How Do Hospitals Respond Differently to Competition? Quality, Price, and Operational Efficiency *

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Abstract

Using a data set of hospitals which are graded based on a comprehensive matrix, this paper analyzes the effects of competition on hospital quality, price, and operational efficiency. The study finds that hospitals improve quality in response to competition when the quality improvement could be revealed to patients through future upgrading. The top-grade hospitals, in contrast, reduce prices in response to competition. All hospitals improve operational efficiency. The study emphasizes the role of informational asymmetry between hospitals and patients and offers an explanation for the puzzle of mixed findings in the literature on the impact of competition on hospital quality.

Keywords: Competition, Hospital quality, Price, Operational efficiency, Heterogeneous responses

JEL Classification: I11, I18, L15

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1 Introduction

Quality health care is a matter of utmost importance, but its provision has become increasingly costly in developed and developing countries.[1] A variety of approaches have been taken from the demand and supply sides to achieve quality health care at affordable costs.[2] One of the most often employed strategies is to promote competition in the hospital industry, yet a large literature has uncovered mixed findings about the impact of competition on hospital quality (for a review see, for example, Propper et al., 2006; Cooper et al., 2011; Gaynor et al., 2013). The challenge for further studies, as pointed out by Gaynor and Town (2012), is to identify *"the factors that determine whether competition will lead to increased or decreased quality."* In this paper, we argue that informational asymmetry – whether hospital quality improvement can be revealed to patients – plays a key role in determining whether hospitals improve quality in response to competition.

Informational asymmetry between hospitals and patients is prominent even in the most developed countries (Arrow, 1963; Cutler, 2010). For example, although there are three major hospital rankings in the United States,[3] they usually provide very different and sometimes even contradictory rankings (Austin et al., 2015; Hathi and Kocher, 2017). As a result, patients can hardly tell the quality differences across hospitals from these rankings. It is natural that if patients cannot recognize the quality improvement, hospitals would have no incentive to do so. Using a comprehensive data set of hospitals in a major city in China, this paper shows that hospitals improve quality in response to competition, but only when the quality improvement can be revealed to patients; otherwise, hospitals respond to competition by adjusting prices instead of improving quality. The findings echo the prediction in the theoretical industrial organization literature that emphasizes the importance of information in determining firms' quality response to competition (e.g., Akerlof, 1970; Levin 2001).

The hospital system in China provides an ideal setting to study the impact of competition on hospital quality and the role played by informational asymmetry. China has a hospital-centric health care system, under which patients directly go to hospitals for primary and specialty care without any referral (Yip et al., 2012). The absence of "gatekeepers" exacerbates the pitfall of informational asymmetry between hospitals and patients. Accordingly, Chinese government adopted a rigorous hospital grading system to convey information on hospital

[1] For example, U.S. health expenditure grew 4.3 percent to \$3.3 trillion in 2016, or \$10,348 per person, and accounted for 17.9 percent of gross domestic product (GDP), according to the National Health Expenditures Highlights from the Centers for Medicare and Medicaid Services. Meanwhile, Brazil, Chile, Egypt, Indonesia, the Philippines, and Vietnam experienced more than 25% increase in the share of national health expenditure in GDP over the past two decades (World Health Organization Global Health Expenditure database, 2017).

[2] Take the United Kingdom and the United States for instance: the English National Health Services reforms from 2002 to 2008 provided patients with publicly assessable data on hospital quality and allowed patients to select hospitals for surgery; the U.S. Affordable Care Act introduced new payment models, requiring physicians to shift from the traditional fee-for-service system to the Merit-based Incentive Payment System or Alternative Payment Models.

[3] They are the Hospital Compare of the Centers for Medicare and Medicaid Services, the ratings on the website Healthgrades, and the ratings published by U.S. News & World Report.

quality to patients. The system classifies hospitals into three categories: Grade 1 (primary), Grade 2 (secondary), and Grade 3 (tertiary), with increasing quality, based on a comprehensive assessment matrix of hospital quality measures. The gradings are reviewed periodically, with hospitals being upgraded for improving quality or downgraded for deteriorating quality. The gradings are discriminative and informative, with 7.5 percent of hospitals being graded as tertiary hospitals, 26 percent secondary hospitals, and the rest primary hospitals (China's Health and Family Planning Statistical Yearbook, 2015). Chinese patients use the gradings in their choices of hospitals, as a higher grade indicates better quality. As a result, "upgrading" reveals quality improvement.

Two challenges emerge when investigating how hospitals respond to competition. The first is how to measure precisely the degree of competition faced by individual hospitals, given the large heterogeneity in quality and size across hospitals. The literature uses the number of hospitals, usually without considering the difference in quality across hospitals. Given the hospital grading system in China, however, we expect that the competition a hospital faces mostly come from hospitals of the same grade as the concerned hospital. To capture this feature, we develop a refined measure of competition by focusing on within-grade competition. Furthermore, we take into account the distance between hospitals, their similarity in specialties, and their relative size when measuring competition, because these factors can also affect the degree of competition.

The second challenge is to deal with the endogeneity of market structure. We use a simulated instrumental variable (SIV) approach (e.g. Gruber and Saez, 2002; Dahl and Lochner, 2012) to address this issue, employing the (heterogeneous) impacts of two government policy shocks in 2009. The policy shocks suddenly opened the gate for existing hospitals to upgrade to a higher level and encouraged private capital to establish new, mostly Grade 1 hospitals. They not only dramatically increased the total number of hospitals, but also changed the distribution of hospitals across grades and geographic areas. Compared with the relatively marginal changes in market structure in developed countries, such as the United States and the United Kingdom, the substantial variations in market structure in China following the two policy shocks lend us a big advantage to identify the impact of competition. We exploit the timing of the policy shocks together with localized market condition and individual hospitals' grade and geographical characteristics to construct the simulated IVs for the competition measures. The idea is to simulate the market structure by predicting individual hospitals' decisions on entry, exit, and grade change, which depend on the policy shocks, localized market condition, and the lagged state variables of individual hospitals. The simulated IVs are by construction correlated with the actual competition measures, but they are unlikely to be correlated with the unobserved outcome-associated shocks.

Using the refined and instrumented competition measures, we find that competition drives hospitals to improve quality when such quality improvement can be revealed to patients in the future. We measure quality by emergency department (ED) mortality rates similar to

Bloom et al. (2015) and the nurse-to-bed staffing ratio following Lin (2015) and Tay (2003). Both measures are reviewed by the government when evaluating hospitals' applications for upgrading. When facing intensified competition, Grade 1 hospitals and Grade 2 hospitals reduce the ED mortality rate and increase the nurse-to-bed staffing ratio, because they have the chance to reveal their quality improvement through future upgrading. Economically, increasing competition by one standard deviation reduces the number of deaths per 1,000 ED patients by 0.48 for Grade 1 hospitals (a 59 percent reduction) and 0.28 for Grade 2 hospitals (a 25 percent reduction). It also leads to an increase in the number of nurses per bed by 0.24 for Grade 1 hospitals (a 59 percent increase) and 0.09 for Grade 2 hospitals (a 19 percent increase). However, Grade 3 hospitals neither reduce the ED mortality rate nor increase the nurse-to-bed staffing ratio, presumably because they are already at the top grade and have no means to reveal their quality improvement through further upgrading.

Rising costs due to quality improvement and increased competition pressure could push hospitals to adjust prices to a higher or lower level. We find that when facing competition, Grade 3 hospitals reduce prices to attract patients, because the hospitals have no incentive to improve quality as the top-grade providers and must resort to price reduction to maintain competitive. A one standard deviation increase in competition reduces the average price by 38 percent for Grade 3 hospitals. However, Grade 1 and Grade 2 hospitals have no statistically significant changes in their price levels in response to competition, although they do improve quality. The reason is that it takes time for them to be upgraded to signal their quality improvement, but patients can immediately observe price changes.

To offset the increased costs due to quality enhancement or decreased revenue due to price reduction, hospitals are further found to improve operational efficiency when facing competition. Grade 3 hospitals reduce their operating expenditure per patient (average cost). A one standard deviation increase in competition reduces the average cost for Grade 3 hospitals to treat patients by 31 percent. Given that Grade 1 and 2 hospitals increases quality when facing competition, their insignificant changes in average costs implies improvement in operational costs too. The efficiency improvement may be achieved by reallocating resources across different specialty departments or improving the bed occupancy rate. Grade 2 and Grade 3 hospitals, with considerably more specialty departments to begin with, cut the number of departments, presumably to achieve specialization; whereas Grade 1 hospitals, with much fewer specialty departments to begin with, do not change the number of departments significantly. All hospitals generally increase bed occupancy rates to improve efficiency.

Our paper relates to the literature on the impact of competition on hospital quality, which finds mixed results. A positive competition effect is found in Kessler and McClellan (2000), Shen (2003), and Kessler and Geppert (2005) for the United States, and Cooper et al. (2011), Gaynor et al. (2013), and Bloom et al. (2015) for England; in contrast, a negative competition effect is found in Gowrisankaran and Town (2003) for the United States, and Propper et al. (2004, 2008) for England.[4] Our paper contributes to this literature by investigating the factors that drive the potential heterogeneous responses of hospitals, and as a result provides an explanation to the puzzle of mixed results found in the literature.

The existing literature is also almost silent on what factors determine how competition affects hospital quality, as stated in Gaynor (2004) and Gaynor and Town (2012). While Chandra et al. (2016), Gaynor et al. (2016), and Santos et al. (2017) provide evidence that higher-quality health care providers attract more patients, the question remains unanswered whether it is worthwhile for hospitals to compete on quality if patients cannot tell which hospitals are of high quality. Our work speaks directly to the question by highlighting the role of informational asymmetry about hospital quality between hospitals and patients in hospitals' quality responses to competition. We show that competition has a positive impact on quality, but only for those hospitals that have a chance to reveal their quality improvement through upgrading in the future. Otherwise hospitals resort to price reduction when responding to competition.

This study is also part of a growing literature on quality disclosure in the health care industry.[5] Dranove et al. (2003) find that cardiac surgery report cards in New York and Pennsylvania result in selection behaviors by providers (doctors and hospitals have incentives to decline to treat sicker patients). Lu (2012) finds that in response to quality disclosure, scores of reported quality items improve but those of unreported ones deteriorate in nursing homes. Zhao (2016) finds that the launch of the Five-Star Quality Rating System in the United States in 2009 enhances the effect of competition on nursing home quality. Our study differs by showing positive impacts of competition on hospital quality in a setting where quality certification is based on a comprehensive matrix of measures, and highlights the importance of developing such a quality certification system that is difficult for hospitals to manipulate.

The paper is structured as follows. Section 2 introduces the background of China's health care system. Sections 3 and 4 introduce the data and variable construction, respectively. Section 5 discusses the empirical strategy, and Section 6 reports the empirical results. Section 7 discusses robustness checks, and Section 8 concludes.

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[4] Also see Sari (2002), Volpp et al. (2003), Pan et al. (2015), and Colla et al. (2016). Comprehensive reviews of this literature can also be found in Gaynor (2004), Romano and Mutter (2004), and Vogt and Town (2006).

[5] There is a larger literature on quality certification in other industry settings. See, for example, Jin and Leslie (2003), and a comprehensive review article by Dranove and Jin (2010).

2 Background

2.1 Hospital-Centric Health Care System

Health care in China is hospital-centric, with hospitals delivering more than 90 percent of the country's outpatient and inpatient services (Yip et al., 2012).[6] Most Chinese patients go directly to a hospital for both primary and specialty care without any referral. This is different from the case in the United States or the United Kingdom, where patients first visit a family doctor or general practitioner for primary care and only go to a hospital for specialty care with a referral from their primary care provider (the well-informed "gatekeeper"). Compared with the referral system in other countries, the hospital-centric system in China may render the negative effects of the informational asymmetry between hospitals and patients more significant, because patients need to choose hospitals by themselves.

2.2 Hospital Grading System

To alleviate the informational asymmetry between hospitals and patients, the Chinese government inaugurated a comprehensive hospital grading system at the end of 1989, "aiming to achieve standardization, improve quality...and to better serve patients..." (*"Directive on Hospital Classification,"* Ministry of Health of the People's Republic of China, 1989). Hospitals are classified into three categories: Grade 1 (primary, the lowest in quality),[7] Grade 2 (secondary), and Grade 3 (tertiary, the highest in quality), based on a comprehensive matrix of hospital quality measures.

Specifically, the *National Health and Family Planning Commission* (NHFPC)[8] sets different criteria/indicators for Grade 2 and Grade 3 hospitals.[9] These criteria/indicators can be grouped into six broadly defined categories: (i) the basic requirements, including the number of beds, physical space for each inpatient, number of chief physicians, and compliance with medical standards; (ii) service process management; (iii) medical safety; (iv) clinical quality, skills, and research, as proxied by the readmission rate, complications/mortality after surgery, emergency department mortality rate, mortality rates for various diseases, ability to perform all required

[6] The remaining health care providers are mainly community clinics, each of which has one or two doctors, providing minor health care services for the general public.

[7] There is a category of ungraded hospitals, which are similar to Grade 1 hospitals in terms of medical inputs, patient profiles, and public medical insurance policies applied to them, and henceforth, they are usually grouped together with Grade 1 hospitals.

[8] NHFPC is the executive agency under the State Council that is mainly responsible for drafting laws and regulations on health and family planning and for planning the resource allocation of medical care, public health, and family planning services (Notice of the State Council No.14, 2013).

[9] The latest version of the national hospital grading criteria was published in 2011. Here are the links to the criteria (accessed July 31, 2018):
http://www.nhfpc.gov.cn/yzygj/s3585u/201112/06f754a213d8413787904e9e6439d88b.shtml for Grade 3 hospitals; http://www.nhfpc.gov.cn/yzygj/s3586q/201201/b8dda05b1d23413c94150b5c17b5cc6f.shtml for Grade 2 hospitals.

diagnostics/treatment practices and procedures, and research publications; (v) nursing care management as proxied by the nurse-to-bed staffing ratio and nurse qualifications; and (vi) general hospital management. Each criterion is labeled "core" or "other" according to its relative importance. The numbers of required core and other criteria differ for each grade, with Grade 3 hospitals having more requirements. Table 1 summarizes the required numbers of core and other criteria for each of the six categories for Grade 2 and Grade 3 hospitals, as defined by the national hospital grading system. The majority of these requirements are associated with clinical quality and general hospital management. A hospital will receive a grade (A-excellent, B-good, C-pass, D-fail, E-not applicable) for each criterion given its grade (Grade 2 or Grade 3). For the core criteria, each hospital should receive at least 20 percent A and 70 percent B, and D is not acceptable. For the other criteria, each hospital should receive at least 20 percent A and 60 percent B, and the share of D should be less than 10 percent. Finally, following the national criteria for Grade 2 and Grade 3 hospitals, the local government sets the criteria for Grade 1 hospitals, which are generally lower than those specified for higher-grade hospitals.

