of employment.

to admitted hospitals are more than 30 km (around 20 miles).

Table 2 outlines the exclusion restriction we imposed and the observation number after each exclusion criteria. In total, there are 716,093 new stroke and cardiac cases with valid hospital and patient information. About one-quarter of hospitals are eliminated due to the hospital restriction. Because most of them are smaller ones, it only affects less than 2% of the total observation. Approximately, two-fifths of the sample is dropped due to constraints of premium supporters and groups of enrollment. Nevertheless, there is no strong evidence showing that the exclusion constraint changes the severity mix of patients (Table 2). The remaining 15% is dropped due to 30-km distance constraint. The final sample consists of 340,456 cases, roughly half of the original size, of which very few are repeated observations of the same patient.

C. Sample Statistics

To illustrate the extent of market concentration, we show the change of two different HHI indices (HHI_k^{pat*} and $HHI_j^{75\%}$) since 1997. It is clear from the table that exits of small hospitals and entries of large hospitals indeed increase the market concentration regardless of the HHI index used. For example, the upper part of Table 3 shows that the mean of the HHI^{pat*} increases from 0.14 in 1997 to 0.17 in 2001, about a 20% increase in 7 years; a similar pattern is observed when measuring by the median value. Compared with $HHI_j^{75\%}$, HHI^{pat*} captures more market dynamics over this period. This is due to the fact that $HHI^{75\%}$ is likely to be contaminated by other unobserved factors. Given the value of HHI is harder to interpret, we follow Kessler and McClellan (2000) by dividing HHI^{pat*} into four groups: very high, high, low, and very low based on its distribution across 5 years. We show only the distribution of four dummies using HHI^{pat*} because that is the main index used in our estimation. As one could expect, a sharp decrease and a sharp increase in the portion of very low and very high concentration is observed, while two middle concentration groups do not change in any systematic way.

Table 4 displays the summary of treatment expenditure and health outcomes of new stroke and cardiac patients by four concentration levels. From the table, a stroke or cardiac case costs more when treated in less concentrated areas. The average expenditure is NT60,094, NT48, 913, NT48,304, and NT40,254 in very low, low, high, and very high concentration, respectively. Likewise, this pattern is consistent with the total expenditure in the following year. For the health outcome, higher mortality is associated with higher concentration, except for the one with the very high quartile. Overall, treatment of higher concentration incurs lower expenditure and results in worse health outcomes.

One possible explanation for the association between market concentration and treatment expenditure as well as concentration and health outcomes is the difference of severity mix among patients. If hospitals of lower concentration (or higher competition) tend to provide better quality of care, those hospitals may attract high-risk patients, resulting in a higher expenditure; or those hospitals may choose

TABLE 3
Measures of Market Concentration on Stroke and Cardiac Patients

	1997	1998	1999	2000	2001	1997–2001 (%)
$HHI^{75\%}$						
Median	0.151	0.165	0.154	0.158	0.166	10.1
Mean (SD)	0.217 (0.192)	0.228 (0.193)	0.232 (0.193)	0.233 (0.184)	0.238 (0.184)	9.6
HHI^{pat*}						
Median	0.120	0.136	0.137	0.136	0.146	21.3
Mean (SD)	0.142 (0.067)	0.153 (0.070)	0.158 (0.073)	0.161 (0.068)	0.170 (0.081)	19.9
HHI^{pat*} (by quartile) (%)						
Very low (first quartile)	48.20	38.79	41.82	37.73	30.60	−36.5
Low (second quartile)	26.64	27.50	21.48	21.66	26.11	−2.0
High (third quartile)	16.15	18.61	21.43	23.78	22.35	38.4
Very high (fourth quartile)	9.01	15.09	15.26	16.82	20.94	132.4

