Physician education mix and patient case-mix in hospital

Chengxiang Tang（✉ tang.chengxiang@gmail.com ）

Guangzhou University   https://orcid.org/0000-0002-7375-4896

Gordon Liu

Peking University

Jiayi Jiang

Guangzhou University

Hanqing Zhao

Division of Ageing Research and Development

Research

Abstract

Background

Previous literature pays little attention on relationship between hospital case-mix and physicians' human capital, while it is truly important topic in studies about health workforce. A multi-tiered medical education system resulted in substantial variation in physician education mix in hospital. We first exploit this heterogeneity in physician human capital across hospitals to explore its role as one of determinants of hospital case-mix.

Methods

The hospital case-mix index (CMI) from DRGs system is dependent variable. The school years of medical education is used to measure variation in physician human capital, that can be aggregated and averaged by each hospital. The study uses both descriptive analysis and regression modelling to investigate this association.

Results

Descriptive results show a positive relationship between physician human capital and patient case-mix in hospital. The model results illustrated that hospitals have higher level of physician education tend to have more serious case mix. In specific, when average medical school years increased by one, the hospital CMI increased by nearly 0.05.

Conclusion

The study findings highlight the importance and influences of physicians' education mix in patients' outcomes and healthcare delivery. We argue that physician groups with lower human capital are more likely to manage case volume with lower CMI. For future health care studies in some unstandardized health care system, it is important to control for physician-level variation in education.

Introduction

Becker and Steinwald first examined the determinants that affect hospital case-mix complexity in their Health Services Research paper in 1981 [1], while one major limitation of the study is the missing of medical staffs' characteristics in hospitals. We adopt the framework of Becker and Steinwald (1981) and extend it to include physician human capital, because complexity in health care often represented by a more serious case mix, while physicians with higher human capital are more capable to manage and treat inpatient volume. The aggregation of patients with serious illness is not random, but may implies

heterogeneity in physician human capital or education mix. We will further review a brief conceptual framework about hospital case-mix and its determinants.

This paper employs hospital case-mix index (CMI) extracted from DRGs system to measure the concept of case-mix. Technically, case mix can be of prime importance in hospital reimbursement or physicians' payment design. Case-mix can represent both patients' searching and matching in health care market, and physicians' efforts of diagnosis and treatment, or even physicians' case-mix management. Factors that underlie CMI variation among hospitals still need to be investigated. The behavioural framework in Becker and Steinwald (1981) assumes that variations in hospital case-mix complexity are a function of variables of hospitals, patients, and local areas. The critical limitation of the previous study is lacking of consideration of physician's characteristics, in particularly the years of the medical training or physician human capital.

Heterogeneity in physicians' medical education

Hsieh and Tang illustrated that the heterogeneity of different types of medical students in China's medical education is a long-term phenomenon and will not phase out in a short time [2]. There are at least three approaches for a medical student to become a physician with full licensure in China. The most common approach for a medical student with a bachelor degree is taking the national exam for medical practitioners and receiving hospital training as a resident for at least three years. Afterwards, the medical graduate earns the opportunity to become a licensed doctor. However, this is the most common approach to become a doctor, this approach only accounts for half of all new licensed doctors even till 2015. The second approach to become a physician is for medical graduates from junior medical colleges to earn a vocational diploma that requires three years of study after secondary school. The third approach involves secondary-level medical education through secondary vocational schools that provide very limited medical training after junior middle school. This program leads to a secondary vocational diploma (equal to a high school education) [2–5].

The heterogeneity in physicians' medical education resulted in huge variation in their training and further influence the education mix of hospital physician in labour market. Therefore, it is a direct and forward question whether and what kind of effects of physician education mix will be, while there are no previous studies ever examined the role of physician education mix and its impacts on hospital outcomes, like patient case-mix. By exploiting multi-tiered medical education system and relevant physician human capital variation across hospitals, this study aims to re-examine this topic and address this gap in the literature. This paper offers a useful perspective on the topic of medical education and health care market interaction and extends our previous study on heterogeneous physician human capital in a more general way [2]. The rest of this article is organised as follows: The Methods section details the hospitals data and variables, and the regression model. The Results section presents descriptive results and empirical analysis. Finally, we make discusses and conclusion in the last section.

Methods

Study data

China has launched a pilot program to implement hospital reimbursement based on diagnosis-related groups (DRGs) system since 2019. Before the program, the infrastructure of health care information from provincial health department to each hospital, in particular for secondary and tertiary hospital that are highly standardised and regulated by governments, have been built and prepared effectually over last decade.

This study utilized the DRG data extracted from a provincial health information system. The present population-based DRG system annually collects over sixteen million inpatient medical records from a large province with more than 83 million populations. To construct case-mix index, the system will process a unified International Classification of Disease (ICD-10) coding of diagnoses and treatment procedures from inpatient face-sheet. This DRG data provides annual CMI for each secondary and tertiary hospitals based on 2017 inpatient records, so it enables us to measure a hospital's case-mix complexity, and comparing it with other hospitals.

Measuring the impact of physician human capital on hospital CMI requires information about physicians, therefore a de-identified hospital staff dataset including age, gender, education level, professional qualification and working hospital from provincial medical workforce system will be aggregated and linked to the main data. The hospital annual report dataset was also included to provide background variables for each hospital. All three datasets were cross-sectional and come from the study year in 2017.

Dependent variable

The DRG provides a systematic approach to group patients based on a diagnosis classification and a similar resource consumption and length. Case-mix index is defined as the sum of all DRG relative weights (RW) dividing by the number of inpatient admission for a hospital. Relative weight is a value number that have been technically calculated by clinical experts and assigned to a group of patients, namely diagnosis-related group (DRG). The RW for each DRG usually measure the relative resource consumption and reflect clinical complexity associated with this DRG. Overall, the average DRG weight determines the hospital CMI and represent a comprehensive severity and relative resource consumption of the hospital.