[Table 1 about here]

The hospital grading system has several advantages. First, it is clearly based on a comprehensive matrix of performance measures, leaving little room for hospitals to manipulate. This is in contrast to a performance indicator for treating a single disease or a couple of diseases, which could be manipulated by doctors and hospitals (e.g., Dranove et al., 2003). Second, the grading system is discriminative and hence informative. According to the China's Health and Family Planning Statistical Yearbook (2015), 7.5 percent of Chinese hospitals are classified as Grade 3, 26 percent Grade 2, and the remaining 66.5 percent Grade 1. In contrast, based on the Hospital Consumer Assessment of Healthcare Providers and Systems survey, the Centers for Medicare and Medicaid Services' *Hospital Compare* (a counterpart in the United States) ranks 97-98 percent of American hospitals as "no worse than the national average," and the remaining 2 percent as "worse than the national average" or "better than the national average," providing very limited information about the differences in quality across hospitals (Hathi and Kocher, 2017).[10] Lastly, although the grading is comprehensive and informative, it is also easy to understand and user-friendly: it is a single, intuitive index of value. Chinese patients do not need to struggle to understand that a higher grade indicates higher quality. This is different from the experiences of American patients who try hard to make sense of confusing and contradicting information such as rankings varying widely (Austin et al., 2015).

[10]Most recently, the Centers for Medicare and Medicaid Services tried to improve the accessibility, interpretability, and usability of the Hospital Compare website by releasing its first-ever Overall Hospital Quality Star Ratings. The overall rating ranges from one to five stars, with the most common overall rating being three stars (5 stars accounts for 2.2 percent; 4 stars 20.3 percent; 3 stars 38.5 percent; 2 stars 15.7 percent; 1 star 2.9 percent; n/a 20.4 percent) (Data Brief: Evaluation of National Distributions of Overall Hospital Quality Star Ratings by CMS, 2016).

Chinese patients have been found to choose hospitals based on the gradings (e.g., Li et al., 2001; Chen et al., 2012).[11] Hence, if a hospital wants to use quality as a means to attract patients, it will try to signal its otherwise unobserved quality improvement through upgrading to a higher level. Upgrading, however, is very costly to hospitals, because it requires expensive investment in beds, equipment, and recruitment of better physicians beforehand to satisfy the higher standards set for the next grade. Once ready, hospitals send their upgrading applications to the government, which will send an inspection team to the candidate hospitals to evaluate their quality according to the grading criteria and decide whether to approve the applications. Each successful applicant will receive a large bronze plate with its new grade carved on it, and hang it high at its main entrance. To spread the news of their upgrading to the public, many hospitals even hold a plate-awarding ceremony and invite local media to cover the event. Patients can also search the latest information on hospital gradings on the government website.

3 Data: Differences across Grades and Changes in Market Structure

Our data set covers all hospitals in a major city of 14 million population in China from 2007 to 2014. The health care market served by those hospitals is large, with 40 million patient visits and RMB 26 billion revenue in 2014.[12] The data are collected and audited annually by the Health and Family Planning Commission of the city. In this study, we focus on all general and specialty hospitals, but exclude alternative medicine (Chinese medicine) hospitals. We also exclude general hospitals that only cater to employees of a specific company (usually a state-owned enterprise) or students/staff of a university, because the competition they face is minimum.

We have detailed information on individual hospital characteristics, such as grade, location, and ownership. We also have in-depth information on hospital operations, including inputs such as doctors, nurses, beds, and equipment, outputs such as outpatient visits and inpatient admissions, and medical performance measures. Moreover, we also observe the financial performance of each hospital, including revenues and costs.

[11] In a pro bono project conducted by one of the authors for the government, using confidential patient-level discharge data for all Grade 3 hospitals and most Grade 2 hospitals in the sample city for the 2015-2016 period, she finds that 52 percent of the surgeries conducted in Grade 3 hospitals are level 3 (for example, hepatectomy) and level 4 (coronary artery bypass graft surgery), whereas 80 percent of the surgeries at Grade 2 hospitals are level 1 (appendectomy) and level 2 (leg amputation). Grade 1 hospitals, which are not in the patient-level data, are encouraged by the government to perform level-1 surgeries only, according to the Grade-specific Measures for the Administration of Surgeries by the Ministry of Health.

[12] One Chinese currency RMB is about 15 U.S. cents.

3.1 Differences across Grades

In the data, we observe substantial differences across hospitals of different grades. First, higher-grade hospitals are in general larger. As shown in Table 2, panel A, the average number of physicians for Grade 3, Grade 2, and Grade 1 hospitals is 439, 107, and 19, respectively. Higher-grade hospitals on average also have more specialty departments, with the average number of departments for the three grades being 13, 10, and 4, respectively. The average number of beds is 1,105, 290, and 69 for the three grades, respectively. Higher-grade hospitals also have larger output. In 2014, on average, Grade 3 hospitals had the greatest total number of patients (888,143), followed by Grade 2 hospitals (178,471), and Grade 1 hospitals (26,077). Grade 3 hospitals also had the greatest numbers of outpatient visits, ED admissions, and inpatient admissions, followed by Grade 2 hospitals and Grade 1 hospitals. See details in Table 2, panel B.

Second, higher-grade hospitals in general have more high-quality inputs. As shown in Table 2, panel A, higher-grade hospitals have more large equipment,[13] which is essential for the diagnosis, monitoring and treatment of medical conditions. The number of units of large equipment is 29, 3, and 0.3, for Grade 3, Grade 2, and Grade 1, respectively. The value of equipment for the three grades is RMB 227 million, RMB 24.2 million, and RMB 3.3 million, respectively. Higher-grade hospitals also have more sub-departments under the main specialty departments, which enable them to provide more specialized health care services. For example, Grade 3 hospitals have sub-departments for respiratory medicine, cardiology, and hematology under the general internal medicine department; in contrast, in Grade 1 hospitals these sub-departments are combined into one single internal medicine department. Grade 2 hospitals usually lie in the middle. In addition, Grade 3 hospitals have the highest nurse-to-bed staffing ratio (0.62), followed by Grade 2 hospitals (0.49), and then Grade 1 hospitals (0.40). All these differences confirm the effectiveness of the national hospital grading system in differentiating and signaling hospital quality.

Third, the average price for all patients, defined as the ratio of total patient revenue to total number of patients, varies substantially across grades. As shown in Table 2, panel C, Grade 3 hospitals charge the highest average price (RMB 870), which is much higher than that for Grade 2 (RMB 530) and Grade 1 (RMB 630). Surprisingly, Grade 1 hospitals on average charge slightly more than that for Grade 2. This is due to their predominantly private ownership nature and hence greater discretion in drug prescriptions (e.g., prescribing drugs whose prices are not regulated).[14] When comparing the average price for inpatients, which is more indicative of hospital quality and less sensitive to drug sales, the results are more sensible. Grade 3 hospitals have the highest average price for inpatients (RMB 9,490), followed by Grade

[13] Large equipment is defined as equipment with market value more than RMB 1 million, such as magnetic resonance imaging machines and 64-slice-or-above computed tomography scanners.

[14] As in many other countries, China also has a dual system of health care providers, featuring a combination of public and private hospitals. In 2014, there were 25,860 hospitals in total, among which 13,314 were public and 12,546 private (China's Health and Family Planning Statistical Yearbook, 2015).

2 (RMB 4,940) and finally Grade 1 (RMB 4,260).

[Table 2 about here]

3.2 Impact of the Policy Shocks in 2009 on Market Structure

For a decade until 2009, there was a moratorium on hospital upgrading. Entry into the hospital industry had also been highly restricted. As a result, the market structure in the sample city was mainly stable before 2009.

However, two policies in 2009 led to dramatic changes in market structure. The first policy allowed hospitals in the city to upgrade again after a decade-long moratorium. The second policy was to support the establishment of new hospitals, particularly Grade 1 hospitals, by significantly reducing the entry barriers into the hospital industry, especially for private capital.[15] The policies were a product of the nationwide health care reform initiated by the central government to increase competition in the hospital industry (Yip and Hsiao, 2014).

As shown in Figure 1(a), the total number of hospitals doubled in the sample period, from 179 in 2007 to 360 in 2014. The fastest growth occurred right after 2009, following the implementation of the above two policies. The number of hospitals grew from 203 in 2009 to 276 in 2011, at an annual growth rate of 17 percent. It increased by 84 over the next three years, at an annual growth rate of 9 percent. Such dramatic changes in market structure demonstrate the substantial impact of the policy shocks.

[Figure 1 about here]

The impact of the policy shocks was heterogeneous across the hospital grades. As shown in Figure 1(b) and (d), the number of Grade 1 hospitals increased the most (from 108 to 270), followed by that of Grade 3 hospitals (from 10 to 29). The number of Grade 2 hospitals remained at 61 in 2007 and 2014 (Figure 1(c)). Figure 2 provides information on hospital upgrading and de novo entry by grade. It again confirms the policy impact, by showing that the massive upgrading and new entries in each grade occurred right after the policy shocks.

[Figure 2 about here]

Table 3 provides an anatomy of the changing market structure, by presenting the breakdown of entry and exit of hospitals to each grade. Entry into a grade includes de novo entry and upgrading (downgrading) to this grade, while exit from a grade may arise from outright exit from the industry or downgrading (upgrading) from this grade to the lower (higher) grade.[16]

[15] In a government directive, the national target was set to increase the market share for private hospitals to 20 percent by 2015 (Yip and Hsiao, 2014).

[16] Along with the upgrading of hospitals from lower grades to higher grades, there was also substantial

The new Grade 3 hospitals were all upgraded from Grade 2, and there was no exit from incumbent Grade 3 hospitals during this period. For Grade 2 hospitals, on top of the 16 that were upgraded to Grade 3, seven hospitals exited the industry completely and 13 downgraded to Grade 1. However, these losses of Grade 2 hospitals were made up by the 26 hospitals upgraded from Grade 1 and the de novo entry of 10 hospitals. Therefore, the number of Grade 2 hospitals in 2014 remained the same (61) as in 2007, albeit its composition changed due to de novo entry, outright exit, and more importantly grade changes. Finally, there was a massive de novo entry of 213 Grade 1 hospitals versus the outright exit of 38 Grade 1 hospitals from the industry. In addition, 26 Grade 1 hospitals upgraded to Grade 2, and 13 hospitals were downgraded from Grade 2 to Grade 1.

[Table 3 about here]

The policy impact was heterogeneous for hospitals in different locations. The newly upgraded Grade 3 hospitals were mainly located near the city center (Figure 3a), because the local government prioritized these traditionally strong Grade 2 hospitals for upgrading.[17] The majority of new entrants (213 of 223) were in Grade 1 and most of them entered newly developed, suburban areas (Figure 3b). This was due to the local government policy *"to support new entry of hospitals, especially those entering the newly developed urban areas and the outskirts where medical resources are relatively limited"* ("Suggestions on further encouraging and guiding private capital to enter the health care industry," 2010).

[Figure 3 about here]

In sum, these two policy shocks of 2009 changed the total number of hospitals in the city, the distribution of hospitals across the three grades, and the geographic distribution of hospitals of different grades. All these changes generated valuable variations in the competition individual hospitals face by time, grade, and location. Figure A1 provides two examples to illustrate the heterogeneous impacts of the policy shocks. We will discuss in Section 5.3 how we take advantage of the policy shocks to identify the competition effects.

4 Key Variables

In this section, we discuss how we construct the competition measures in the context of the hospital grading system, and a battery of hospital performance measures aiming to capture

downgrading of hospitals, which implies that the requirements of the hospital grading system are rigorous and strictly enforced.

[17] Prior to the policy change, Grade 2 hospitals near the city center were of higher quality compared with those away from the center, due to historical reasons (e.g., better location and longer history). When the moratorium on upgrading was lifted, the government encouraged these higher-quality Grade 2 hospitals to upgrade, and they naturally had a larger chance of being upgraded to Grade 3.

hospitals' heterogeneous responses to competition. Table 4 provides descriptive statistics for these variables.

[Table 4 about here]

4.1 Hospital-Level Competition Measures

In the literature, hospital competition is typically measured by the number of hospitals in a catchment area (e.g., Bloom et al., 2015). Given the hospital grading system in China, hospitals in our sample differ substantially across grades, but they are relatively similar within the same grade. As a result, the competition that a hospital faces comes mostly from hospitals in the same grade. Hence, we refine the competition measure used in the literature by differentiating within-grade and cross-grade competition. Specifically, we focus on within-grade competition as measured by the number of other hospitals of the same grade in the city, while we control for the potential cross-grade competition as measured by the number of other hospitals of higher grades and lower grades separately.

We make three further adjustments to refine the measures of competition. First, we take into account the role of physical distance in measuring competition. Hospital competition has a strong geographical element, since the service requires patients to travel to a hospital. This implies that a hospital would face less competition from a farther-away hospital of the same grade. Hence, instead of counting the number of hospitals of the same (higher/lower) grade(s) as the hospital concerned, following Forder and Allan (2014), we construct distance-weighted competition measures using the inverse of the distances between the hospital concerned and its competing hospitals as weights.

Second, we make an adjustment for the degree of specialty similarity between hospitals when measuring competition.[18] Other things being equal, hospitals face more head-to-head competition against competitors if they offer more similar specialties. To capture this idea, we adjust the competition measure using the specialty similarity defined as the Manhattan distance between the hospital concerned and its competitors as weights (constructed using the shares of beds across specialties; see Appendix A for details).

Finally, we adjust the competition measures by the relative sizes between the hospital concerned and its competitors.[19] This is because, controlling for the physical distance and specialty similarity in service of a hospital compared with its within-grade (cross-grade) competitors, the concerned hospital is expected to face greater competition from larger hospitals.

Let g_{it} denote the grade of focal hospital i in year t, where $g_{it} \in \{1, 2, 3\}$. We formally define the competition faced by hospital i from competing hospitals of grade k in year t as

[18] See Table A1 for a full list of specialty departments in hospitals in China.