TABLE 4
Summary Statistics by Levels of Market Concentration

	Very Low HHI (First Quartile)	Low HHI (Second Quartile)	High HHI (Third Quartile)	Very High HHI (Fourth Quartile)
Expenditure and mortality				
One-month mortality (%)	6.9	7.8	8.3	7.7
One-year mortality (%)	18.2	20.1	21.0	20.9
Index admission expenditure[a]	60,094 (100,429)	48,913 (88,891)	48,304 (84,870)	40,254 (75,340)
One-year expenditure[a]	96,603 (173,630)	78,130 (143,557)	77,258 (133,002)	65,242 (118,037)
Hospital characteristics				
Teaching status (%)				
Major teaching hospitals	36.1	23.0	17.7	2.6
Minor teaching hospitals	31.0	32.4	36.9	46.1
Community hospitals	32.8	44.6	45.5	51.3
Bed number (%)				
0–100	16.2	26.5	21.8	19.5
100–300	21.3	25.4	29.2	41.3
300–600	29.0	23.7	24.9	27.6
Over 600	33.5	24.4	24.2	11.6
Demographic and prehealth status				
Male (%)	66.1	58.5	56.1	54.9
Age, year				
40–60 (%)	20.2	17.2	15.9	11.3
60–70 (%)	24.9	26.1	26.0	25.1
70–80 (%)	39.6	39.1	38.4	41.4
≥80 (%)	15.3	17.6	19.7	22.2
AMI (%)	6.5	5.0	5.3	4.5
CHF (%)	16.1	18.5	16.6	19.9
IHD (%)	49.5	48.1	45.2	45.7
Hemorrhage stroke (%)	7.0	6.7	6.8	5.7
Ischemic stroke (%)	21.0	21.8	26.1	24.2
DxCG risk score	2.705 (0.762)	2.729 (0.708)	2.743 (0.684)	2.832 (0.613)
Inpatient expenditure in preceding year (/0000)	0.219 (4.081)	0.122 (2.744)	0.101 (2.278)	0.111 (2.808)
Outpatient expenditure in preceding year (/0000)	2.335 (5.990)	2.027 (5.405)	2.086 (5.624)	1.803 (4.839)
Charlson index	0.949 (1.252)	0.959 (1.247)	0.974 (1.261)	1.012 (1.267)
Nearby population (/000,000, 10 km)	20.716 (14.022)	7.779 (6.856)	4.723 (3.628)	1.925 (1.321)
Average household income (yearly)(/10,000, county/town)[b]	117.204 (24.719)	100.233 (14.175)	90.941 (12.029)	91.042 (8.587)
N	133,008	83,048	70,035	54,365

Note: Standard errors are in parentheses.

[a]Expenditure are in NT dollars and deflated using CPI (2001 = 100).

[b]The household income is the average income in the zip code of Taipei and Kaohsiung, and the average county income for the rest of Taiwan.

healthier patients, resulting in better health outcomes. To examine this possibility, Table 4 shows the descriptive statistics of stroke and cardiac patients by concentration quartiles. The summarized statistics of patient variables provide mixed evidence. Comparing cases across four quartiles, patients in areas of lower concentration on average are younger and have lower value of Charlson indices, but incur higher outpatient and inpatient expenditures in the preceding year. In terms of admitted illness, however, hospitals in lower quartiles are not necessarily the ones who admitted more serious illnesses. The portion of CHF has no consistent pattern across the HHI distribution, but the portion of hemorrhage stroke is slightly higher in the lower quartile.

Another explanation for the expenditure and outcome difference is due to the difference in the hospital's supplied health care. Other things being equal, better hospitals are likely to deliver good outcomes. Table 4 also shows the characteristics of hospitals by their concentration quartiles. While over 36% and 23% of hospitals in very low and low concentration quartiles are major teaching hospitals, respectively, the portion for high and very high concentration quartiles is less than 20%. In addition, almost 34% of hospitals in very low concentration quartiles have beds over 600 while that portion is less than 12% in very high concentration quartiles. Although large or better accredited hospitals are not associated with lower mortality rates, hospitals in different quartiles exhibit very distinct characteristics. This demonstrates the importance of controlling the possible correlation between market concentration and the supplied health service in the estimation.

VI. EMPIRICAL RESULTS

A. Different Measures of Market Competitiveness

Table 5 shows the impact of market competition on expenditure and health outcomes using two measures of HHI (HHI_k^{pat*} and $HHI_j^{75\%}$). For comparison purposes, we employ linear and quadratic terms of HHI. We first compare our results without controlling hospital fixed effects versus those with the control. In particular, for both short-term and long-term mortality outcomes, controlling hospital fixed effects significantly reduce the magnitudes of the HHI coefficients as well as the significance levels, regardless of using HHI_k^{pat*} or $HHI_j^{75\%}$. These results suggest that the endogeneity bias on mortality outcomes largely arises from hospitals unobserved characteristics that are time invariant. Once we control hospital fixed effects, hospital competition has no significant impacts on mortality outcomes.