An easy approach to understand hospital CMI is to compare it with a student's Grade Point Average (GPA). The higher GPA may reflect the student's academic achievement, in a similar way, the higher CMI is able to reflect the ability of a hospital or the workshop of physicians to diagnosis and manage to treat a more serious case mix. The most common application of CMI is to help insurance organization adjust and determine how much they should pay the hospital for cases.

We plotted hospital CMI distribution by hospital level in the Fig. 1. As we see, the CMI for both secondary and tertiary hospital are nearly normal distributed that allow for a statistically sound regression for a

small sample size. In addition, the average CMI of tertiary hospitals and its distribution are significantly larger than the average CMI of secondary hospitals.

Figure 1. CMI distribution across hospitals

Independent variable

In terms of physician human capital for a hospital, we used average years of medical training of all physicians for the measurement because the substantial differences in medical education programs caused a large variation in training years. The first type is bachelor-degree-oriented medical education which includes at least four to five years of undergraduate study in medical college. The second type is still a tertiary-level medical education which provide 3 years of study after high school and lead to a vocational diploma. The third type is secondary level medical education that provide very limited medical training, commonly for two years, after junior middle school and lead to a secondary vocational diploma (SVD) [3–5]. Finally, some doctors may continue to do their master or doctoral program by extending the training years after undergraduate study. Those post-graduate programs generally need seven years to finish the whole medical education training.

As the present legislation allows medical students without bachelor degree to become assistant doctors and then they have the chance to obtain the full doctor licensure after they accumulate certain years of work experience and pass an examination [2, 5, 6]. At a given point in time, the pool of Chinese physicians containing at least four types of physicians with different level of education training, thus, we use school years of medical education for each physician to measure physician human capital, that have been aggregated and averaged by each hospital.

Figure 2 shows the education composition and its change pattern of physicians during period of 2002 and 2018. For simplicity, we combine both bachelor and post-graduate level physicians into the group of bachelor degree and refer them as a group of "bachelor degree or above." Although the proportion of physicians with bachelor degree or above has risen over time, from 28% in 2002 to 63% in 2018, there are still more than one third of practicing physicians have received no full entry-level medical training according to the current international standard (Please refer to: http://www.who.int/topics/education_medical/en/). The substantial variations in the years of medical education program across physicians allows us to exploit and analyze its impacts on hospital performance.

Figure 2. Physicians by Education Level in China, 2002–2018

Beyond physicians' variable, other independent variables are from the conceptual framework in Becker and Steinwald (1981), which covers hospital, patients and local areas characteristics. First, to account for different aspects of hospital, we include binary variables identifying Teaching hospital, Government owned, Tertiary hospital, Specialty hospital, and TCM (Traditional Chinese Medicine) hospital service. In addition, both Occupancy rate and Outpatient per admission featured the hospital's patient flow. The former indicates the number of occupied beds compared to the total number of available beds annually;

the latter refers to a ratio of outpatient visits to inpatient days. Second, the previous model considered the composition of hospital medical staff proxied by hospital service distribution: Proportion of internal medicine, Proportion of OBG. Third, the model specification includes three variables to represent the association between health insurance distribution and case-mix: the proportion of hospital income from Urban residents insurance, Employee insurance, Rural residents insurance, respectively. Finally, the regression models used prefecture-level city fixed effects to account for local areas characteristics (See Table 1).

Table 1
Definition of variables

Variable	Definition
CMI	Hospital case-mix index (CMI) is extracted from the provincial DRGs system that represent a comprehensive severity of patients and relative resource consumption of the hospital
Physician human capital	Educational level of hospital physicians measured by hospital-level average years of medical training of all physicians
Physician experience	Another hospital-level variable for all physicians in a hospital measured by age subtracted years of medical schooling
Teaching hospital	Whether the hospital is a teaching hospital
Government owned	Whether the hospital is a government owned hospital
Tertiary hospital	Whether the hospital is a tertiary hospital
Specialty hospital	Whether the hospital is a specialty hospital
Occupancy rate	Number of occupied beds compared to the total number of available beds annually
Outpatient per admission	Refers to a ratio of outpatient visits to inpatient days
Urban residents insurance	Proportion of hospital income from Urban residents insurance
Employee insurance	Proportion of hospital income from Employee insurance
Rural residents insurance	Proportion of hospital income from Rural residents insurance
Proportion of internal medicine	Hospital service distribution: proportion of internal medicine
Proportion of OBG	Hospital service distribution: proportion of obstetrics and gynecology
TCM hospital service	Whether the hospital provide traditional Chinese medicine services

Table 1. Definition of variables

Descriptive analysis and empirical strategy

Figure 3 depicts hospital CMI distribution by physician human capital measured by average years of medical schooling. We see that hospitals with higher level of physician human capital treat patients' volume with higher case-mix index. Even though the number of hospital is much smaller than the number of secondary hospital, this relationship between CMI and physician human capital is stronger and significant for tertiary hospital. There are three explanations for this striking relationship: first, the casual effect of additional medical training; second, patients' sorting across hospitals (or physicians); third, physicians' ability bring about higher medical education and further generated higher CMI. Beyond the impacts of medical education on hospital CMI, we see that the next two reasons as confounding factors.

Figure 3. Distribution of hospital case-mix index by physician human capital

The purpose of our empirical strategy is to eliminate other two alternative explanations that attributes this relationship to the patients' choice on hospital and physicians' unobservable characteristics. As documented in literature, to obtain quality health care, patients often choose hospital or physician for outpatient-visiting and inpatient services based on unobservable social network and information sources. Our model specification followed Becker and Steinwald's conceptual framework, in which at least four dimensions of explanatory variables contributed to the model. The first is the teaching hospital status and other hospital characteristics; the second dimension is about hospital service distribution; the third concerns patients' coverage by different insurance; and the fourth includes area background features.