[19] A hospital's size is measured by the number of beds or the capacity for inpatient service.

follows:

$$COMP_{it}^{k} = log\left[1 + \sum_{j \neq i} \frac{1}{Distance_{ijt}} * Similarity_{ijt} * \frac{Size_{jt}}{Size_{it}} * I(g_{jt} = k)\right] \tag{1}$$

where $Distance_{ijt}$ is the physical distance between focal hospital i and its competitor j in year t; $Similarity_{ijt}$ measures the specialty similarity between hospitals i and j; $Size_{jt}/Size_{it}$ measures their relative size; and $I(g_{jt} = k)$ is an indicator variable taking value 1 if hospital j is in grade k, and zero otherwise. When $k = g_{it}$, $COMP_{it}^{k}$ measures the within-grade competition faced by hospital i.

In a similar fashion, we measure the competition faced by hospital i from hospitals of higher grade(s), $COMP_{it}^{H}$, and lower grade(s), $COMP_{it}^{L}$, as follows,

$$COMP_{it}^{H} = log\left[1 + \sum_{j} \frac{1}{Distance_{ijt}} * Similarity_{ijt} * \frac{Size_{jt}}{Size_{it}} * I(g_{jt} > g_{it})\right], \tag{2}$$

$$COMP_{it}^{L} = log\left[1 + \sum_{j} \frac{1}{Distance_{ijt}} * Similarity_{ijt} * \frac{Size_{jt}}{Size_{it}} * I(g_{jt} < g_{it})\right]. \tag{3}$$

Where $I(g_{jt} > g_{it})$ is an indicator variable equal to 1 if hospital j is in the higher grade(s) than hospital i, and zero otherwise. Similarly, $I(g_{jt} < g_{it})$ is an indicator variable taking value 1 if hospital j is in the lower grade(s) than hospital i, and zero otherwise.

4.2 Dependent Variables

In this subsection, we discuss the construction of measures for hospital quality, prices, and operational efficiency as our main dependent variables.

Quality. We use two variables to measure hospital quality: the ED mortality rate and the nurse-to-bed staffing ratio. The ED mortality rate is defined as the death rate for all causes following admissions in the emergency department in a given year. It is similar to the in-hospital mortality rates following emergency admissions for surgery used by Bloom et al. (2015).[20]

The ED mortality rate is closely related to a hospital's overall clinical quality. The hospital emergency department in China has a triaging area, resuscitation area, consultation rooms, minor procedure rooms, major operating rooms, 24-hour pharmacy, observation units, and other supporting units ("Guideline for Construction and Management of Emergency Department," Ministry of Health of the People's Republic of China, 2009).[21] ED patients, who often have a large variety of medical conditions, are sent to the emergency department to receive a

[20] A commonly used measure of hospital quality is acute myocardial infarction (AMI) mortality, which we however cannot use due to data limitation.

[21] The requirements in the national guideline are applied to Grade 2 and Grade 3 hospitals; the local government sets the requirements for Grade 1 hospitals accordingly.

wide range of medical treatments and services. This largely assures the ED mortality is a good indicator of hospital overall quality. Moreover, there is a city-level medical emergency operations center in the sample city, providing coordination and support to send most ED patients to the nearest hospitals with capacity and capability. This substantially mitigates hospitals' ability to select healthier patients for care.

The second quality measure we use is the nurse-to-bed staffing ratio, following Tay (2003) and Lin (2015). It is defined as the number of registered nurses divided by the number of beds in a hospital in a given year. A higher nurse-to-bed staffing ratio is linked to a lower risk of death following treatment (Ozdemir et al., 2016), and therefore contributes to a hospital's quality.

Prices. Following a similar idea of Dafny (2009) and Dafny et al. (2016), we use (logarithm) the ratio of a hospital's total patient revenue to its total number of patients in a given year to measure the average price the hospital charges per patient. Henceforth, we refer to it as the *price* or *average price* for simplicity, unless otherwise indicated. This price is the overall charge by a hospital for all the services and drugs it provides to an average patient, and it obviously influences patients' choice of hospital.[22]

We similarly define two related price measures, focusing on outpatients and inpatients separately. Outpatient price (OP price) is defined as the total outpatient revenue divided by the total number of outpatients, in logarithm, and inpatient price (IP price) is defined as the total inpatient revenue divided by the total number of inpatients, in logarithm.

Unlike in other countries, hospitals in China also sell drugs. In fact, drug sales account for a major part of hospital revenue in China, ranging from 42 percent for Grade 3 and Grade 2 public hospitals, to 47 percent for Grade 1 public hospitals (China's Health and Family Planning Statistical Yearbook, 2015). Hence, we also break down the hospital price into drug price and non-drug price. The drug price is defined as the patient revenue from selling drugs divided by the total number of patients, in logarithm; the non-drug price is defined as the patient revenue excluding drug sales divided by the total number of patients, in logarithm.

Like in many other countries, prices are regulated in the hospital industry in China. Such regulation is more stringent for public hospitals than private ones. However, this does not preclude hospitals' ability to adjust charges to each patient for multiple reasons. First, hospitals may over-prescribe. Second, the price regulation is mostly confined to a list of essential drugs and non-drug services. This leaves much room for hospitals to maneuver for those drugs and services off the list.

Although public hospitals receive some direct government subsidies, the amount is very small and accounts for only 8 percent of their total expenses in 2014, according to China's Health and Family Planning Statistical Yearbook (2015).[23] As a result, public hospitals, like

[22] While patients may not have the explicit price lists, they know the ballpark figures for hospital care at hospitals of different grades and choose hospitals accordingly.

[23] According to the same source, for public hospitals, patient revenue accounts for 90% of the hospital's total

their private counterparts, have a strong incentive to manipulate charges to patients so as to make ends meet. Both public and private hospitals are pressured to over-prescribe drugs (especially drugs off the essential drug list, which are typically patented or branded off-patent and often imported) through hospital-owned pharmacies and non-drug service (such as unnecessary tests and examinations). Doctors have an incentive to do so, because their income depends on the profits their departments make (Yip et al., 2010).

Finally, patients in China are price sensitive, as they pay a substantial part of the price of health care service. For instance, in 2010, the inpatient reimbursement rates were 68.2, 47.9, and 43.9 percent, respectively, for the three major government-subsidized insurance schemes in China (the Urban Employee Basic Medical Insurance program, the Urban Resident Basic Medical Insurance program, and the New Cooperative Medical Scheme), and in most cases, the outpatient reimbursement rate is zero for all insurance schemes (Yip, et al., 2012). Thus, when facing competition, hospitals could be pressured to reduce over-prescription of drugs and services to retain patients with lower prices.

Operational efficiency. If hospitals respond to competition by improving the quality of hospital care or lowering prices, one would expect them to make related changes in their operations. Hence, we further examine the impact of competition on hospital operational efficiency using a series of measures of hospital operations that are associated with quality and price responses.

The first operational efficiency measure, following Gaynor et al. (2013), is hospital operating expenditure per patient (*average cost*). The second is the *bed occupancy rate*, defined as the ratio of the total number of inpatient days to the total number of available bed days in a given year. The bed occupancy rate depends on how well the hospital manages its bed usage (say, through allocation across specialties) given the number of beds and admissions to the hospital. Third, we measure the scope of hospital service or service mix using the number of specialty departments for which a hospital offers inpatient and outpatient services (*number of departments*). When facing competition, a hospital may expand its service scope to draw more patients or reduce its service scope to increase specialization.

4.3 Other Control Variables

One potential concern is that different hospitals may have different compositions of patients with varying service complexity. We address this problem by controlling for a hospital case-mix indicator (defined as the inpatient revenue share), which measures the different levels of service complexity across hospitals. We control for a series of dummies, including year dummies, grade dummies, and hospital dummies in all of the regressions, to control for potential time trend and time-invariant heterogeneity for each grade and hospital. As a result, we use the within-hospital variations in outcome variables within the same grade to estimate the competition

income, while direct government subsidies and other revenue cover the rest.

effect, which largely reduces the patient selection problem as long as the composition of the patients for a given hospital/grade does not change immediately after changes in the outcome variables.

5 Empirical Strategy

We are mainly interested in answering the following questions. Does competition necessarily improve hospital quality? Are there other possible responses (e.g., price reduction) to competition? What is the role of comprehensive quality certification (e.g., China's hospital grading system) in determining the possibly heterogeneous responses of hospitals to competition? And are there corresponding changes in operational efficiency (average cost, bed occupancy rate, and number of departments) along with hospitals' main responses to competition? In this section, we discuss the empirical challenges in answering these questions and our strategy to deal with the challenges in detail.

5.1 Basic Regression Equation

Our baseline estimation equation is

$$\begin{aligned} y_{it} &= \sum_{k=1}^{3} \beta_k COMP_{it}^k * G_{it}^k + \beta^H COMP_{it}^H + \beta^L COMP_{it}^L \\ &\quad + \mathbf{X}_{it}\eta + \delta_i + \zeta_g + \phi_t + \varepsilon_{it} \end{aligned} \tag{4}$$

where y_{it} is the dependent variable capturing the response of hospital i to competition in year t, which includes quality, prices, and operational efficiency. $G_{it}^k \equiv I(k = g_{it})$ is a dummy variable taking value 1 if k equals g_{it}, the grade of hospital i in year t. $\mathbf{X}_{it}$ is a vector of observed, time-varying hospital characteristics, including a hospital case-mix indicator. We also control for hospital fixed effects (δ_i), grade fixed effects (ζ_g), and year fixed effects (ϕ_t) in the regression. Controlling for both the hospital fixed effects and grade fixed effects is well-grounded because a substantial number of hospitals experienced grade change over the sample period. ε_{it} is the i.i.d. error term representing any unobserved shock to the dependent variable.

We have two sets of independent variables of major interest. The first set is the within-grade competition measures, $COMP_{it}^1 * G_{it}^1$, $COMP_{it}^2 * G_{it}^2$, and $COMP_{it}^3 * G_{it}^3$, as discussed in Section 4.1. Because the head-to-head competition from hospitals within the same grade is the most direct and important competition faced by individual hospitals, the impact of within-grade competition on hospitals' performance is of our central focus. The second set of independent variables, denoted as $COMP_{it}^H$ and $COMP_{it}^L$, captures the impact of competition from higher-grade and lower-grade hospitals, respectively.

5.2 Empirical Challenges

As pointed out by many other studies that estimate the impact of competition on hospitals, market structure is endogenous (e.g., Cooper et al., 2011; Gaynor et al., 2013; Bloom et al., 2015). Some unobserved factors may affect both the intensity of competition a hospital faces and its possible responses, leading to the classical simultaneity problem. It is also possible that some hospital performance measures, such as quality, might affect the market structure. Such endogeneity of market structure may bias the estimates of the competition effects. Following the literature, we use an IV approach to address this problem.

Our refined competition measures create two additional challenges to solving the endogeneity problem. The competition measures are adjusted by the physical distance, specialty similarity of services, and relative size of the target hospital to its competitors. While the distance is arguably exogenous, the other two adjustment components may be driven by some common factors that affect hospitals' performance simultaneously. We address this issue by using the lagged values of these two adjustment components, taking advantage of the panel nature of our data.

The second challenge is that we have *multiple* endogenous competition measures. In total, we have five endogenous competition measures, with three within-grade measures, $COMP_{it}^k * G_{it}^k$ ($k = 1, 2, 3$), and two cross-grade measures, $COMP_{it}^H$ and $COMP_{it}^L$. These five competition measures are closely related to each other, in that they are jointly determined by the same market structure, which depends on individual hospitals' entry/exit and upgrade/downgrade decisions. Given this feature, we use a simulated instrumental variable (SIV) approach following the similar idea of Gruber and Saez (2002) and Dahl and Lochner (2012) to solve the problem of multiple endogenous variables.[24] Specifically, by taking advantage of the exogenous policy shocks in 2009, we simulate the market structure of the hospital industry by predicting individual hospitals' decisions on de novo entry, outright exit, and grade changes based on the policy shocks, localized market condition, and the lagged state variables at the hospital level. Then we calculate the simulated competition measures from the predicted market structure as IVs for the actual competition measures and estimate the model using two-stage least squares (2SLS).

5.3 Estimation Based on Simulated IVs

In this subsection, we elaborate the construction of the simulated IVs. As discussed in detail in Section 3.2, the two policy shocks in 2009 dramatically changed the market structure of the

[24] The basic idea of SIV is to simulate a variable (e.g., tax rate) which captures only the variations from exogenous shocks as IVs for the actual variable to solve the endogeneity problem. This approach was first discussed by Feldstein (1995) and Currie and Gruber (1996), and it is often used to estimate an individual's or household's response to changes in tax policies (e.g., Gruber and Saez, 2002; Dahl and Lochner, 2012). Han and Kung (2015) use this method to quantify the responses of local governments to fiscal incentives. See Moffitt and Wilhelm (1998) for a general discussion of the SIV approach.

hospital industry in the sample city, including the number of hospitals, grade composition, and geographical distribution. The policy changes were initiated by the central government as a national campaign in 2009, and therefore it is reasonable to have confidence in exogeneity of the policy shocks to the sample city. More importantly, the impacts of the policy shocks were heterogeneous on hospitals of different grades in different locations, although all hospitals were exposed to the same shocks. The two policy shocks offer us the key exogenous variations in competition to identify how hospitals respond to changes in market structure.

5.3.1 Decisions of Existing Hospitals

In the data, existing Grade 3 hospitals never had any grade change or exit, and hence we assume that the probability for Grade 3 hospitals to remain in Grade 3 is one. Grade 2 hospitals have four possible choices: stay the same, upgrade, downgrade, and exit. Grade 1 hospitals have three possible choices: stay the same, upgrade, and exit. Our choice of the model is informed by the data.

Aside from the policy shocks in 2009, we also consider two other factors that may influence the decisions of the existing hospitals: their location and the competition they face. We observe from the data that hospital location matters. For example, upgrading to Grade 3 is usually restricted to those existing Grade 2 hospitals located near the city center, which are traditionally better equipped and have a better reputation. Meanwhile, the competition faced by an existing hospital obviously affects its grade change and exit decisions.

Specifically, we model existing hospitals' grade change and exit decisions for time t as a function of three factors: the policy shocks, hospital location, and competition in time $t-1$. We use lagged terms because it usually takes time for hospitals to change grade or even decide to exit. We include the interaction term between the policy shocks (defined as a dummy variable equal to 1 after 2009 or 0 otherwise) and location (distance from hospital i to the city center), $Policy_{t-1} * Dis_{it-1}$, in the regression, which provides the main exogenous variations. Aside from the competition faced by hospital i from hospitals of the same grade, $COMP_{it-1}$, we also include competition from hospitals of higher grade(s), $COMP^H_{it-1}$, and of lower grade(s), $COMP^L_{it-1}$, in the regression to capture the full impact of the competition environment on the decisions of the existing hospitals.