Comparing the results with hospital dummies vertically, regardless of the measures of HHI, our results indicate that higher HHI values (higher market concentration and lower market competition) increase health expenditures, but have no significant impacts on health outcomes. To gauge the endogenous

TABLE 5

Competition on Expenditures and Outcomes by Different Measures of Market Competitiveness

	Without Hospital Dummies				With Hospital Dummies			
	Log (Expenditure)[a]		Mortality[a]		Log (Expenditure)[a]		Mortality[a]	
	Admission	1 Year	1 Month	1 Year	Admission	1 Year	1 Month	1 Year
HHI^{pat*} (linear term)	−0.695*** (0.101)	−0.437*** (0.107)	−0.099*** (0.034)	−0.158*** (0.049)	−0.929*** (0.150)	−0.944*** (0.156)	−0.018 (0.048)	0.028 (0.070)
HHI^{pat*} (quadratic term)	0.552*** (0.140)	0.358** (0.158)	0.133** (0.055)	0.222*** (0.079)	1.219*** (0.212)	1.149*** (0.239)	0.025 (0.078)	−0.097 (0.116)
Predicted patient volume			−0.003** (0.001)	−0.007*** (0.002)			−0.011*** (0.004)	−0.023*** (0.006)
$HHI^{75\%}$ (linear term)	−1.135*** (0.033)	−1.018*** (0.035)	−0.031*** (0.009)	−0.073*** (0.014)	−0.365*** (0.094)	−0.402*** (0.100)	0.006 (0.028)	0.002 (0.041)
$HHI^{75\%}$ (quadratic term)	0.926*** (0.033)	0.833*** (0.034)	0.021** (0.009)	0.061*** (0.014)	0.302*** (0.087)	0.306*** (0.096)	0.011 (0.027)	0.018 (0.040)
Predicted patient volume			−0.003*** (0.001)	−0.008*** (0.002)			−0.011*** (0.004)	−0.023*** (0.006)
N	340,456	340,456	340,456	340,456	340,456	340,456	340,456	340,456

[a]All regressions include variables listed in Table 4 and interactions between years and residence counties.

**Significant at the 5% level (two-tailed test); ***significant at the 1% level (two-tailed test).

TABLE 6
Results of Competition on Expenditures and Outcomes (HHI^{pat*})

	Log (Expenditure)[a]		Mortality	
	1 Month	1 Year	1 Month	1 Year
Low HHI	−0.008 (0.008)	−0.008 (0.008)	0.000 (0.002)	0.001 (0.003)
High HHI	−0.037*** (0.011)	−0.029*** (0.011)	(0.002) (0.003)	(0.003) (0.004)
Very high HHI	−0.060*** (0.014)	−0.060*** (0.014)	−0.002 (0.004)	−0.007 (0.006)
Predicted patient volume (000)			−0.001*** (0.000)	−0.001*** (0.000)
Demographic and prehealth status				
Male	0.104*** (0.004)	0.026*** (0.003)	−0.003*** (0.001)	0.014*** (0.001)
Age, year				
60–69	0.039*** (0.007)	0.048*** (0.007)	0.004*** (0.002)	0.015*** (0.003)
70–79	0.083*** (0.009)	0.051*** (0.009)	0.020*** (0.002)	0.070*** (0.003)
80+	0.181*** (0.009)	0.026** (0.009)	0.080*** (0.002)	0.221*** (0.003)
AMI	−0.631*** (0.009)	−0.683*** (0.008)	−0.117*** (0.003)	−0.007* (0.004)
IHD	−0.748*** (0.008)	−0.606*** (0.008)	−0.169*** (0.003)	−0.143*** (0.003)
Hemorrhage stroke	0.137*** (0.011)	0.159*** (0.010)	0.066*** (0.004)	0.153*** (0.004)
Ischemic stroke	−0.600*** (0.008)	−0.211*** (0.008)	−0.132*** (0.003)	−0.064*** (0.004)
Previous year's outpatient expenses (′0,000)	0.025*** (0.001)	0.038*** (0.002)	−0.001*** 0.000	0.003*** 0.000
Previous year's outpatient expenses (′0,000)	0.001*** (0.000)	0.049*** (0.001)	−0.000*** 0.000	−0.001*** 0.000
DxCG risk score	0.000 (0.005)	0.022*** (0.004)	0.004*** (0.001)	0.013*** (0.002)
Charlson index	0.080*** (0.001)	0.044*** (0.001)	0.020*** 0.000	0.064*** (0.001)
Average household income (county/town) (′0,000)	−1.182*** (0.190)	−0.504*** (0.181)	−0.127*** (0.047)	−0.326*** (0.070)
Bed number				
100–300	0.045*** (0.013)	0.028** (0.013)	0.007* (0.004)	0.006 (0.006)
300–600	0.105*** (0.017)	0.073*** (0.017)	0.013*** (0.005)	0.008 (0.007)
Over 600	0.149*** (0.021)	0.098*** (0.020)	0.017*** (0.006)	0.013 (0.008)
N	340456	340456	340456	340456