We further run a regression based on only physician human capital variable to examine this relationship between medical education and hospital case-mix complexity. To eliminate the first confounding factor, we further controlled prefecture-level city fixed effects, because it is likely that the difference in patient need and choices will not account for variation in hospital CMI. In order to examine impacts of physicians' ability, we include experience variable that used age subtracted years of medical schooling to test contribution of a part of personal ability. The experience variable represent returns of learning-by-doing and of patient volume. We correct the standard errors for clustering on city-level because a prefecture-level city is often seen the hospital referral region in China.

Results

Table 2 presents summary results of both dependent variable and independent variables that have been defined in the Methods section, including number of observations, means and standard deviations. The sample analysed consists of 435 hospitals out of 557 whole tertiary and secondary hospitals in the area. The final analysed sample excluded 142 hospitals because those hospitals contains no patients from obstetric-gynaecological departments. For sample hospitals, the average CMI is 0.730, compared to 0.73 for all hospitals. For sample hospitals, the average physician human capital level is 4.00 years, while this value is 3.98 for all hospitals. We find no significant differences in common hospital characteristics between sample and the universe, and therefore conclude that this sample hospital can represent all

tertiary and secondary hospitals. Table 3 displayed hospital case-mix index decomposition by selected hospital characteristics. In terms of government-owned, specialty hospital, and TCM services, CMI differences do not appear large. Both hospital teaching status and hospital level seems have larger impacts on the hospital case-mix complexity. The hospital CMI is distributed from 0.567 to 0.826 across cities, among them two cities – Aba and Ganzi – appears smaller as they are located in remote areas. To examine the sources of variation in hospital CMI, we cannot be satisfied with descriptive results and further use linear regression analysis to explore human capital impacts on hospital case-mix.

Table 2
Summary results

Variable	count	mean	p50	sd	min	max
CMI	435	0.73	0.73	0.12	0.44	1.27
Physician human capital	435	4.00	4.00	0.74	2.31	6.19
Physician experience	435	20.61	19.59	4.67	9.88	42.17
Teaching hospital	435	0.09	0.00	0.29	0.00	1.00
Government owned	435	0.81	1.00	0.40	0.00	1.00
Tertiary hospital	435	0.24	0.00	0.43	0.00	1.00
Specialty hospital	435	0.03	0.00	0.17	0.00	1.00
TCM hospital service	435	0.19	0.00	0.39	0.00	1.00
Occupancy rate	435	0.90	0.93	0.21	0.09	1.43
Outpatient per admission	435	13.74	12.02	8.74	1.74	98.70
Urban residents insurance	435	0.10	0.05	0.13	0.00	0.74
Employee insurance	435	0.12	0.08	0.14	0.00	0.80
Rural residents insurance	435	0.13	0.05	0.17	0.00	0.84
Proportion of internal medicine	435	0.40	0.39	0.14	0.00	0.98
Proportion of OBG	435	0.10	0.09	0.08	0.00	0.73

Table 3
Hospital case-mix index by selected hospital characteristics

Variable		CMI(mean)	Number of hospital
Teaching hospital			
	No	0.713	395
	Yes	0.911	40
Government owned			
	No	0.714	84
	Yes	0.735	351
Tertiary hospital			
	No	0.694	332
	Yes	0.850	103
Specialty hospital			
	No	0.732	422
	Yes	0.700	13
TCM hospital service			
	No	0.736	354
	Yes	0.709	81
City			
	Aba	0.567	19
	Bazhong	0.749	10
	Chengdu	0.778	80
	Dazhou	0.782	19
	Deyang	0.795	16
	Ganzi	0.557	16
	Guangan	0.755	11
	Guangyuan	0.714	28
	Leshang	0.728	24
	Liangshan	0.645	29
	Luzhou	0.746	16

Variable		CMI(mean)	Number of hospital
	Meishan	0.717	7
	Mianyang	0.767	28
	Nanchong	0.758	28
	Neijiang	0.763	15
	Panzhihua	0.724	10
	Suining	0.755	15
	Yaan	0.676	18
	Yibin	0.738	25
	Zigong	0.745	14
	Ziyang	0.826	7

Table 2. Summary results

Table 3. Hospital case-mix index by selected hospital characteristics

Table 4 reports results from ordinary least squares regressions. The first regression uses only physician human capital as independent variable. In with our expectation, one additional year of physicians' medical training in a hospital is associated with 0.088 increase in hospital case-mix index. This is consistent with primary findings in descriptive results. The second model includes prefectural-level city fixed effects to estimate impacts of physician. The main coefficient of interest is 0.70 (S.E. = 0.006), showing that the estimation of physician human capital is very similar with the model without any additional controls. One difference with previous model is that the R square significantly increased from 0.218 to 0.333, which implies relative contributions of more independent variables regarding local areas greatly augmented. This improves performance of our model specification, because local area fixed-effects is used to control patients sorting across hospitals that is expected to be a major confounding factor to estimates of human capital effects.

Table 4
Regression model results

CMI	(1)	(2)	(3)	(4)
	b/se	b/se	b/se	b/se
Physician human capital	0.088***	0.070***	0.070***	0.045***
	(0.009)	(0.006)	(0.013)	(0.015)
Physician experience			-0.000	-0.001
			(0.003)	(0.003)
Teaching hospital			0.059***	0.093***
			(0.016)	(0.017)
Government owned			-0.055***	-0.025
			(0.019)	(0.016)
Tertiary hospital			0.056***	0.052***
			(0.009)	(0.007)
Specialty hospital			-0.014	-0.032
			(0.022)	(0.025)
Occupancy rate			0.077**	0.032
			(0.034)	(0.026)
Outpatient per admission			-0.001**	-0.002**
			(0.001)	(0.001)
Urban residents insurance			0.052	0.014
			(0.044)	(0.054)
Employee insurance			0.010	-0.013
			(0.035)	(0.032)
Rural residents insurance			0.028	-0.014
			(0.025)	(0.025)
Proportion of internal medicine			0.034	0.056
			(0.035)	(0.035)

Notes: we correct the standard errors for clustering on city-level that is often seen as hospital referral regions in China