As a result, we estimate a multinomial logit model of three choices for Grade 1 hospitals and a multinomial logit model of four choices for Grade 2 hospitals:

$$\begin{aligned} Pr(Grade1\_choice)_{it} &= \gamma^1_1 Policy_{t-1} * Dis_{it-1} + \gamma^1_2 Dis_{it-1} + \gamma^1_3 COMP_{it-1} \\ &\quad + \gamma^1_4 COMP^H_{it-1} + \phi^1_t + \varepsilon^1_{it} \qquad (5) \\ Pr(Grade2\_choice)_{it} &= \gamma^2_1 Policy_{t-1} * Dis_{it-1} + \gamma^2_2 Dis_{it-1} + \gamma^2_3 COMP_{it-1} \\ &\quad + \gamma^2_4 COMP^H_{it-1} + \gamma^2_5 COMP^L_{it-1} + \phi^2_t + \varepsilon^2_{it} \qquad (6) \end{aligned}$$

where ϕ_t^1 and ϕ_t^2 are year fixed effects, and ε_{it}^1 and ε_{it}^2 are i.i.d. shocks.

Tables A2 and A3 report the grade change and exit decisions for existing hospitals in Grades 1 and 2, respectively. In all regressions, we control for year dummies. We find that location (as proxied by distance to the city center) and the 2009 policy shocks play an important role in the grade change and exit decisions of Grade 1 and Grade 2 hospitals.

5.3.2 Prediction of New Entrants

Next we model the probability of having new Grade 1 hospitals across different districts in the city. Specifically, we divide the city into 315 districts according to the administrative boundaries, with each district equivalent to "*Jie Dao*" (neighborhood) in urban areas and "*Xiang Zhen*" (village) in rural areas in Chinese. We estimate a multinomial logit model to predict the probability that each district will have a specific number of new Grade 1 hospitals. As the geographical area for the districts is very small,[25] the number of new entrants in each district is small. Ninety-eight percent of the districts have two or fewer entries per year in the data, and so we choose the number of entry $n = 0, 1, 2$ in the regression, with $n = 2$ representing two or more entrants in that district in that year.

As discussed in Section 3.2, the policy shock in 2009 unleashed a massive entry of Grade 1 hospitals, and hence it provides the key independent variable for predicting the likelihood of new entry. The second factor determining new hospital entry is the economic conditions of each district. Because the new entrants are more concentrated in the outskirts, especially in newly developed urban areas, we collected information on new land sales and land price for each district as major predictors of new entry. New land sales proxy for the change in the demand for health care services in each district, and the land price proxies for the costs to set up new hospitals. In the estimation, we interact the policy shock with land sales and land price, to capture the heterogeneous policy impacts on new entry in different districts. Lastly, we also control for the local competition environment for the potential entrants. Because the specialty department and size information for new entrants is not available one year before entry, we cannot use the refined competition measures. Instead, we add the number of existing Grade 1 hospitals (Num_{jt-1}^{G1}) and the number of higher-grade hospitals (Num_{jt-1}^{H}) in a given district into the regression, to proxy the within- and cross-grade competition faced by potential entrants.

Similar to the estimation of the decisions of existing hospitals, the entry decision for time t is made one period earlier, and is modeled as a function of the aforementioned factors in time

[25] The average area of a district in the downtown areas is 6.12 km^2, and 48.7 km^2 in the non-downtown areas.

$t-1$ as state variables. The estimation equation is therefore as follows:

$$
\begin{aligned}
Pr(New\_Grade1 = n)_{jt} = \quad & \alpha_1 Policy_{t-1} * Land\_S_{jt-1} + \alpha_2 Policy_{t-1} * Land\_P_{jt-1} \\
& + \alpha_3 Land\_S_{jt-1} + \alpha_4 Land\_P_{jt-1} + \alpha_5 Num^{G1}_{jt-1} \\
& + \alpha_6 Num^{H}_{jt-1} + \phi_t + \varepsilon_{jt}, \qquad (7)
\end{aligned}
$$

where the dependent variable, New_Grade1_{jt}, is a categorical variable ($n = 0$ if no entry; $= 1$ if one entry; $= 2$ if two or more entries in district j in year t); $Land\_S_{jt-1}$ and $Land\_P_{jt-1}$ are the area of new land sales and land price, respectively, in district j in year $t-1$; ϕ_t are year fixed effects, and ε_{jt} is an i.i.d. shock.

The estimation results for new entry decisions are reported in Table A4. Land sales have a significant impact on hospital new entry, suggesting that the new hospital entrants may be mainly driven by demand growth. In contrast, the impact of land prices is not significant, as captured by the insignificant coefficients on land price and its interaction with policy. This suggests that hospital setup costs may not be the main driving force for establishing a new hospital.

5.3.3 Simulated IVs for Competition Measures.

After estimating the decisions of existing hospitals and new entrants, we can predict the market structure with randomness, where the randomness arises from the prediction errors in Equations (5), (6), and (7). To predict one realization of market structure, we randomly draw these prediction errors from their distribution estimates and obtain the predicted number of hospitals in the market.[26] We then calculate the simulated competition measures following Equations (1), (2), and (3), using the predicted number of hospitals, except that here we use the lagged specialty similarity and size of hospitals as adjustment factors instead of the current period values. The five simulated competition measures satisfy the IV conditions for the endogenous competition measures in Equation (4). They are correlated with the endogenous competition measures, but uncorrelated with the error term in Equation (4) by construction.[27] See Table A5 for comparison of the actual competition measures and the simulated ones.

5.3.4 2SLS Estimator

Finally, we estimate our parameters of interest in Equation (4) in a 2SLS procedure, using the simulated competition measures, $\tilde{C}OMP^k_{it} * G^k_{it}$ ($k = 1, 2, 3$), $\tilde{C}OMP^H_{it}$, and $\tilde{C}OMP^L_{it}$,

[26] Refer to Appendix B for details about how to sample the prediction errors and predict one realization of market structure.

[27] The purpose of such projection of competition is to minimize its correlation with other unobserved factors. Because the predicted competition measures, with lagged specialty similarity and size as adjustment, are projected on the space of the observed hospital characteristics and the exogenous policy shocks, they are uncorrelated with the idiosyncratic shocks ε_{it} in Equation (4) by assumption.

as the instrumental variables for the corresponding actual competition measures in the main equation.[28]

Because the realization of market structure is random due to our random draw of prediction errors, our 2SLS estimator is subject to this random sampling. To solve this problem, we repeat the construction of market structure and estimate the model 100 times. The parameter estimates and standard deviations are calculated as the means of the corresponding estimates in the 100 repetitions. The details of the procedure are discussed in Appendix B.

5.3.5 Discussion

The simulated IV approach in this paper in essence uses the heterogeneous impacts of the policy shocks in 2009 on hospitals to identify the competition effects. The interactions of the policy shocks, local information,[29] and the lagged competition level, provide variations to form simulated competition measures for each hospital as IVs for the five endogenous independent variables in the main equation.

Compared with the conventional IV approach, the simulated IV approach has two advantages in our application. First, it recognizes that the impact of the policy shocks on the competition measures may be nonlinear by affecting decisions of existing hospitals on grade changes (upgrading and downgrading) and outright exit, and decisions of new entrants. Hence, the approach constructs the IVs based on the predicted individual decisions of all (existing and potential) hospitals. Second, it recognizes that the five endogenous competition measures capture different facets of the same market structure and thus are closely related to each other.[30] The solution to this interdependence is to predict the market structure and calculate the five simulated competition measures simultaneously based on the simulated market structure as IVs for the five endogenous variables. Due to these two advantages, in our context the simulated IVs are stronger than the linear-interaction IVs typically used in the conventional IV approach. In a robustness check, we show that the conventional IV approach predicts qualitatively similar yet statistically less precise results.

The underlying assumption for the above simulated IVs to be valid is that lagged state variables (policy shocks, distance to the city center, land sales, land price, competition measures, together with some interactions) used to predict hospital turnover and grade change decisions are uncorrelated with the error term in the main regression. This is in general reasonable given that all these lagged measures are market-level measures or location measure, except the lagged hospital-level competition measures whose current-period counterpart is in our main regression. To further mitigate the concern that these lagged state variables might be correlated with some current-period hospital characteristics that may affect our outcome variables (e.g.,

[28] See Table A6 for the first-stage results for the main equation. All regressions include hospital fixed effects, grade fixed effects, year fixed effects, plus a hospital case-mix indicator.

[29] The local information includes hospitals' distance to the city center, land sales, and land prices in each district.

[30] See Table A7 for the correlations among the five competition measures.

hospital quality), we control for hospital case mix in all regressions. In addition, we control for hospital, year, and grade fixed effects, so we are not worried about unobserved time-invariant hospital characteristics, even if they are correlated with the lagged state variables used for predicting hospital decisions.

6 Empirical Results

In this section, we report the estimation results and evaluate how hospitals respond to competition, by changing hospital quality, prices, and operational efficiency. All models are estimated based on 2SLS, using the simulated competition measures as IVs for the actual competition measures. The first-stage estimation results are reported in Table A6, in which we regress the actual competition measures on the simulated IVs, together with a full set of other controls. We find that the simulated IVs explain their corresponding actual competition measures reasonably well, with coefficients ranging from 0.349 to 0.932. The second-stage main results will be discussed in detail in the rest of this section. As a comparison, we also report ordinary least squares (OLS) results without dealing with the endogeneity of market structure in Table A8, which shows qualitatively consistent results.

6.1 Quality Response to Competition

We first investigate whether hospitals respond to competition by improving hospital quality, and what role the quality certification (i.e., China's hospital grading system) plays in determining this effect. We use two measures of hospital quality: the ED mortality rate and the nurse-to-bed staffing ratio.

The estimation results are reported in Table 5. As shown in the first column for ED mortality, the coefficients on the within-grade competition variables are negative and statistically significant for both Grade 1 and Grade 2 hospitals, but the coefficient is positive and statistically insignificant (with a t-value at 0.63) for Grade 3 hospitals.[31] These results suggest that within-grade competition reduces the ED mortality rate for Grade 1 and Grade 2 hospitals, but not for Grade 3 hospitals. Economically, increasing the competition measure by one standard deviation reduces the number of deaths per 1000 ED patients by 0.48 for Grade 1 hospitals and 0.28 for Grade 2 hospitals. This represents a reduction in the ED mortality rate by 59 percent and 25 percent for Grade 1 and Grade 2 hospitals, respectively.

We also find consistent results on the impact of competition on the nurse-to-bed staffing ratio. As reported in the second column of Table 5, the coefficients of the within-grade competition variables are positive and statistically significant for Grade 1 and Grade 2 hospitals, but the coefficient is insignificant for Grade 3 hospitals. These results suggest that within-grade

[31] This positive coefficient implies that Grade 3 hospitals may even encounter quality deterioration when facing competition.

competition improves the nurse-to-bed staffing ratio for Grade 1 and Grade 2 hospitals, but not for Grade 3 hospitals. The impact is substantial: increasing the competition measure by one standard deviation increases the nurse-to-bed staffing ratio by 19 percent for Grade 2 hospitals, from 0.49 nurses per bed to 0.58 nurses per bed; it affects Grade 1 hospitals even more by 59 percent, from 0.40 nurses per bed to 0.64 nurses per bed.

We also find that, the coefficients for $COMP_{it}^{H}$ and $COMP_{it}^{L}$ are insignificant for all hospitals of different grades no matter whether we use the ED mortality rate or the nurse-to-bed staffing ratio as the measure of hospital quality. These results imply that there is little significant impact of cross-grade competition on hospital quality. This is consistent with the stylized facts presented in Section 3.1 that hospitals of different grades are largely different in medical inputs and outputs, thereby facing little cross-grade quality competition. It lends further support to the use of grade-specific competition measures in our study.

[Table 5 about here]

In sum, using the ED mortality rate and nurse-to-bed staffing ratio as measures of hospital quality, we find contrasting patterns between Grade 3 hospitals and hospitals of lower grades in the impact of competition on hospital quality. Competition pushes Grade 1 and Grade 2 hospitals to improve quality, but not Grade 3 hospitals. These contrasting findings echo some of the mixed findings reported in the literature on the impact of competition on hospital quality (Gowrisankaran and Town, 2003; Propper et al., 2004, 2008; Cooper et al., 2011; Gaynor et al., 2013; Bloom et al., 2015). However, they point to an important determinant of whether hospitals improve quality in response to competition.

Intuitively, hospitals would only improve quality in response to competition if such quality improvement could be revealed to patients and hence bring benefits immediately or in the future. In our setting, Grade 1 and Grade 2 hospitals have a chance to move up in grade, which would send a signal of quality improvement and allow them to attract more patients and charge higher prices.[32] So they are more likely to have an incentive to improve quality when facing competition. In contrast, at the top grade, Grade 3 hospitals have no chance for further upgrading, and hence no current or future returns from improving quality in response to competition. As a result, they have no incentive to improve quality. In other words, it is the possibility of revealing quality improvement through future upgrading that explains why some hospitals improve quality whereas others do not.

6.2 Price Response to Competition

Next we investigate the impact of competition on prices charged by hospitals for what they provide to patients, including average price, OP price, IP price, drug price, and non-drug

[32] The regulated prices for drugs and services on the essential list are grade-specific, with higher prices for higher-grade hospitals.

price. Standard industrial organization theory predicts a price reduction effect of competition for homogeneous goods or services. However, the quality of hospital services varies across hospitals, and furthermore patients may not have perfect information about hospital quality. In settings of imperfect information about hospital quality, patients might associate high service price with high quality service, providing an incentive for hospitals to raise prices. Moreover, if hospitals improve quality in response to competition, they may be pressured to increase prices to cover the increased costs for higher quality service. This seems to suggest a mixed or even a positive effect of competition on price. Indeed, the existing literature almost exclusively focuses on the impact of competition on quality, not on price, due to the restricted context of regulated prices. Here the following questions on price response will be explored. Would Grade 3 hospitals be immune from price competition? Would Grade 1 and Grade 2 hospitals raise prices for their services as they improve quality in response to competition?

The estimation results are reported in Table 6. Similar to what we find for the impact of competition on quality, there are contrasting patterns between Grade 3 hospitals and hospitals of lower grades in their price response to competition. The within-grade competition variable has a negative and statistically significant coefficient for the average price charged by Grade 3 hospitals, but the coefficients of the same variable are positive and statistically insignificant for the average prices of Grade 1 and Grade 2 hospitals. These results suggest that Grade 3 hospitals respond to competition by reducing price for patients, but Grade 1 and Grade 2 hospitals do not. Economically, increasing the competition measure by one standard deviation reduces the average price by 38 percent for Grade 3 hospitals.