[a]All regressions include hospital dummies and interactions between years and residence counties. In addition, the regressions include hospital characteristics not reported in the table such as dummies of ownership and accreditation status. Standard errors shown in parentheses accounted for hospital clusters. Intercepts are not shown.

*Significant at the 10% level (two-tailed test); **significant at the 5% level (two-tailed test); ***significant at the 1% level (two-tailed test).

bias resulting from unobserved patient and hospital characteristics, we compare the marginal effects of HHI evaluated at the mean in 1997.[28]

Our results suggest that decreasing market concentration by 10% (or increasing market competition by 10%) will increase the short-term expenditures by 5.8% based on HHI^{pat*} and 2.2% based on $HHI^{75\%}$. Similar magnitudes are also observed for long-term expenditures. Obviously, based on the conventional 75% variable-radius HHI, the impact of market competition is underestimated. It implies that the source of our endogeneity is more likely to come from the contemporary changes on market competitiveness and expenditures after the NHI. That is, the introduction of NHI may be associated with higher growth in medical expenditures as well as a more

28. Marginal effects are calculated as $\hat{\gamma}_1 + 2\hat{\gamma}_2\overline{\text{HHI}}$ where $\hat{\gamma}_1$ and $\hat{\gamma}_2$are the estimated coefficients for linear and quadratic terms, respectively. We use the mean HHI in 1997 in calculation.

concentrated hospital market. Consequently, the effect using $HHI^{75\%}$, calculated based on actual patient flows, also captures the positive impact of NHI on health expenditures.

B. Basic Results

Table 6 shows the impact of market competition on expenditures and outcomes using HHI_k^{pat*} by controlling for patient demographics and severity, hospital characteristics, year, and county/city interaction effect along with the hospital fixed effect. Because a hospital's characteristics are unlikely to change over time, the hospital fixed effect essentially removes the explanatory power of many hospital-related variables. For the purpose of exposition, we omit results of hospital variables that are unlikely to change over time (e.g., accreditation and ownership status). From Table 6, it is clear that high-risk patients consistently incur higher expenditures and suffer worse health outcomes; this applies to variables indicating patient's age, DxCG risk score, and Charlson index, as well as disease dummies. We also observe negative relationship between predicted patient volume and mortality rates, which is consistent with most of volume-outcome literature.

Our variable of interest is the competition measure. As stated earlier, the analysis employs quartile dummies with quartile cutoffs in all years based on the 1997–2002 pooled distribution of HHI_k^{pat*}. From Table 6, treatment expenditures for stroke and heart patients during the index admission in more concentrated markets in general are comparatively higher, but not monotonically, than those in less concentrated areas. The difference between the fourth and the first quartile was 6.0%, larger than the effect of moving from the first to the third quartile, 3.7%. Nonetheless, the differential is minimal when moving from the first quartile to the second quartile. The long-term expenditures were also the lowest in the most concentrated market. For health outcomes, none of the coefficients are statistically significant either measured in terms of 1-month or 1-year mortality.

C. Robustness Checks

To confirm our findings, we check whether the results are robust to different specifications. We consider three other specifications. First, we allow a flexible setting for the Charlson index in the estimation. Previous studies (e.g., Goldstein et al. 2004) have indicated that the risk value assigned for each illness embedded in the Charlson index may be inappropriate for strokes or heart diseases. The estimation thus includes a set of disease dummies contained in Charlson indices so that the risk value could vary by each disease. Secondly, we estimate the model separately by stroke and cardiac patients to examine if our results are driven by differences in illnesses. Table 7 displays results from these three different specifications.