CMI	(1) b/se	(2) b/se	(3) b/se	(4) b/se
Proportion of OBG			-0.159*	-0.089
			(0.090)	(0.086)
TCM hospital service			-0.005	-0.020*
			(0.011)	(0.010)
Constant	0.390***	0.460***	0.424***	0.559***
	(0.045)	(0.022)	(0.098)	(0.099)
City fixed effects	N	Y	N	Y
N	435	435	435	435
ll	372.067	416.086	460.552	504.632
R2	0.218	0.333	0.520	0.608
bic	-731.497	-825.853	-829.974	-924.210
* p < 0.10 ** p < 0.05 *** p < 0.01				
Notes: we correct the standard errors for clustering on city-level that is often seen as hospital referral regions in China				

In the third model, we further added all of control variables, while the main result of physician human capital is identical to the model (2). For physicians' ability indicator as a confounding factor, we found no effects on hospital case-mix. In terms of hospital characteristics, teaching commitment, tertiary hospital, and outpatient per admission, are generally significant and in line with our expectation. For example, hospitals with approved teaching programs has an important effect on case-mix complexity, because teaching hospitals have advanced staff to diagnoses and treat complex illnesses, and complex cases provide valuable teaching opportunities. Similarly, tertiary hospitals also treated more patients with more complex condition. The R square in the third model is 0.520, compared to 0.333 in the second, suggesting these control variables have a considerable amount of contribution in determining variation of hospital case-mix.

The last column for dependent variable of hospital case-mix index includes all controls in Table 3 and city-level fixed effects. In this model specification, we considered that two confounding factors regarding to patients' sorting and physician ability have been controlled. The parameter estimated show that hospitals have higher level of physician human capital significantly have more serious case mix. In specific, when average medical school years increased by one, the hospital CMI increased by nearly 0.05. Meanwhile, there is little relationship with physicians' experience that is used to proxy their ability. By

controlling two potential confounding factors, we therefore obtained the robust positive effects of physician human capital on hospital case-mix.

Table 4. Regression model results

In the Fig. 3, we can draw a positive relationship between hospital case-mix index and physician human capital within a hospital measured by average year of medical training without controlling for any covariates. These patterns could arise through channels other than a causal effect of medical training on patients' case-mix complexity. As we have mentioned in the Methods, both patients' sorting across hospitals and physicians' ability instead of their schooling could be confounding factors. Therefore, the findings from Fig. 3 are strongly suggestive but not definitive evidence that human capital on case-mix index. Figure 4 further displays a binscatter plot of the relationship estimated in model 4 of Table 4. Specifically following Cattaneo (2019), we present binned scatterplots of physician human capital/hospital CMI using regression model with covariates set to mean values [7]. The figure still shows that an increase in physician human capital level corresponding to a significant rise in hospital case-mix complexity after controlling for hospital, patients, and local community characteristics. The effect size of human capital is particularly high at tertiary hospital level, suggesting that physicians in larger hospitals are even more important in determining hospitals' case-mix complexity.

Figure 4. Determinants of hospital case-mix by hospital level: binscatter

Discussion

The objectives of this study is to investigate the relationship between hospital case-mix and physician education mix, by exploiting a specific phenomenon of substantial variation in physician education mix in hospital that is originated from a multi-tiered medical education system. Based on results from our extended model, we find out a positive relationship between physician human capital and patient case-mix. In specific, the hospital CMI increased by nearly 0.05 when average years of medical training for physicians increased by one. In order to focus on the issues of medical staff and their patients, we will discuss its theoretical and practical implications from three dimensions as below.

Education mix

Hsieh and Tang first introduced the context and consequences of multi-tiered medical education system, in which one of the most important outcome is an education mix among medical staff [2]. Although the multi-tiered medical education system could launch a mass production of medical students at the same time, it also pays the price of low overall quality of physician and the mixed quality of physician. As we found in this study, the educational level of hospital physicians significantly accounts for a substantial part of variation in case-mix of hospital.

From the perspective of hospital, managing human resources for health in a facility often involves how to organise groups of staff with different specialty, skills, grades, qualifications and experience in order to

provide better care. Therefore, those definitions, like staff mix, specialty mix and skill mix are commonly issues discussed in previous literature [8–11]. For example, there has been a long-term focus on staff mix or staffing level. These "macro" studies often employ large-scale datasets, usually from multiple sites or even country-level [3, 12]. Researchers' interests generally focus on the relationship between human resources and outcomes of health or cost [13]. In addition, the definition of skill mix is often not so clear, but "micro" in general, and may cover a series of topics of skill mix [8, 14]. For instance, these topics may include skill substitution between physicians and nurses, delegation of different professional groups, cost and effectiveness of traditional practitioners (such as doctors who still practice complementary and alternative medicine in inner and remote areas), and some other relevant topics [15].

Studies at least partly regarding education mix are still few and limited, in contrast to other research in this field, such as specialty mix, skill mix or qualification mix. First, education mix previously often used in the nursing group [16, 17], because it is not common to achieve uniform quality standard in nurses' medical education or training. Second, studies concerning variation in physician education and its influences on healthcare can only pay attentions on the ranking of medical schools and the ranking of hospitals [18, 19], instead of fundamental differences in physicians' medical education, like secondary or tertiary medical education [2]. To the best of our knowledge, the issue of multi-tiered medical education still need more concerns across countries.

Overall, we have identified some literature evidences on heterogeneity in features of health workforce and its impacts on health care provision. While for some health care system, they still need to face the problems of physician education mix. Thus one of the most important contribution of our study is to measure the physician education mix across hospitals and further investigate its influences on health care provision, namely, the case-mix index.

Reasons for case-mix complexity variation

Before we discuss that physician group as one of the most important determinants of hospital case-mix, we need to give a view on reasons for case-mix variation. Reasons for patient case-mix in hospital are often complicated, mixed and dynamical, because hospital case-mix is an outcome of interaction between physician group and patient pool and their decision and choices.