Breakdown analysis along different types of patients (OP price and IP price in columns (2) and (3), respectively, in Table 6) reveals that the negative impact of competition on the price of Grade 3 hospitals is more driven by the reduced price for outpatients than inpatients.[33] Intuitively, when facing competition, Grade 3 hospitals reduce price for outpatients whose demand for quality healthcare is less acute than inpatients and hence are more price sensitive. A one standard deviation increase in the within-grade competition measure reduces the outpatient price by 33 percent for Grade 3 hospitals.

Columns (4) and (5) in Table 6 report the results for price measures focusing on different sources of hospital revenue. Grade 3 hospitals are found to reduce both drug price and non-drug price, consistent with their overall price reduction. Economically, increasing the within-grade competition measure by one standard deviation reduces their drug price by 46 percent and non-drug price by 33 percent. Note that price reduction is greater for drug than non-drug service.[34] It implies that, to some degree, overprescription of drugs is more severe than other medical services.

[33] The coefficient of within-grade competition for the IP price is also negative for Grade 3 hospitals, although it is statistically insignificant (t-value = 1.18).

[34] Table A9 further shows that within-grade competition has a smaller negative effect on the price of diagnostic imaging (e.g., CT scans and ultrasound scans), which is included in non-drug service in hospitals. In the same table, it is also reported that the impact of within-grade competition on drug price are similar in magnitude for outpatients and inpatients.

It is also interesting to note that, of the two measures for cross-grade competition ($COMP_{it}^H$ and $COMP_{it}^L$), the one representing competition from hospitals of higher grades (certainly including the competition from Grade 3 hospitals) has significantly negative coefficients for all prices except the price for inpatients. Intuitively, when Grade 3 hospitals reduce prices for their top-quality service, they force all hospitals, including those of lower grades, to reduce prices, especially for outpatients, who are more price sensitive than inpatients. And the other one representing competition from hospitals of lower grades (certainly including the competition from Grade 1 hospitals) has significantly positive coefficients for the average price and drug price, presumably because the unchanged prices in Grade 1 allow higher-grade hospitals to raise price for their higher-quality services.

[Table 6 about here]

Combined with the results reported in the previous subsection, we find that in response to competition, Grade 3 hospitals do not improve quality but reduce prices for their patients, whereas Grade 1 and Grade 2 hospitals improve quality and maintain their price levels. These results reveal the possibility of heterogeneous responses of hospitals to competition, although the existing literature almost exclusively focuses on the impact of competition on quality in the context of regulated prices. Indeed, like in other industries that have been extensively studied, hospitals may respond to competition by reducing prices or improving quality.

What is even more interesting and important is the factors determining the possibly different responses of hospitals to competition. In the setting of China's hospitals, it is clear that Grade 3 hospitals have no incentive to improve quality, as there is no chance for further upgrading to signal quality improvement and obtain returns for effort in this direction. Hence, Grade 3 hospitals must resort to price reduction to stay competitive.[35] Meanwhile, Grade 1 and Grade 2 hospitals must maintain competitive prices, although they improve quality in response to competition, because it takes time for them to be upgraded to signal their quality improvement, but patients can immediately observe price changes. Taking into account the improved hospital quality due to competition, the quality-adjusted prices charged by Grade 1 and Grade 2 hospitals actually fall.

Our results lend strong support to competition-enhancing government policies. When patients have good knowledge of hospital quality through the hospital grading system in China, competition in the hospital industry forces even top-quality Grade 3 hospitals to reduce prices and puts pressure on hospitals of lower grades to improve quality without significantly raising prices.

[35] However, the price reduction does not undermine patients' confidence in quality, due to the rigorous and strict enforcement of the hospital grading criteria.

6.3 Impact of Competition on Operational Efficiency

Facing cost increases due to quality improvement and/or revenue losses due to price reduction, how do hospitals respond to maintain their profitability? Would they improve their operational efficiency? In this subsection, we examine the impact of competition on operational efficiency using three measures: hospital operating expenditure per patient (*average cost*), *bed occupancy rate* for inpatient service, and the number of specialty departments for which a hospital offers inpatient and outpatient services (*number of departments*). The average cost is a comprehensive measure of operational efficiency, while bed occupancy rate and the number of departments cover specific mechanisms through which operational efficiency can be improved.

[Table 7 about here]

Table 7 reports these results. Grade 2 and Grade 3 hospitals reduce their number of departments, whereas the impact on that of Grade 1 hospitals is statistically and economically insignificant. The summary statistics presented in Section 3.1 show that Grade 2 and Grade 3 hospitals have substantially more departments than Grade 1 hospitals do. Thus, reducing the number of departments is possibly a move toward specialization for Grade 2 and Grade 3 hospitals, allowing for reallocation of their precious resources (beds, space, and nurses) among different departments, for example, by cutting less popular departments, strengthening some weak departments, or expanding their more popular departments to meet greater demand, all of which result in improvement in the bed occupancy rate. In fact, Grade 1 hospitals are found to have a positive albeit slightly insignificant coefficient of the within-grade competition variable for the bed occupancy rate.[36] This suggests that Grade 1 hospitals improve their bed occupancy rate in response to competition, although their improvement is not as significant as that of higher-grade hospitals.

The most striking difference across hospitals of all grades in their operational response to competition is that only Grade 3 hospitals reduce their average cost. Increasing the within-grade competition measure by one standard deviation reduces the average cost for Grade 3 hospitals by 31 percent, while the impact on Grade 1 and 2 hospitals is insignificant. We argue, however, that these seemingly divergent findings on the average cost are in fact highly consistent with the earlier findings on the main responses (in quality or price) of hospitals to competition. Grade 3 hospitals, which reduce prices in response to competition, need to lower their average cost of operation to stay profitable, and they can achieve that goal because they do not improve the quality of their service. When facing competition, Grade 1 and Grade 2 hospitals improve quality (which increases their average cost) and operational efficiency (which reduces their average cost). As a result, there is a muted effect of competition on the average cost for Grade 1 and Grade 2 hospitals. In sum, we observe operational changes that are related to the heterogeneous responses (quality improvement or price reduction) of hospitals

[36] $t-$value=1.48; $p-$value<0.15.

to competition.[37]

7 Robustness Checks

Alternative explanation: financial condition. It is likely that a hospital's quality decisions hinge on its financial condition. When implementing the pro-competition policies of 2009, the government might have an incentive to give hospitals subsidies to improve their performance at the same time, and hospitals would then be better positioned to improve quality with better financial conditions. If this is the case, our estimates of the competition effect may be confounded, because our IV strategy relies on the exclusion condition that the policy shocks in 2009 affected hospital performance only through competition, but not through other channels such as financial condition. To address this concern, we include two measures of hospital financial condition, the amount of fiscal subsidies and the debt-to-asset ratio, in our IV analysis. Our results remain robust to the addition, as shown in Table 8.

[Table 8 about here]

Exclusion of a nationally-reputed hospital. One Grade 3 hospital in the sample city is nationally reputed, and it attracts patients from other cities in the province or even outside the province. Thus, this hospital faces competition from hospitals outside the city, and might respond to competition differently from other hospitals in our sample, which focus almost exclusively on the local market. As a consequence, our findings might be contaminated by this hospital's potential response to the non-local competition pressure. To rule out this concern, we exclude this hospital from our sample. The results are consistent with our main results, as shown in Table 9.

[Table 9 about here]

Alternative classification of the ungraded hospitals. Recall that there is a category of ungraded hospitals in the hospital grading system. In our main results, we group the ungraded hospitals with Grade 1 hospitals, because the ungraded ones are in general similar to Grade 1 hospitals in medical inputs and public medical insurance policies.[38] However, there is a concern

[37] The impacts of cross-grade competition on operational efficiency are generally minimal. One exception is the impact of cross-grade competition on average cost. However, such impact is consistent with the findings on hospitals' price response. Price reduction due to competition from higher grade(s) will pressure hospitals to reduce average cost; price increase due to competition from lower grade(s) will allow hospitals to relax cost controls.

[38] In 2014, 87 percent of the ungraded hospitals in our sample have fewer than 100 beds, the criterion about the number of beds for Grade 1 hospitals in the hospital grading system. In addition, in the public medical insurance schemes, same rates of deductibles and coinsurance are applied to both the ungraded hospitals and Grade 1 hospitals.

that a few ungraded hospitals with larger capacity may position themselves as higher-grade hospitals and compete with higher-grade hospitals. To address this concern, we regroup the ungraded hospitals according to their capacities. Specifically, we classify the ungraded hospitals with more than 500 beds as Grade 3 hospitals, those with between 100 and 500 beds as Grade 2 hospitals, and the rest as Grade 1 hospitals. The analysis after reclassifying the ungraded hospitals yields generally similar results as our earlier ones, as shown in Table 10.

[Table 10 about here]

Alternative estimation method. In our main results, we use the simulated IV approach to address the endogeneity of market structure, in which we predict the market structure by directly estimating individual hospitals' grade change and entry/exit decisions. This strategy well suits our context with multiple grade-specific competition measures, because it allows for non-linear effects of the 2009 policy shocks on competition intensity and interdependence among the five competition measures that capture the different facets of the same market structure. So the simulated IV approach in our case is more likely to capture the impact of competition, compared with the conventional linear IV approach.

As a robustness check, we use the conventional IV approach, although we expect to lose statistical significance for some of the estimates. Specifically, we use the interactions among the policy dummy, grade dummies, hospitals' local information, and the lagged terms of those competition measures as the instruments for the endogenous variables. The local information for Grade 3 hospitals includes whether they are near the city center and the area of new land sales in the districts in which they are located, while for Grade 1 and Grade 2 hospitals, the local information includes whether they are in suburban areas and the area of new land sales in the districts in which they are located.

The results are reported in Table 11. Consistent with the main results, competition has a negative impact on the ED mortality rate for lower-grade hospitals, although it is not statistically significant for Grade 2 hospitals (but it is economically significant). The loss of significance for Grade 2 hospitals is probably because the conventional linear IV approach ignores the interdependency among the five competition measures and thus loses some valuable information. All the other results are consistent with our main results: Grade 3 hospitals respond to competition by reducing prices for patients, but Grade 1 and Grade 2 hospitals do not; Grade 2 and Grade 3 hospitals reduce the number of departments; hospitals of all three grades increase their bed occupancy rates in response to competition (although it is not statistically significant for Grade 1 and Grade 2 hospitals, most likely due to the reason mentioned above); and finally Grade 3 hospitals reduce the average cost of operations.

[Table 11 about here]

8 Conclusion

Confronted with the challenge of pushing for better-quality health care and reining in its ever-increasing cost, many countries have been counting on the forces of market competition. What is puzzling, however, are the ambiguous findings in the literature on the impact of competition on hospital quality. Moreover, when quality is not guaranteed, we are not in favor of pushing for lower prices, for fear that hospital quality could be further compromised. As a result, we have limited public policy recommendations on this front.

In this paper, we take the view that hospitals would improve quality in response to competition only if information about the quality improvement can be revealed to patients; otherwise, hospitals may have other responses (such as price reduction) to competition. Using a data set covering all the hospitals in a major city in China over 2007-2014, where hospitals are strictly graded by the government based on a comprehensive matrix of indicators, we find heterogeneous responses of hospitals to competition. Grade 1 and Grade 2 hospitals improve quality, whereas Grade 3 (the highest grade) hospitals reduce prices. Intuitively, the lower-grade hospitals have a chance to reveal quality improvement to patients through future upgrading, with which they can attract more patients and charge higher prices. But Grade 3 hospitals have no means to reveal quality improvement through further upgrading; instead, they resort to price reduction to stay competitive. In addition to the quality and price responses to competition, we also find that hospitals make consistent and related operational efficiency improvements by adjusting the scope of service or degree of specialization, improving the bed occupancy rate, and ultimately lowering down the operating expenditure per patient.

This study contributes to the existing literature by addressing the challenge of identifying the factors that determine whether competition will lead to increased or decreased quality as pointed out by Gaynor and Town (2012). It highlights the importance of comprehensive and discriminative quality certification in ensuring what we desire to have from competition. More importantly, this study reaffirms our belief in market competition, by showing that competition makes hospitals of the highest grade reduce prices while pushing lower-grade hospitals to improve quality and maintain their prices, leading to higher consumer welfare through different channels.