It is clear that changing to the setting allowing flexible Charlson indices does not have much impact on our results. As for the competition effect on cardiac and stroke patients, we still obtain similar patterns on expenditures and health outcomes for cardiac patients. Expenditures are significantly lower in more concentrated markets, but mortality rates are not different by the extent of market concentration. For the stroke patients, except for the coefficient of the fourth quartile for the long-term expenditure, all other coefficients on expenditures are not statistically significant. Compared with cardiac treatment, our results indicate that stroke patients, no matter where they live, receive very standardized treatment. By contrast, market competition more greatly affects the treatment of cardiac patients that has been under dramatic developments in the recent years.

D. Sources of Higher Hospital Expenditure

So far, our results consistently show that treatment of stroke and heart patients is less expensive in a more concentrated market. Because NHI pays the regulated price on fee-for-service basis, the higher treatment expenditure itself implies that there is higher treatment intensity for less concentrated areas. Nonetheless, the sources of higher treatment expenditure are still unclear. To further investigate the underlying factors, we replace the dependent variable with four other variables (Table 8). First, we break the health expense into two components, length of stay and expense per day, and check which one is affected most by market concentration. Next, we check if the expenditure difference is associated with the difference in the usage of expensive equipment or surgical procedures.

TABLE 7
Robustness Checks for Competition on Expenditures and Outcomes (HHI^{pat*})

	Log(Expenditure)[a]		Mortality[a]	
	Admission	1 Year	1 Month	1 Year
Charlson index (flexible setting)[b]				
Low HHI	−0.008 (0.008)	−0.008 (0.008)	0.000 (0.002)	0.001 (0.003)
High HHI	−0.035***(0.011)	−0.029*** (0.011)	(0.002) (0.003)	(0.002) (0.004)
Very high HHI	−0.059*** (0.014)	−0.061*** (0.014)	−0.001 (0.004)	−0.006 (0.006)
Predicted patient volume			−0.010** (0.004)	−0.020*** (0.006)
Cardiac illnesses				
Low HHI	−0.018* (0.009)	−0.015 (0.009)	0.000 (0.002)	0.000 (0.004)
High HHI	−0.042*** (0.013)	−0.037*** (0.013)	0.002 (0.003)	0.001 (0.005)
Very high HHI	−0.065*** (0.016)	−0.058*** (0.017)	0.001 (0.004)	−0.002 (0.007)
Predicted patient volume			−0.008* (0.005)	−0.024*** (0.007)
Strokes				
Low HHI	0.01 (0.015)	0.002 (0.014)	0.000 (0.005)	0.005 (0.006)
High HHI	−0.024 (0.020)	−0.009 (0.019)	−0.013** (0.006)	−0.011 (0.008)
Very high HHI	−0.041 (0.027)	−0.048** (0.024)	−0.007 (0.008)	−0.016 (0.011)
Predicted patient volume			−0.017* (0.009)	−0.015 (0.012)

[a]All regressions include hospital dummies and interactions between years and residence counties. In addition, the regressions include hospital characteristics not reported in the table such as dummies of ownership and teaching status. Standard errors shown in parentheses accounted for hospital clusters. Intercepts are not shown.

[b]Instead of setting risk value for each illness, we include dummies of illnesses contained in Charlson index (ami, diabetes, pvd, etc.). For details on the illnesses used in Charlson index, see Goldstein et al. (2004).

*Significant at the 10% level (two-tailed test); **significant at the 5% level (two-tailed test); ***significant at the 1% level (two-tailed test).

We do so by substituting hospital expenditure with the utilization of expensive diagnostic equipment such as CT or MRI for all patients, and surgical procedures such as PTCA and bypass for heart patients.