Previous literature shows that reasons for CMI changes were attributed to (1) whether the real patients case-mix changed due to changes in patients' medical needs; (2) the completeness of DRGs coding, e.g. improvements of medical documentation regarding Comorbidity & Complication; (3) the upcoding or "DRG creep" refers to that physician recoding the cases in higher weight of DRG category without changes in hospital resources consumption [20]. Nevertheless, the association between case-mix and hospital accreditation category, hospital ownership, and other hospital features are also documented [21, 22].

Becker and Steinwald (1981) explicitly mentioned that they expected the characteristics of hospital's medical staff will affect case-mix complexity, however they had no direct information on medical staff,

which is a critical limitation in previous published studies [1]. Our study addressed this literature gap, and first discussed and examined the association between physician human capital and hospital's case-mix complexity by exploiting variation in hospital physicians' medical education.

Medical staff as a determinant of hospital case-mix

Previous studies regarding hospital case-mix implicitly assume that physicians are homogeneous, which is based on a fact that all developed countries have a unified standard medical education system. However, the medical education system greatly varied across countries that often resulted in heterogeneity in physician human capital. Arrow illustrated four key variables determining the physicians market in a classic health economics paper. Among these four factors, both quality of entering students and medical education programs are concerned with medical education system, and are strongly relevant to physician human capital [23]. As a consequence, both supply quantity and quality of physician human capital are of significantly importance in influencing health care market.

However, it is complicated to linking health workforce characteristics mix to health care dynamics [24]. Because we still need to discuss three causes for this striking relationship: (1) the casual effect of additional medical training; (2) patients' sorting across hospitals (or physicians); (3) physicians' ability bring about higher medical education and further generated higher CMI. For the relationship between these factors, we have presented in the Fig. 5 regarding physician education mix and other factors as determinants of hospital case-mix. According to our model specification, we have simply controlled both patient-level variables and physicians' ability or experience in confounding the regression model. Thus we may focus on and interpret the first reason for association between physician human capital and hospital case-mix.

While there are still two explanations with respect to the casual effect of higher medical education: One of possible explanation is that "good" doctor may have incentives to manage and treat cases with higher relative weights and thus promote CMI. Yet this may not be the case in China as the incentive structure for healthcare providers is inappropriate based on a review of evidences [25]. The other possible explanation is that those physician groups with lower human capital are more likely to manage case volume with lower CMI. Previous literature has shown that the hospitals and their doctors prefer to manage both case volume and case-mix complexity given capacity and budget constraints [26, 27].

This is the first study that investigating the physician human capital as one determinant of hospital case-mix. However, our study has at least two potential limitations. First, this is a cross-sectional model and a more rigorous model exploring causality may still be present; second, confounder from other unobservable hospital characteristics still exist. We also have plans to conduct further studies on (1) whether physician education mix or human capital variation influence health outcomes of patients? (2) what the role of the variation in physician human capital in determining health workers' compensation is?

Figure 5. Physician education mix and other factors as determinants of hospital case-mix

Conclusion

This paper first investigates the relationship between hospital physician education mix and patient case-mix using solid data from DRG system. In particular, we first present that hospitals with higher level of physician education mix are more likely to treat more serious case mix. Our investigation may inform researchers and policymakers of health workforce in at least two aspects: first, we need to pay more attention on the role of physician education mix, beyond topics such as staff mix, specialty mix and skill mix that are commonly issues discussed in previous literature; second, it is important to control for physician-level variation in education in future studies that used data from some unstandardized health care system. This study also contributes to current literature in two points: first, our paper addressed a limitation and extended the classical framework of Becker and Steinwald, in which they first examined the determinants of hospital case-mix complexity, but they missed the role of educational level of physicians in hospital; second, we further developed an idea about multi-tiered medical education and its impacts on health care market from Hsieh and Tang's paper.

Declarations

Competing interests:

No competing interests.

Availability of data and material:

The data is not available for this project.

Consent for publication:

Not applicable.

Ethics approval and consent to participate:

Not applicable.

Authors' contributions:

T. conceived the idea of this project, H.Z. and G.L. designed the study design; J.J. applied for the dataset; C.T. and H.Z. further analysed the data and wrote the paper.