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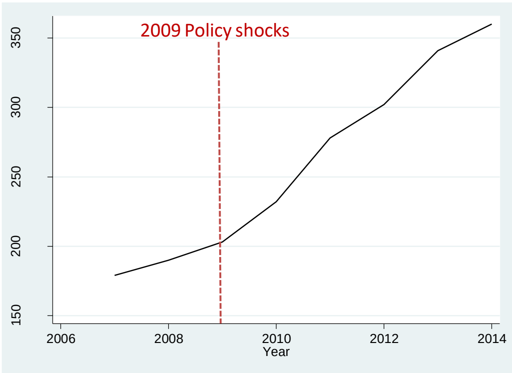
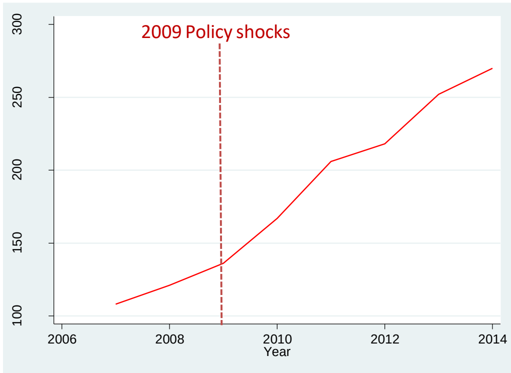
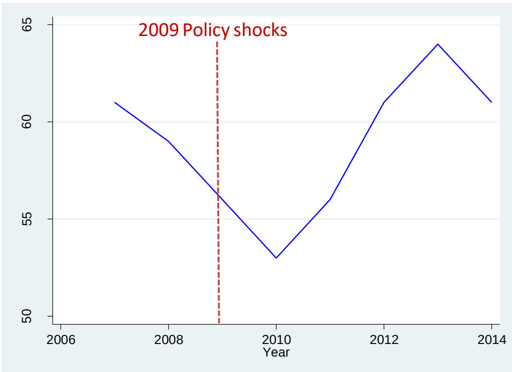
Figure 1: Changing Market Structure by Grade (2007-2014)



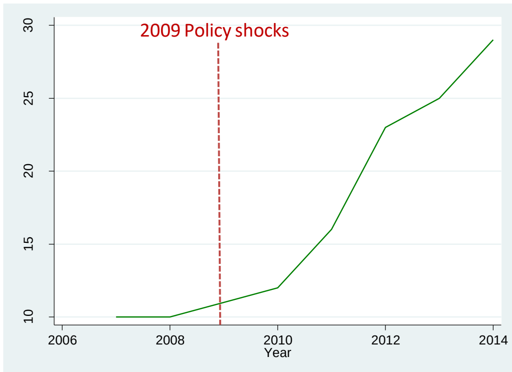
(a) Total number of hospitals



(b) Number of Grade 1 hospitals



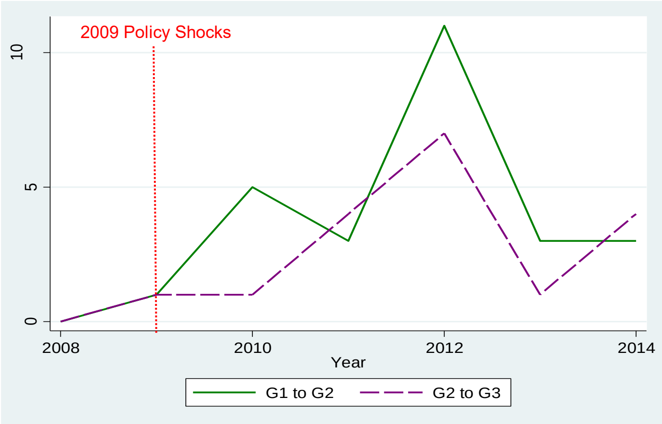
(c) Number of Grade 2 hospitals



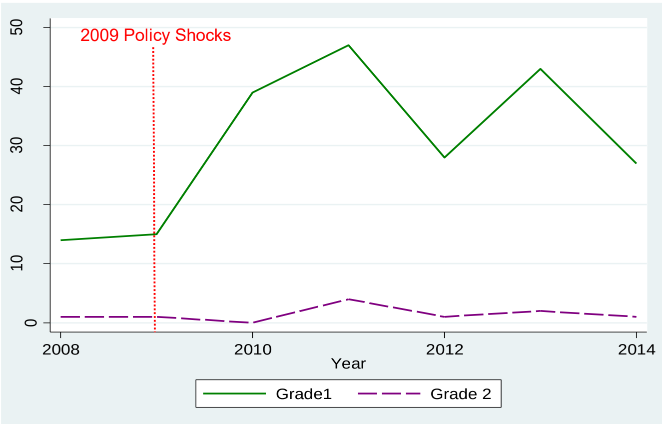
(d) Number of Grade 3 hospitals

Notes: The total number of hospitals in our sample increased substantially in the sample period, starting from 179 in 2007, rising moderately to 203 in 2009, jumping sharply to 276 in 2011, and finally achieving 360 in 2014. The number of Grade 1 hospitals increased the most (from 108 to 270), followed by that of Grade 3 hospitals (from 10 to 29). The number of Grade 2 hospitals, however, was 61 in 2007 and 2014, although its composition changed due to entry and exit.

Figure 2: Impact of the Policy Shocks of 2009 on Upgrading and de novo Entry



(a) Number of upgraded hospitals by grade



(b) Number of de novo entries by grade

Notes: Panel (a) shows that the first policy shock led to a sharp increase in the number of upgrading since 2009. The first batch of hospitals were upgraded successfully from Grade 1 to Grade 2 in 2010. It took one more year for hospitals to be upgraded from Grade 2 to Grade 3 because upgrading to the highest level required more effort and work. Panel (b) shows that the second policy shock led to a huge increase in the number of de novo entries since 2009.

Figure 3a: Geographic Distribution of New Grade 3 Hospitals Upgraded from Grade 2

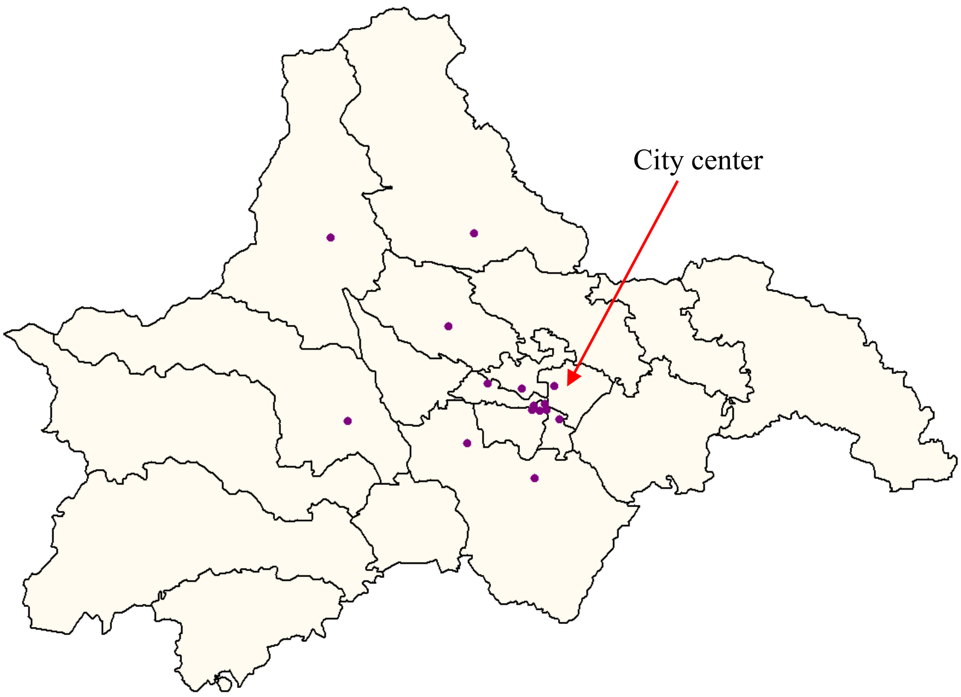
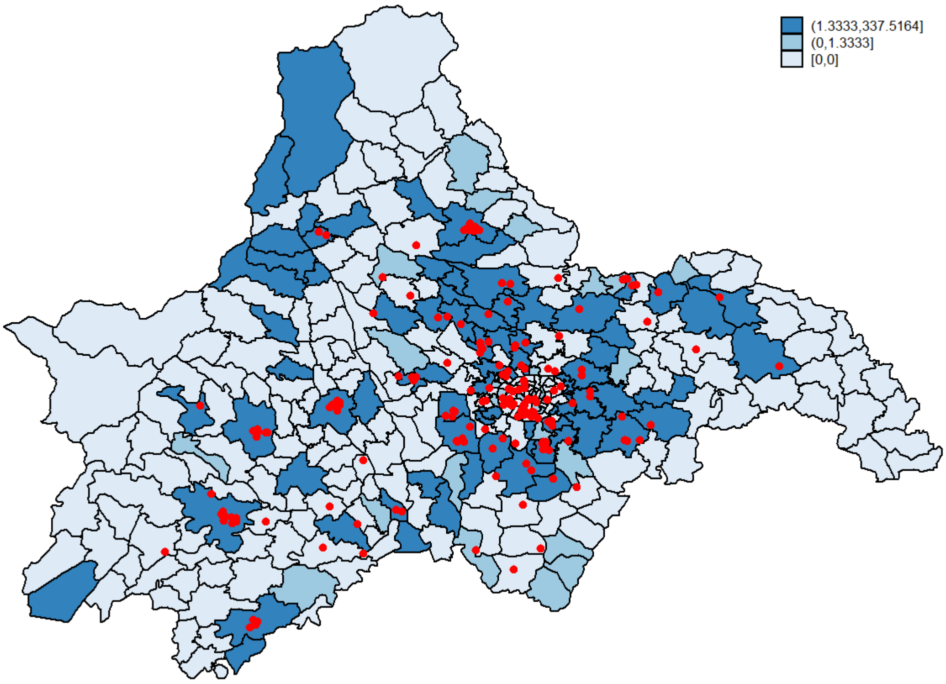


Figure 3b: Geographic Distribution of de novo Entry of Grade 1 Hospitals



Notes: Darker shades indicate more land sales in 2009.

Table 1: National Hospital Grading Criteria

Criteria	Example	Grade 2		Grade 3	
		# Core	# Other	# Core	# Other
Basic requirements	Number of beds, physical space for each inpatient, and number of chief physicians	3	26	4	29
Service process management	Booking services, waiting-time, treatment with dignity and respect, compassionate care, and privacy protection	3	45	5	33
Medical safety	Patient identity validation, number of medical disputes and malpractice, and compensation for medical disputes and malpractice	6	20	4	22
Clinical quality, skills, and research	Readmission rate, complications/mortality after surgery, emergency department mortality rate, mortality rates for various diseases, ability to perform all required diagnostics/treatment practices and procedures, and publications	13	309	27	352
Nursing care management	Nurse-to-bed staffing ratio and nurse qualification	1	52	2	51
General hospital management	Length of stay, total debt to total assets, financial compliance, corporate social responsibility, and physician ethics	7	98	6	101

Source: The National Health and Family Planning Commission.

Notes: Each criterion is labeled "core" or "other" according to its relative importance. Higher cutoff scores are set for the core criteria than the other ones. The majority of these requirements are associated with clinical quality and general hospital management.

Table 2: Differences across Grades in the Sample

			Grade 3	Grade 2	Grade 1
Panel A	Physicians	#Physicians	439	107	19
	Specialty dept.	#Dept.	13	10	4
	Beds	#Beds	1,105	290	69
	Equipment	#Pieces of large equipment	29	3	0.3
		Equipment value (RMB million)	227	24.2	3.3
	Nursing service	Nurse-to-bed staffing ratio	0.62	0.49	0.40
Panel B	Number of patients/visits/ admissions	Total	888,143	178,471	26,077
		OP visits	792,603	155,370	23,001
		ED admissions	76,736	20,243	1729
		IP admissions	37,489	9,695	1,397
Panel C	Prices (RMB)	Average price	870	530	630
		OP price	280	180	260
		IP price	9,490	4,940	4,260

Notes: Panel A reports the differences in inputs across grades. *Physicians* includes all types of licensed physicians (i.e., clinical, Chinese medical, dental, and preventive care). *Specialty dept.* reports the average number of specialty departments in general hospitals. *Large equipment* is equipment with market value more than RMB 1 million, such as magnetic resonance imaging (MRI) machines and 64-slice-or-above CT scanners. Panel B reports average outputs in numbers across grades. Panel C reports prices.

Table 3: Breakdown of Entry and Exit to Each Grade (2007-2014)

			2007	2008	2009	2010	2011	2012	2013	2014
Grade 3	Total # of G3		10	10	11	12	16	23	25	29
	Entry	Upgraded from G2	n/a	0	1	1	4	7*	2	4
		De novo entry	n/a	0	0	0	0	0	0	0
	Exit	Downgraded to G2	n/a	0	0	0	0	0	0	0
		Outright exit	n/a	0	0	0	0	0	0	0
	Net change		n/a	0	1	1	4	7	2	4
Grade 2	Total # of G2		61	59	56	52	55	61	64	61
	Entry	Upgraded from G1	n/a	0	1	5	3	11	3	3
		De novo entry	n/a	1	1	0	4	1	2	1
	Exit	Changed to G3/G1	n/a	-3	-4	-6	-4	-5	-1	-6
		Outright exit	n/a	0	-1	-3	0	-1	-1	-1
	Net change		n/a	-2	-3	-4	3	6	3	-3
Grade 1	Total # of G1		108	121	136	167	205	218	252	270
	Entry	Downgraded from G2	n/a	3	3	5	0	0	0	2
		De novo entry	n/a	14	15	39	47	28	43	27
	Exit	Upgraded to G2	n/a	0	-1	-5	-3	-11	-3	-3
		Outright exit	n/a	-4	-2	-8	-6	-4	-6	-8
	Net change		n/a	13	15	31	38	13	34	18
Total # of hospitals			179	190	203	231	276	302	341	360

Notes: The total number of hospitals doubled from 2007 to 2014, resulting from massive entries and exits in each grade after the policy shocks of 2009. All of the new Grade 3 hospitals were upgraded from Grade 2. The entries in Grade 2 are cancelled out by the exits. The large increase in the number of Grade 1 hospitals was mainly driven by a massive de novo entry of 213 new ones.

* Two Grade 2 hospitals were closed before 2007 but they were reopened and upgraded to Grade 3 in 2012. Hence, they are excluded when counting the exits of Grade 2 hospitals. One similar case happened in 2013.

Table 4: Descriptive Statistics for the Main Variables

	Variable	Mean	SD
Competition	Within-grade competition of Grade 3	0.82	0.65
	Within-grade competition of Grade 2	1.11	0.55
	Within-grade competition of Grade 1	1.74	0.88
	Cross-grade competition from higher grade(s)	2.14	1.36
	Cross-grade competition from lower grade(s)	0.21	0.41
Quality	ED mortality (‰)	0.97	3.24
	Nurse-to-bed staffing ratio	0.44	0.30
Prices (RMB 1,000)	Average price	0.64	0.86
	OP price	0.24	0.37
	IP price	4.77	5.07
	Drug price	0.24	0.32
	Non-drug price	0.38	0.54
Operational efficiency	Hospital operating expenditure per patient (RMB 1,000)	0.41	0.67
	Bed occupancy rate	0.70	0.35
	# of specialty departments providing inpatient and outpatient services	3.55	2.53
Covariates	Inpatient revenue/total patient revenue	0.61	0.22

Table 5: Quality Response to Competition (2SLS)

	ED mortality	Nurse-to-bed staffing ratio
	(1)	(2)
$COMP^3*G^3$	0.160	0.000
	(0.255)	(0.124)
$COMP^2*G^2$	-0.504**	0.317***
	(0.222)	(0.094)
$COMP^1*G^1$	-0.546*	0.528***
	(0.328)	(0.155)
$COMP^H$	0.086	-0.165
	(0.233)	(0.122)
$COMP^L$	-0.059	0.164
	(0.250)	(0.129)
One SD increase in	Change (%)	Change (%)
- $COMP^2*G^2$	-25^	+19
- $COMP^1*G^1$	-59^^	+59
Observations	902	1,369
No. of hospitals	210	302

Notes: This table reports the results of Equation (4). In column (1), dependent variable is (logarithm) the ED mortality, death rate for all causes following admissions in the emergency department in a given year (‰). In column (2), dependent variable is (logarithm) the nurse-to-bed staffing ratio measured as the number of registered nurses of a hospital divided by the number of beds in the hospital.