On average, the length of stay is significantly shorter, and the treatment intensity is significantly lower, in the very high concentration and high concentration markets. Each part contributes roughly a half to the difference of treatment expenditure across various concentration groups. For instance, in the most concentrated market, the length of stay was 2.1% shorter than those in the least concentrated market while the expenditure per day was 3% lower in the most concentrated market. As for the usage of expensive equipment, we found that the probability of using

TABLE 8
Sources of Differences in Medical Expenditure at the Index Admission (HHI^{pat*})[a]

	Log (Length of Stay)	Log (Per Day Expenditure)	Use of PTCA or Bypass[b]	Use of CT or MRI
Low HHI	−0.013* (0.007)	0.005 (0.006)	−0.002 (0.002)	−0.006** (0.003)
High HHI	−0.016* (0.010)	−0.017** (0.008)	−0.003 (0.003)	−0.009** (0.004)
Very high HHI	−0.021* (0.012)	−0.030*** (0.010)	−0.007* (0.004)	−0.001 (0.005)

*Significant at the 10% level (two-tailed test); **significant at the 5% level (two-tailed test); ***significant at the 1% level (two-tailed test).

[a]All regressions include hospital dummies and interactions between years and residence counties. In addition, the regressions include hospital characteristics not reported in the table such as dummies of ownership and accreditation status. Standard errors shown in parentheses accounted for hospital clusters. Intercepts are not shown.

[b]Includes only cardiac patients.

CT or MRI is significantly lower in the second and the third quartiles, but not the last one. The probability of having PTCA is also found to decrease as the market concentration increases, although the effect is statistically significant only in the fourth quartile. In sum, our results suggest that hospital competition leads to higher treatment intensities in terms of longer length of stay, higher expenditure per day, and higher probabilities of using expensive technology and equipment.

VII. DISCUSSION

This article investigates the effect of hospital competition on treatment expenditures and health outcomes for stroke and cardiac treatment. Because hospitals with distinctive services often attract unobservable high-cost patients, the conventional competition measures could introduce the endogenous bias due to correlations between a patient's hospital choice and his or her unobserved characteristics. Thus, we follow the method developed by Kessler and McClellan (2000) that first estimates patient-level hospital choice models using exogenous variables (e.g., distance to hospitals), and then calculates the revised Herfindal index based on the predicted patient flows. Using the NHI enrollees hospitalized for these diagnoses between 1997 and 2001 in Taiwan, we examine whether hospitals facing different market concentrations incur different health expenditures or mortalities after treatment.

Our results indicate that market competition significantly increased health expenditures, either measured by the expenditure at the index admission or the expenditure in the following year after the health shock. In addition, the increase of expenditure at the admission is the result of an increase of length of stay, per day expenditure, as well as the use of expensive diagnostic equipment. Finally, we found that competition led to lower mortality rates both in the short run and long run, but the effects are not statistically significant. Those results are consistent with the theoretical prediction when prices are regulated or price competition is weak.

We now discuss several directions for future studies. First, and most importantly, we measure a patient's outcome by his mortality rate, not accounting for his or her functional status. For post-stroke patients, a valuation that incorporates the patient's mortality and functional status may be a better outcome measure (e.g., quality of adjusted year of life).[29] Future analyses should combine the patient's functional status to evaluate the effect of hospital competition on health outcome.

Second, the competition effect in the analysis differs substantially by disease types: competition increases the short- and long-term expenditure of cardiac treatment, but does not impact stroke patients' expenditures or health outcomes. In contrast with treatment for heart diseases, advances in health technology for stroke treatment have been relatively slow in recent years. One explanation is that the technology advances in cardiac treatment permit hospitals to compete more through the use of new medical service, resulting in higher expenditure for cardiac patients. Although we found weak evidence suggesting higher treatment expenditure is the result of an increased use of advanced surgical procedure (e.g., PTCA or CABG), a careful analysis that links the market competition with technology advances might be important.

The main contribution of this article is to add to the sparse literature providing empirical evidence as to how hospital competition affects treatment expenditure and health outcomes in developing countries. Although a significant amount of attention has been paid over the past decade to the consequences of competition, the majority of them focus on the health-care market in the United States. The fact that our study is based on another country, in which the health-care system is less fragmented, could be used to test the robustness of the economic theory. Additionally, the results of the extensive U.S. research may be difficult to generalize to health systems in other countries. By comparison, our analysis uses Taiwan data and investigates the short- and long-term consequences of hospital competition. Our findings should be more applicable to other countries seeking to conduct health reforms through the introduction of market forces.

29. Muennig and Gold (2001) find that the additional quality-adjusted years of life and absolute years of life are very different if strokes are eliminated.

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