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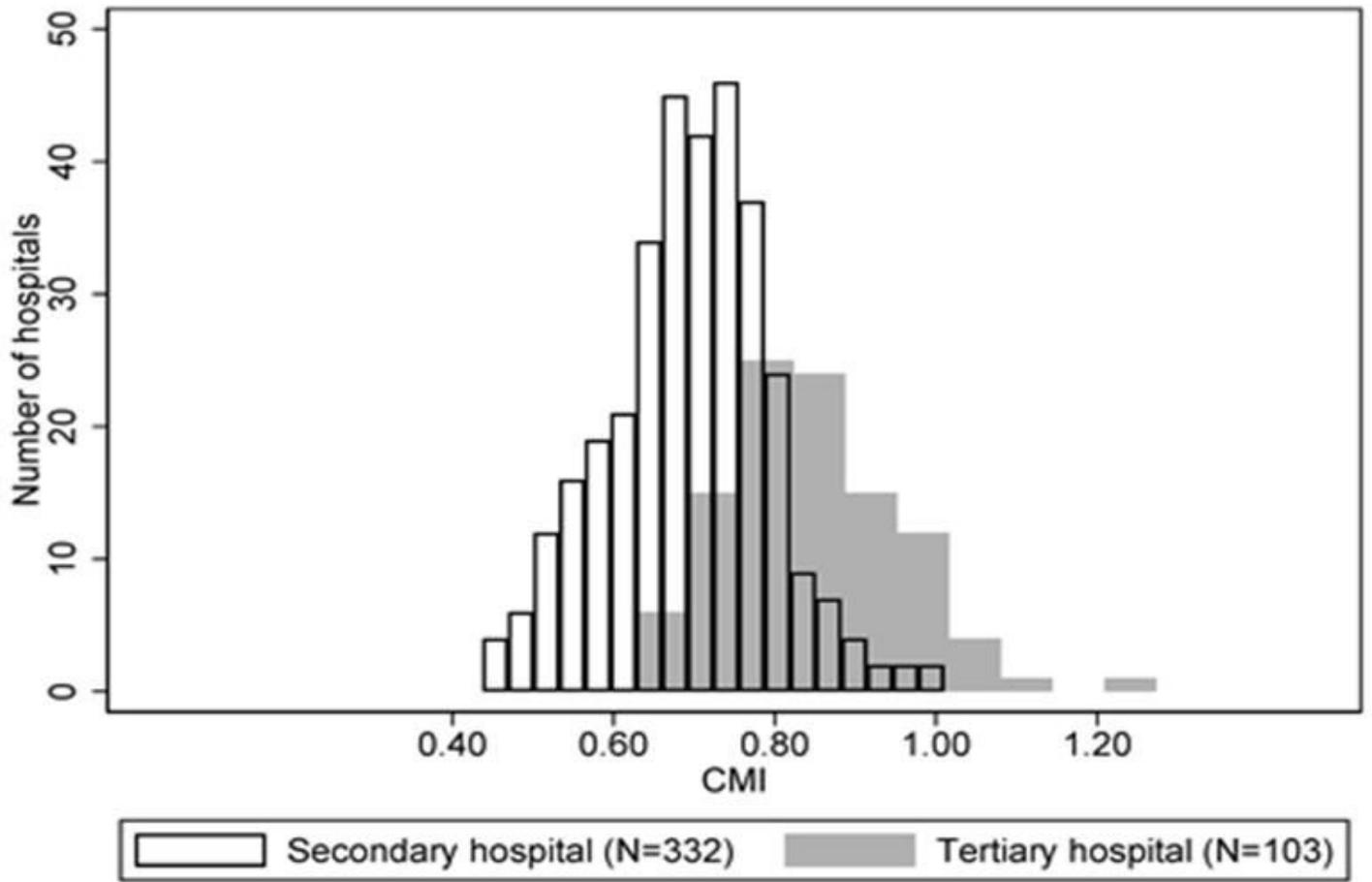
Figures

Figure 1
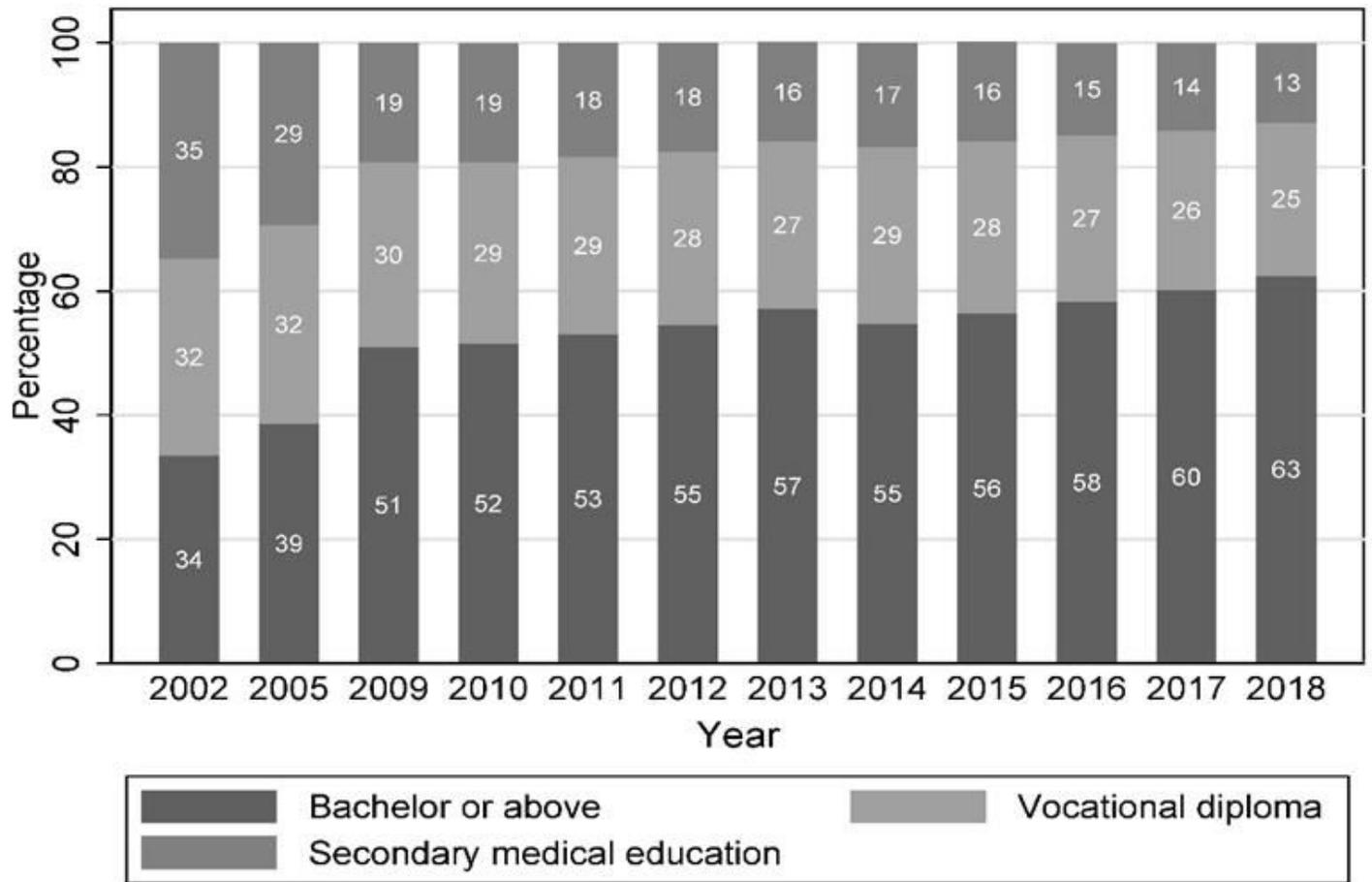
CMI distribution across hospitals