All regressions include hospital fixed effects, grade fixed effects, year fixed effects, plus a case-mix indicator. Heteroskedasticity-robust standard errors are in parentheses, clustered at the hospital level. Stars indicate significance level: * p<0.1, ** p<0.05, *** p<0.01.

Notice that there are fewer observations for the ED mortality than for the nurse-to-bed staffing ratio. This difference simply results from variations in sample size. Similar cases can be seen in the following tables.

^ The absolute change is -0.28 deaths per 1000 ED patients.

^^ The absolute change is -0.48 deaths per 1000 ED patients.

Table 6: Price Response to Competition

	Average price	OP price	IP price	Drug price	Non-drug price
	(1)	(2)	(3)	(4)	(5)
$COMP^3*G^3$	-0.746***	-0.609***	-0.177	-0.948***	-0.622***
	(0.221)	(0.195)	(0.150)	(0.266)	(0.178)
$COMP^2*G^2$	0.027	0.041	-0.039	0.093	-0.079
	(0.138)	(0.133)	(0.094)	(0.150)	(0.137)
$COMP^1*G^1$	0.092	0.098	-0.229	0.306	-0.102
	(0.159)	(0.171)	(0.151)	(0.188)	(0.160)
$COMP^H$	-0.654***	-0.468**	-0.035	-0.802***	-0.455***
	(0.193)	(0.181)	(0.143)	(0.250)	(0.162)
$COMP^L$	0.311**	0.244	-0.098	0.436***	0.181
	(0.141)	(0.151)	(0.099)	(0.164)	(0.126)
One SD increase in	Change (%)	Change (%)	Change (%)	Change (%)	Change (%)
- $COMP^3*G^3$	-38	-33	n/a	-46	-33
Observations	1,368	1,370	1,370	1,356	1,356
No. of hospitals	302	302	302	300	300

Notes: In column (1), dependent variable is (logarithm) total patient revenue divided by the total number of patients. In columns (2) and (3), dependent variables are (logarithm) the outpatient revenue per visit and (logarithm) the inpatient revenue per admission, respectively. In columns (4) and (5), dependent variables are (logarithm) the patient revenue from drug sales divided by the total number of patients and (logarithm) the patient revenue excluding drug sales divided by the total number of patients, respectively.

All regressions include hospital fixed effects, grade fixed effects, year fixed effects, plus a case-mix indicator. Heteroskedasticity-robust standard errors are in parentheses, clustered at the hospital level. Stars indicate significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table 7: Impact of Competition on Operational Efficiency

	Average cost	Bed occupancy rate	Number of departments
	(1)	(2)	(3)
$COMP^3*G^3$	-0.567**	0.218*	-0.203**
	(0.238)	(0.116)	(0.101)
$COMP^2*G^2$	-0.096	0.154*	-0.353***
	(0.173)	(0.084)	(0.112)
$COMP^1*G^1$	0.093	0.181	0.049
	(0.192)	(0.122)	(0.124)
$COMP^H$	-0.368*	0.127	-0.025
	(0.209)	(0.104)	(0.084)
$COMP^L$	0.400**	-0.055	0.146
	(0.174)	(0.087)	(0.141)
One SD increase in	Change (%)	Change (%)	Change (%)
- $COMP^3*G^3$	-31	+15	-12
- $COMP^2*G^2$	n/a	+9	-18
- $COMP^1*G^1$	n/a	n/a	n/a
Observations	1,322	1,353	1,079
No. of hospitals	299	300	267

Notes: In column (1), dependent variable is the logarithm of hospital operating expenditure per patient (average cost). In column (2), dependent variable is the bed occupancy rate defined as (logarithm) the ratio of the total number of inpatient days to the total number of available bed days in a given year. In column (3), dependent variable is (logarithm) the number of specialty departments for which the hospital offers inpatient and outpatient services (number of departments).

All regressions include hospital fixed effects, grade fixed effects, year fixed effects, plus a case-mix indicator. Heteroskedasticity-robust standard errors are in parentheses, clustered at the hospital level. Stars indicate significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table 8: Robustness Check – Alternative Explanation:
Financial Condition (2SLS)

	ED mortality	Nurse-to-bed staffing ratio	ED mortality	Nurse-to-bed staffing ratio
	(1)	(2)	(3)	(4)
$COMP^3*G^3$	0.184	-0.008	0.098	-0.109
	(0.260)	(0.123)	(0.262)	(0.129)
$COMP^2*G^2$	-0.503**	0.323***	-0.491**	0.278***
	(0.222)	(0.093)	(0.221)	(0.101)
$COMP^1*G^1$	-0.568*	0.540***	-0.476	0.542***
	(0.332)	(0.157)	(0.339)	(0.170)
$COMP^H$	0.100	-0.175	0.016	-0.249*
	(0.235)	(0.122)	(0.240)	(0.129)
$COMP^L$	-0.084	0.166	0.010	0.229*
	(0.253)	(0.128)	(0.255)	(0.133)
New Controls				
Fiscal subsidies	Yes	Yes	Yes	Yes
Debt-to-asset ratio	No	No	Yes	Yes
Observations	902	1,369	826	1,212
No. of hospitals	210	302	196	280

Notes: This table reports the results of Equation (4) with additional controls to conduct exclusion restriction checks for our estimation of the effect of competition on quality. In columns (1) and (2), the regressions include fiscal subsidies. In columns (3) and (4), the regressions include both fiscal subsidies and the debt-to-asset ratio.

All regressions include hospital fixed effects, grade fixed effects, year fixed effects, plus a case-mix indicator. Heteroskedasticity-robust standard errors are in parentheses, clustered at the hospital level. Stars indicate significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table 9: Robustness Check – Exclusion of a Nationally-Reputed Hospital (2SLS)

	Quality		Price					Operational efficiency		
	ED mortality	Nurse-to-bed staffing ratio	Average price	OP price	IP price	Drug price	Non-drug price	Average cost	Bed occupancy rate	#Dept. (OP&IP)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$COMP^3*G^3$	0.169	-0.009	-0.756***	-0.624***	-0.187	-0.942***	-0.632***	-0.566**	0.213*	-0.203**
	(0.260)	(0.126)	(0.223)	(0.196)	(0.150)	(0.266)	(0.179)	(0.240)	(0.117)	(0.102)
$COMP^2*G^2$	-0.497**	0.314***	0.027	0.038	-0.042	0.101	-0.078	-0.089	0.148*	-0.352***
	(0.223)	(0.094)	(0.138)	(0.133)	(0.095)	(0.150)	(0.137)	(0.174)	(0.084)	(0.111)
$COMP^1*G^1$	-0.547*	0.531***	0.102	0.111	-0.226	0.308	-0.091	0.102	0.182	0.048
	(0.329)	(0.155)	(0.157)	(0.169)	(0.150)	(0.186)	(0.158)	(0.189)	(0.122)	(0.124)
Observations	897	1,362	1,361	1,363	1,363	1,350	1,350	1,315	1,346	1,073
No. of hospitals	209	301	301	301	301	299	299	298	299	266

Notes: This table reports the results of Equation (4) for a sample that excludes a nationally reputed hospital in the city. All regressions include hospital fixed effects, grade fixed effects, year fixed effects, plus a case-mix indicator. Heteroskedasticity-robust standard errors are in parentheses, clustered at the hospital level. Stars indicate significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table 10: Robustness Check – Alternative Classification of the Ungraded Hospitals (2SLS)

	Quality		Price					Operational efficiency		
	ED mortality	Nurse-to-bed staffing ratio	Average price	OP price	IP price	Drug price	Non-drug price	Average cost	Bed occupancy rate	#Dept. (OP&IP)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$COMP^3*G^3$	0.390*	-0.218	-0.559**	-0.518***	-0.216	-0.747***	-0.546***	-0.238	0.201*	-0.010
	(0.233)	(0.144)	(0.229)	(0.196)	(0.151)	(0.257)	(0.185)	(0.257)	(0.120)	(0.104)
$COMP^2*G^2$	-0.300*	0.099	-0.052	-0.008	-0.239*	-0.059	-0.093	-0.014	0.227**	-0.088
	(0.165)	(0.136)	(0.165)	(0.164)	(0.133)	(0.206)	(0.146)	(0.136)	(0.113)	(0.090)
$COMP^1*G^1$	-0.646**	0.579***	-0.040	0.025	-0.204	0.135	-0.119	-0.046	0.128	-0.088
	(0.277)	(0.155)	(0.193)	(0.196)	(0.154)	(0.235)	(0.173)	(0.197)	(0.130)	(0.115)
Observations	911^	1,378	1,377	1,379	1,379	1,366	1,366	1,331	1,362	1,087
No. of hospitals	211	304	304	304	304	302	302	300	302	269

Notes: This table reports the results of Equation (4) with alternative classification of the ungraded hospitals. Instead of being grouped together with Grade 1 hospitals, ungraded hospitals are assigned to different grades according to the number of beds they have in this robustness check. Following the Hospital Grading Criteria, ungraded hospitals with more than 500 beds are regarded as Grade 3; ungraded hospitals with more than 100 beds but less than 500 beds are regarded as Grade 2; the rest of the ungraded hospitals are regarded as Grade 1.

All regressions include hospital fixed effects, grade fixed effects, year fixed effects, plus a case-mix indicator. Heteroskedasticity-robust standard errors are in parentheses, clustered at the hospital level. Stars indicate significance level: * p<0.1, ** p<0.05, *** p<0.01.

^The slightly smaller number of observations in column (1) in Table 5 than column (1) here in this table is due to that information on hospital grade is missing for some hospitals in the data.

Table 11: Robustness Check – Alternative Estimation Method: Conventional IV Estimation

	Quality		Price					Operational efficiency		
	ED mortality	Nurse-to-bed staffing ratio	Average price	OP price	IP price	Drug price	Non-drug price	Average cost	Bed occupancy rate	#Dept. (OP&IP)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$COMP^3*G^3$	0.517	0.324	-0.995***	-0.870***	-0.147	-1.255***	-0.996***	-0.841**	0.296*	-0.346*
	(0.476)	(0.204)	(0.275)	(0.250)	(0.192)	(0.330)	(0.276)	(0.336)	(0.167)	(0.183)
$COMP^2*G^2$	-0.617	0.404**	0.147	0.032	0.059	0.037	-0.007	-0.070	0.282	-0.493***
	(0.449)	(0.180)	(0.240)	(0.212)	(0.151)	(0.243)	(0.246)	(0.285)	(0.173)	(0.183)
$COMP^1*G^1$	-0.966*	0.292*	0.255	0.233	-0.203	0.466	0.083	0.209	0.152	0.038
	(0.508)	(0.158)	(0.263)	(0.249)	(0.188)	(0.296)	(0.246)	(0.336)	(0.182)	(0.143)
$COMP^H$	0.386	0.079	-0.812***	-0.592**	-0.058	-1.018***	-0.700***	-0.470	0.092	-0.015
	(0.356)	(0.166)	(0.268)	(0.247)	(0.197)	(0.334)	(0.250)	(0.339)	(0.151)	(0.136)
$COMP^L$	-0.399	-0.333	0.868**	0.754**	0.178	1.106***	0.812**	0.831*	-0.143	0.037
	(0.540)	(0.261)	(0.361)	(0.335)	(0.238)	(0.416)	(0.355)	(0.429)	(0.206)	(0.279)
Observations	930	1,448	1,447	1,449	1,449	1,434	1,434	1,392	1,432	1,139
No. of hospitals	192	287	287	287	287	286	286	283	286	254

Notes: This table reports the conventional IV results of Equation (4). All regressions include hospital fixed effects, grade fixed effects, year fixed effects, plus a case-mix indicator. Heteroskedasticity-robust standard errors are in parentheses, clustered at the hospital level. Stars indicate significance level: * p<0.1, ** p<0.05, *** p<0.01.

1 Appendix A: Calculating Specialty Similarity

We obtain the specialty similarity using a Manhattan-distance approach. Suppose two hospitals have beds for 35 specialty departments[1] as a vector $X = (x_1, x_2, ..., x_{35})$, $x_i \geqslant 0$, and a vector $Y = (y_1, y_2, ..., y_{35})$, $y_i \geqslant 0$. We calculate the measure of specialty similarity following the steps below:

1. Normalize X and Y by their total numbers of beds separately: $\tilde{X} = X / \sum_{i=1}^{35} x_i$, $\tilde{Y} = Y / \sum_{i=1}^{35} y_i$;

2. Define $Distance = \sum_{i=1}^{35} (|\tilde{y}_i - \tilde{x}_i|)/2$;

3. Define $Similarity = 1 - Distance$.

There are some nice features of this measure of specialty similarity:

- When the two hospitals have exactly the same structure of allocation of beds among departments (i.e. $X = Y$),
$Similarity = 1$;
- When the two hospitals have no overlap on any specialty services provided,
$Similarity = 0$;
- The measure is within [0,1], increasing (linearly) as the degree of overlapping for any specialty service increases.

2 Appendix B: Simulated-IV Approach

1. Predict grade change:

For existing Grade 1 and Grade 2 hospitals, we obtain their probabilities of grade change by estimating Equations (5) and (6).

2. Predict the number of Grade 1 new entries and determine their locations:

a) Define the number of Grade 1 new entries in district j in time t as New_Grade1_{jt}. Get the probabilities of getting n ($n \in \{0, 1, 2\}$[2]) new hospitals for each district, $pr(New\_Grade1 = n)_{jt}$, by estimating Equation (7).

b) Draw a random number $v : v \in [0, 1]$. We construct the predicted number of new entrants, $\hat{New}\_Grade1_{jt}$, based on the relationship between v and $pr(New\_Grade1 = 0)_{jt}$, $pr(New\_Grade1 = 1)_{jt}$, and $pr(New\_Grade1 = 2)_{jt}$.

- If $0 \leqslant v \leqslant pr(New\_Grade1 = 0)$, then $\hat{New}\_Grade1_{jt} = 0$;
- If $pr(New\_Grade1 = 0) < v \leqslant pr(New\_Grade1 = 0) + pr(New\_Grade1 = 1)$, then $\hat{New}\_Grade1_{jt} = 1$;
- If $pr(New\_Grade1 = 0) + pr(New\_Grade1 = 1) < v \leqslant 1$, then $\hat{New}\_Grade1_{jt} = 2$.

[1] Thirty-five different specialty departments are reported in our data set. Any bed in a hospital can be assigned to one of these 35 departments.