Figure 2

Physicians by Education Level in China, 2002-2018 Sources: Health Statistical Yearbook of China (various years). Notes: 1. Data for 2003-2004 and 2006-2008 are not available. 2. Bachelor or above refers to the category that doctors have educational achievement high than a bachelor degree, including bachelor, master and doctorate degrees; Vocational diploma refers to a junior college degree (Zhuan Ke) or a junior tertiary education, generally including 3-years post-high-school education; Secondary vocational diploma or below refers to both secondary vocational diploma (Zhong Zhuan) and high school education.
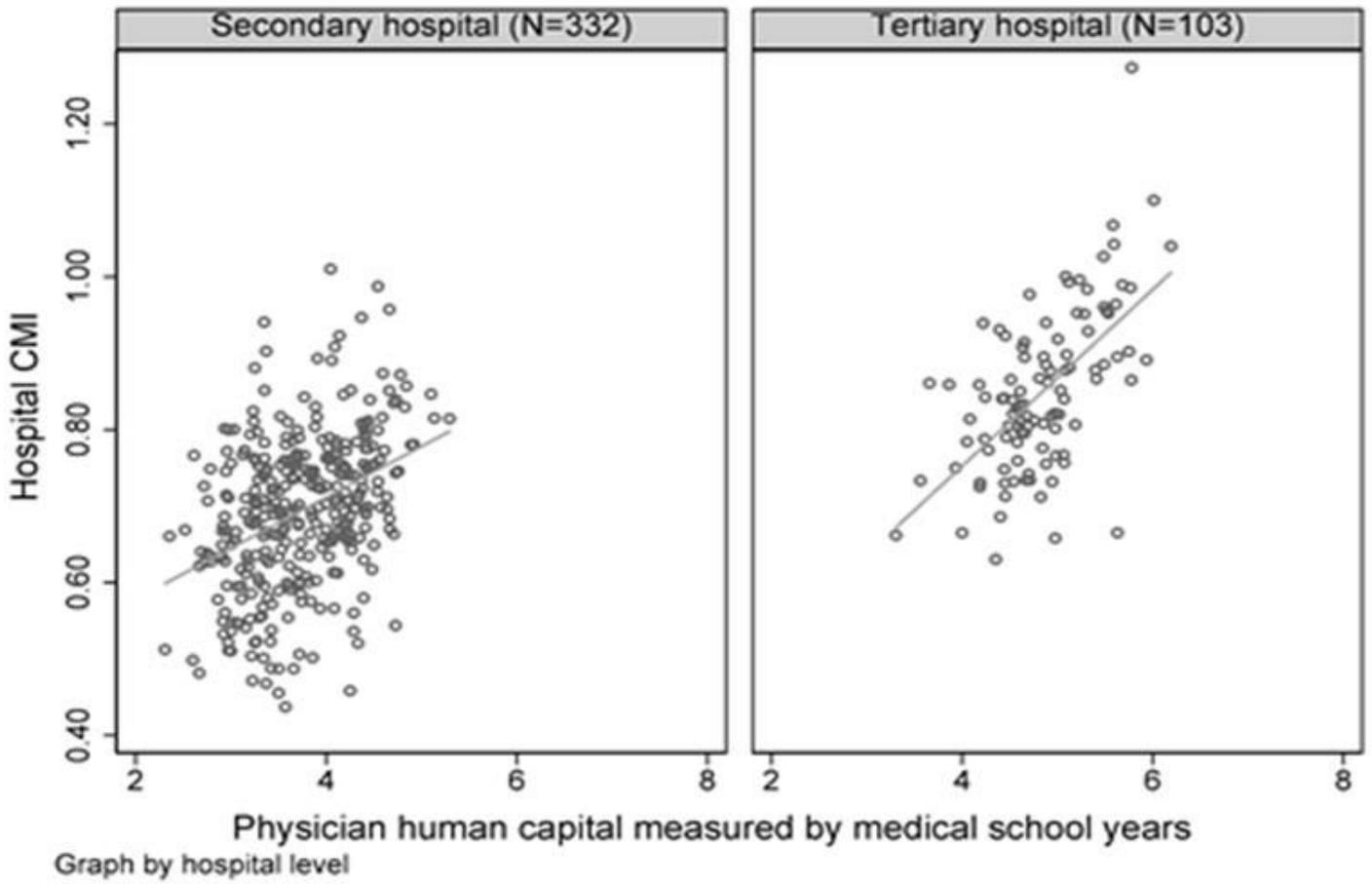
Figure 3

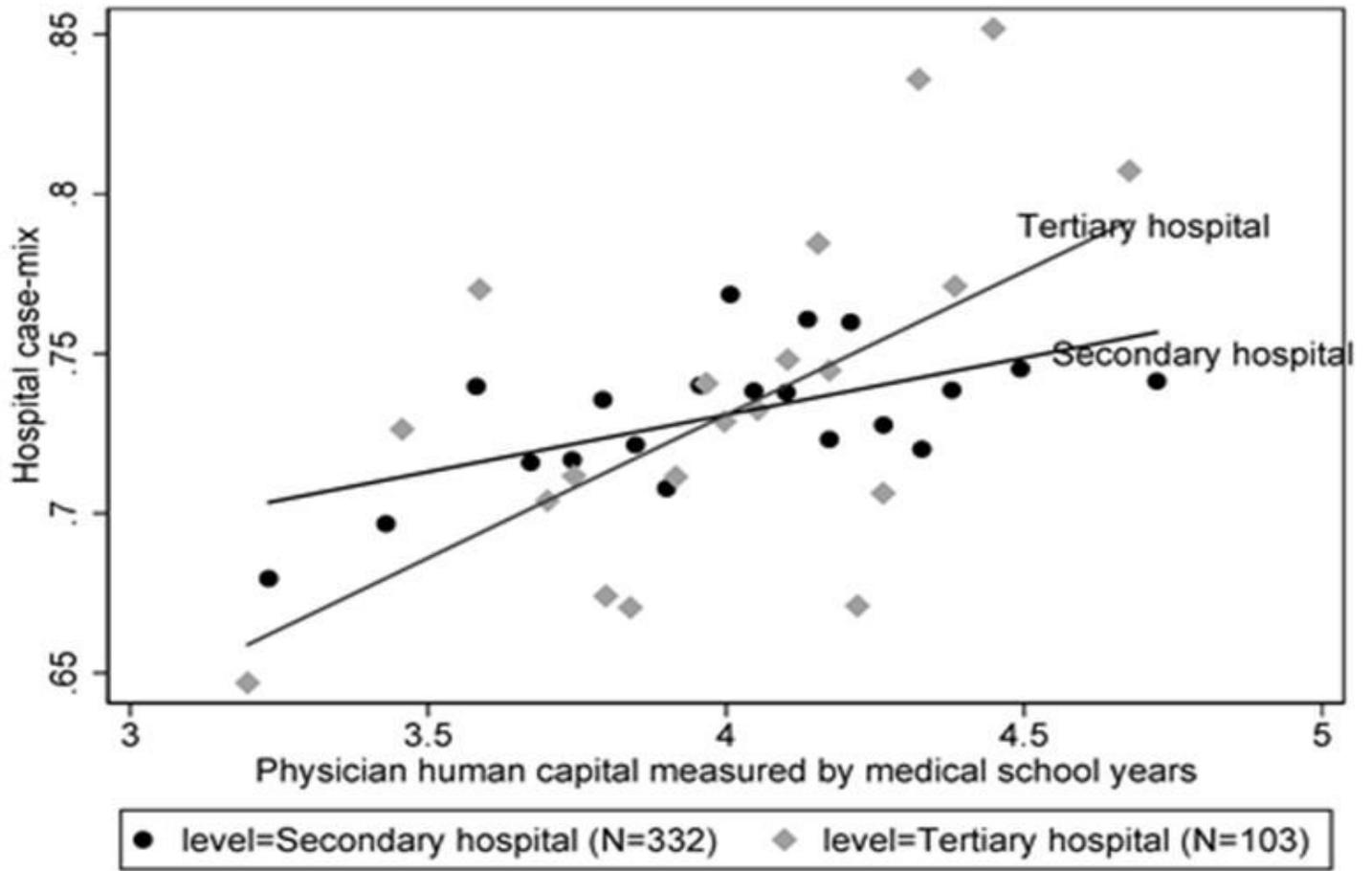Distribution of hospital case-mix index by physician human capital

Figure 4

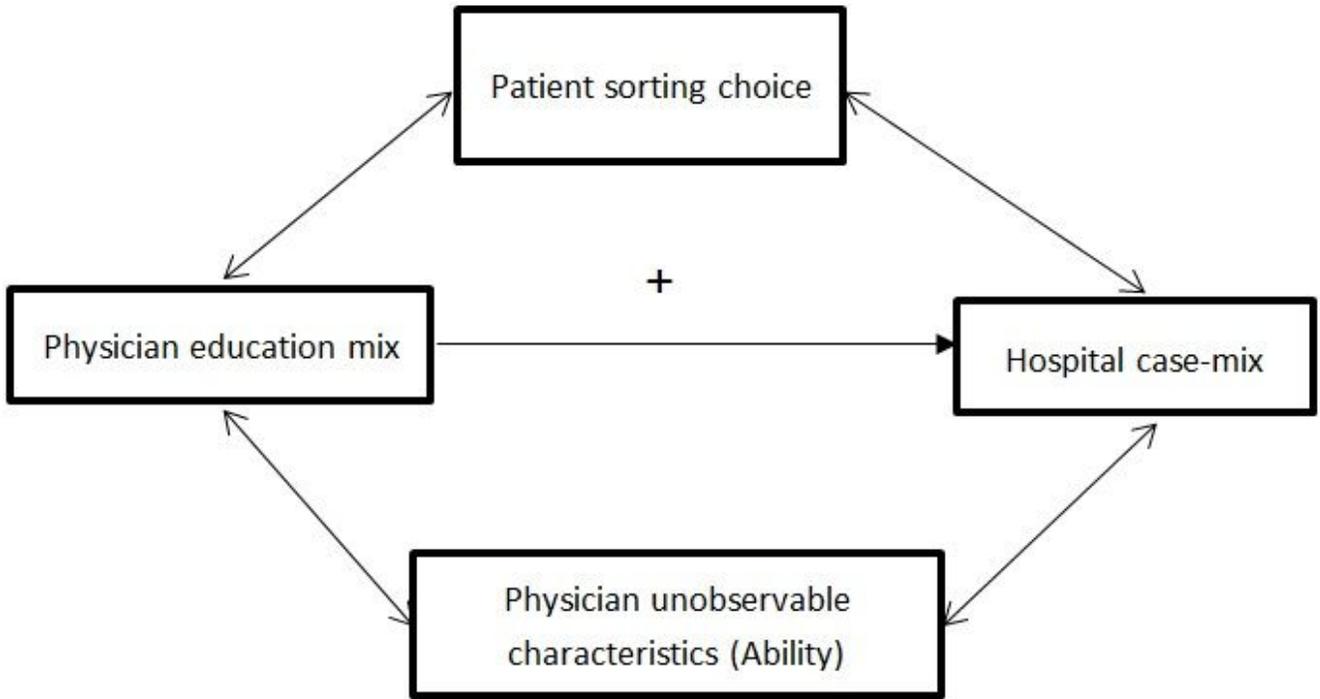Physician human capital as a determinant of hospital case-mix by hospital level: binscatter

Figure 5

Physician education mix and other factors as determinants of hospital case-mix