[2] $n = 2$ represents two or more entrants.

c) Locate the predicted new entrants for each district: if there are new entrants in the district in the data, use their locations; if not, randomly generate longitudes and latitudes within the district as locations for the predicted new entrants.

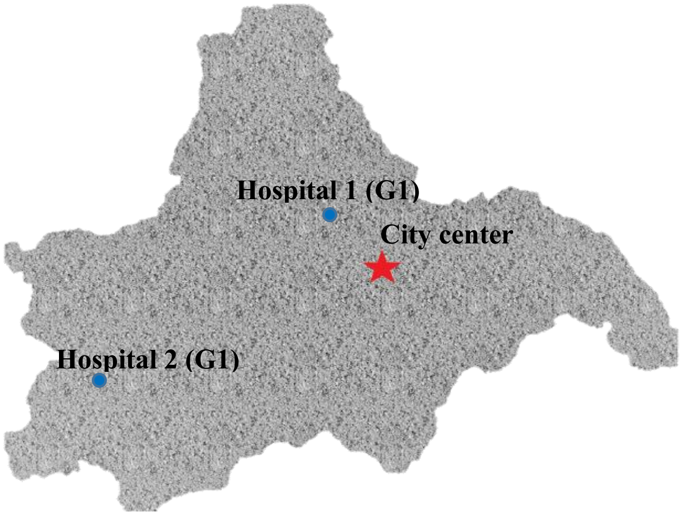
3. Form the simulated market structure and construct simulated within-/cross-grade competition measures according to Equations (1), (2) & (3).[3]

4. Estimate the main equation (Equation (4)) using the simulated competition measures as the instrumental variables. Record the estimated coefficients and their standard deviations as $(Coeff_i, Std_i)$.

5. Repeat from 2(b) to 4 100 times and use the means of $(Coeff_i, Std_i)$ as the final estimation results.

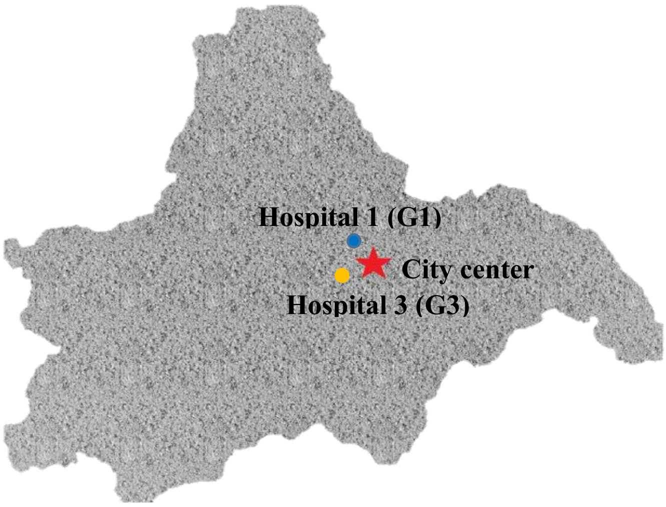
[3] For the existing hospitals: we use the lagged values of similarity and relative size to adjust the competition measures; for the new entrants (in the data or predicted), we use the lagged average values of similarity and relative size for new entrants in the data.

Figure A1(a): Example 1 - Cross-Section Variations by Location



Notes: Consider two incumbent hospitals (target hospitals) of the same grade, say, Grade 1 hospitals without loss of generality, with hospital H1 located near the city center and H2 in the outskirts. In the post-policy years, the within-grade competition faced by H2 increased substantially due to the massive new entries of Grade 1 hospitals in the outskirts. In contrast, the change in competition faced by H1 was much smaller, because fewer new Grade 1 hospitals chose to locate in the city center. The location-based cross-section variations in the intensity of the policy impact gave us the idea to introduce the interaction of the policy shocks and hospital location to predict changes in the market structure after the policy shocks.

Figure A1(b): Example 2 - Cross-Section Variations by Grade



Notes: Consider two incumbent hospitals (target hospitals) located in the same place, say in the city center without loss of generality, with hospital H1 as Grade 1 and H3 as Grade 3. In the post-policy years, the within-grade competition faced by H3 increased substantially due to the many newly upgraded Grade-3 hospitals in the city center near H3. However, the impact of the policy shocks on the within-grade competition faced by H1 was much smaller, because many of the new entries of Grade 1 hospitals were far away from H1. The grade-based cross-section variations in the intensity of the policy impact gave us the idea to introduce the interaction of the policy shocks and the hospital grade as a source of exogenous variations to predict changes in the market structure after the policy shocks.

Table A1: List of Specialty Departments

No.	Department	Average number of beds		
		Grade 1	Grade 2	Grade 3
1	Preventive Health Care	0.1	0.0	3.9
2	Family Medicine	3.2	0.2	9.7
3	General Medicine	25.6	112.0	402.6
4	General Surgery	15.4	94.8	330.2
5	Pediatrics	1.5	21.0	44.9
6	Preventive Health Care for Women	0.2	0.0	0.0
7	Obstetrics & Gynecology	7.1	28.3	50.7
8	Pediatric Surgery	0.0	0.0	1.4
9	Preventive Health Care for Children	0.0	0.0	0.0
10	Ophthalmology	0.6	4.0	27.9
11	Otolaryngology	0.6	5.2	30.5
12	Dentistry	0.1	0.2	2.2
13	Dermatology	1.3	0.5	20.1
14	Cosmetology	0.1	0.0	0.4
15	Psychiatry	0.6	0.8	21.0
16	Infectious Diseases	0.0	2.1	16.0
17	Tuberculosis	0.0	0.0	2.9
18	Endemic Diseases	0.0	0.0	0.0
19	Oncology	0.6	6.9	70.1
20	Emergency Department	0.2	0.3	9.4
21	Rehabilitation Medicine	2.4	3.9	26.3
22	Sports Medicine	0.0	0.0	0.0
23	Occupational Diseases	0.0	0.1	0.0
24	Hospice	0.0	0.0	0.0
25	Pain Management	0.2	1.1	4.3
26	Critical Care Medicine	0.1	2.2	15.7
27	Traditional Chinese Medicine	1.3	4.0	8.9
28	Uighur Medicine	0.0	0.0	0.0
29	Tibetan Medicine	0.0	0.0	0.0
30	Mongolian Medicine	0.0	0.0	0.0
31	Yi Medicine	0.0	0.0	0.0
32	Dai Medicine	0.0	0.0	0.0
33	Medicine of Other Minorities	0.0	0.0	0.0
34	Integrated Chinese and Western Medicine	1.4	1.4	48.9
35	Others	0.8	1.7	79.8

Table A2: Decisions of Existing Grade 1 Hospitals

	(1)	(2)
	Pr(Upgrading to G2)	Pr(Exiting)
Policy*Distance	1.293***	1.246**
	(0.366)	(0.564)
Distance	-1.643***	-1.935***
	(0.309)	(0.537)
COMP	-2.020***	-0.107
	(0.453)	(0.398)
$COMP^H$	0.420	1.74e-05
	(0.335)	(0.291)
Observations	1,126	1,126
No. of hospitals	293	293

Notes: Grade 1 hospitals staying the same is the base outcome. Year fixed effects are included in the regression. Standard errors are in parentheses, clustered at the hospital level. Stars indicate significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table A3: Decisions of Existing Grade 2 Hospitals

	(1)	(2)	(3)
	Pr (Upgrading to G3)	Pr (Downgrading to G1)	Pr(Exiting)
Policy*Distance	-0.896***	2.274	0.859
	(0.293)	(2.153)	(0.617)
Distance	-0.0744	-1.211	-1.931***
	(0.325)	(2.832)	(0.738)
COMP	-4.223***	0.242	-2.411**
	(1.549)	(1.337)	(1.097)
$COMP^H$	0.631	-1.265	-3.180
	(0.618)	(2.091)	(2.172)
$COMP^L$	0.998	4.546***	5.799**
	(1.373)	(1.703)	(2.768)
Observations	396	396	396
No. of hospitals	89	89	89

Notes: Grade 2 hospitals staying the same is the base outcome. Year fixed effects are included in the regression. Standard errors are in parentheses, clustered at the hospital level. Stars indicate significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table A4: Entry Decision of Grade 1 Hospitals

	(1)	(2)
	Pr(No. New G1=1)	Pr(No. New G1>1)
Policy*Land_Sales	0.402**	-0.554**
	(0.173)	(0.219)
Policy*Land_Price	0.120	0.089
	(0.108)	(0.195)
Land_Sales	-0.004	0.885***
	(0.164)	(0.127)
Land_Price	0.076	-0.014
	(0.080)	(0.071)
Num^{G1}	0.681***	1.454***
	(0.193)	(0.464)
Num^{H}	0.816***	1.000**
	(0.229)	(0.501)
Observations	2,205	2,205
No. districts	315	315

Notes: Zero new entry is the base outcome. Year fixed effects are included in the regression. Standard errors are in parentheses, clustered at the district level. Stars indicate significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table A5: Means of Actual and Simulated Competition Measures and Their Correlations

	Actual	Simulated	Correlation
$COMP^3$	1.837	1.833	0.959
$COMP^2$	1.623	1.574	0.939
$COMP^1$	1.377	1.264	0.941
$COMP^H$	2.110	2.066	0.972
$COMP^L$	0.228	0.193	0.977

Table A6: First-Stage Results for the Main Equation

IV	$COMP^3$	$COMP^2$	$COMP^1$	$COMP^H$	$COMP^L$
	(1)	(2)	(3)	(4)	(5)
$COMP^3$_Simulated	0.494***	-0.149*	0.127*	-0.362***	0.052*
	(0.087)	(0.078)	(0.072)	(0.085)	(0.026)
$COMP^2$_Simulated	-0.049	0.460***	0.017	-0.197***	0.024
	(0.058)	(0.052)	(0.050)	(0.055)	(0.019)
$COMP^1$_Simulated	0.098	0.043	0.349***	0.054	-0.053**
	(0.071)	(0.059)	(0.071)	(0.070)	(0.023)
$COMP^H$_Simulated	-0.071*	0.088**	-0.041	0.932***	-0.043
	(0.037)	(0.034)	(0.041)	(0.039)	(0.033)
$COMP^L$_Simulated	0.007	0.011	0.030	0.015	0.801***
	(0.049)	(0.049)	(0.047)	(0.048)	(0.058)
F-value	24.74	33.69	9.81	273.45	112.45
Observations	1,370	1,370	1,370	1,370	1,370
No. of hospitals	302	302	302	302	302

Notes: All regressions include hospital fixed effects, grade fixed effects, year fixed effects, plus a case-mix indicator. Standard errors are in parentheses, clustered at the hospital level. Stars indicate significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table A7 (a): Correlations among Actual Competition Measures

	$COMP^3$	$COMP^2$	$COMP^1$	$COMP^H$	$COMP^L$
$COMP^3$	1.000				
$COMP^2$	0.866	1.000			
$COMP^1$	0.882	0.888	1.000		
$COMP^H$	0.939	0.924	0.912	1.000	
$COMP^L$	-0.120	-0.191	-0.294	-0.327	1.000

(b): Correlations among Simulated Competition Measures

	$COMP^3$_S	$COMP^2$_S	$COMP^1$_S	$COMP^H$_S	$COMP^L$_S
$COMP^3$_S	1.000				
$COMP^2$_S	0.888	1.000			
$COMP^1$_S	0.896	0.909	1.000		
$COMP^H$_S	0.940	0.933	0.926	1.000	
$COMP^L$_S	-0.140	-0.229	-0.332	-0.358	1.000

Table A8: OLS Results for the Baseline Equation

	ED mortality	Nurse-to-bed staffing ratio	Average price	OP price	IP price	Drug price	Non-drug price	Average cost	Bed occupancy rate	Number of departments
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$COMP^3*G^3$	0.187	0.256***	-0.401**	-0.363***	-0.228	-0.508***	-0.385**	-0.331	0.077	-0.179**
	(0.162)	(0.0834)	(0.166)	(0.136)	(0.167)	(0.136)	(0.157)	(0.210)	(0.102)	(0.081)
$COMP^2*G^2$	-0.362**	0.378***	0.169	0.158	0.045	0.197	0.066	-0.001	0.236***	-0.346***
	(0.151)	(0.0819)	(0.120)	(0.114)	(0.075)	(0.120)	(0.112)	(0.137)	(0.090)	(0.100)
$COMP^1*G^1$	-0.080	0.364***	0.054	0.024	-0.006	0.142	-0.001	0.054	0.181**	0.003
	(0.107)	(0.070)	(0.132)	(0.114)	(0.132)	(0.121)	(0.133)	(0.160)	(0.091)	(0.054)
$COMP^H$	0.058	0.050	-0.322**	-0.230**	-0.079	-0.356***	-0.233*	-0.158	-0.037	-0.009
	(0.084)	(0.071)	(0.124)	(0.103)	(0.158)	(0.110)	(0.121)	(0.173)	(0.084)	(0.038)
$COMP^L$	0.079	0.017	0.099	0.062	-0.003	0.162	0.092	0.266*	-0.047	0.188*
	(0.194)	(0.088)	(0.121)	(0.115)	(0.111)	(0.108)	(0.120)	(0.146)	(0.094)	(0.104)
Observations	1,162	1,812	1,810	1,813	1,813	1,789	1,789	1,732	1,779	1,452
No. of hospitals	253	368	368	368	368	366	366	362	367	335

Notes: All regressions include hospital fixed effects, grade fixed effects, year fixed effects, plus a case-mix indicator. Heteroskedasticity-robust standard errors are in parentheses, clustered at the hospital level. Stars indicate significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table A9: Other Price Response to Competition (2SLS)

	Diagnostic-imaging price	Drug price OP	Drug price IP
	(1)	(2)	(3)
$COMP^3*G^3$	-0.476**	-0.656**	-0.645**
	(0.222)	(0.259)	(0.261)
$COMP^2*G^2$	-0.072	0.130	0.113
	(0.194)	(0.152)	(0.138)
$COMP^1*G^1$	0.069	0.225	0.017
	(0.188)	(0.209)	(0.226)
$COMP^H$	-0.321	-0.539**	-0.526**
	(0.197)	(0.234)	(0.251)
$COMP^L$	0.511**	0.182	0.058
	(0.202)	(0.178)	(0.172)
Observations	1,329	1,357	1,368
No. of hospitals	295	300	301

Notes: All regressions include hospital fixed effects, grade fixed effects, year fixed effects, plus a case-mix indicator. Heteroskedasticity-robust standard errors are in parentheses, clustered at the hospital level. Stars indicate significance level: * p<0.1, ** p<0.05, *** p<0.01.