Economies of scale and scope in Chinese hospitals: A case study using panel data from Henan, China

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Abstract: From 2008 to 2011, the numbers of beds and medical workers in Chinese public hospitals are increasing substantially, resulting in growing scale of such hospitals. By using weighted least squares (WLS) method and seemingly unrelated regression (SUR) method respectively, this article estimates a multi-output cost function based in 4-years balanced panel data samples, correlation between individual effects and observable regressors of sample hospitals is permitted in the model. It is shown by WLS results that economy of scale differs greatly among hospitals of different types and in different regions; SUR results show that hospitals at lower levels are more obvious in terms of economy of scale and economy of scale among hospitals in different regions does not vary much. With the growth of scale, economy of scale tends to decrease due to influence of non-observable factors like management ability. This article also indicates that attentions shall be paid to the influence of non-observable factors on parameters estimation of hospital cost function.

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1. Introduction

Public hospitals play a dominating role in the medial service system in China. Up to 2010, there were 14,051 public hospitals in the country, with 3.01 million beds and 3.09 million medical workers, accounting for 66%, 90% and 89% of total hospitals, beds and medical workers respectively in China. Outpatient and inpatient services from public hospitals account for over 90% of such services across the country. There have been many doubts from the public recently about the economic operation of public hospitals, such as weakening of public welfare, rapid growth of cost, over-reliance on market and over-concentration of medical resources in big cities.

It is noticeable that, with the occurrence of the phenomena mentioned above, the numbers of beds and medical workers in public hospitals are increasing substantially, resulting in growing scale of such hospitals. Statistics show that the quantity of large public hospitals with over 800 beds in China increased from 71 in year 2000 to 498 in year 2009. It is noticeable that the increase is still accelerating and now there are huge hospitals with over 5,000 beds. These phenomena present two economic questions, namely, is it certain that excessive scale of medical institutions will lead to growth of cost? What is an effective scale or proper scale?

Most of previous studies on hospital scale and cost set up models with cost function method and made judgments by estimating parameters and calculating such indexes as economy of scale, economy of scope and marginal cost. Earlier studies focused on "behavior" cost function(R.G. Evans, 1971), resulting in doubt due to mono-specification and lack of theoretical support. Later, "flexible" function (Macfadden, 1978; Cowing & Hotman, 1983; Conrad & Strouss, 1983) was employed, whose measurements of multi- input and multi-output complied more with economic theories. "Hybrid" flexible function (Grennemann, 1986; Breyer, 1987; Vita, 1990; Carey, 1997; Weaver, 2004) further intensified the measurements of input and output prices, refined related classifications, improved model setting and parameter calculation. There are two problems to which we shall pay attention to: first, the vast majority of these cost function models used cross-section data (excluding Carey, 1997) and they rarely used panel data. Second, there were few studies that studied hospitals in developing countries and almost none of them were about public hospitals in China.

Adopting cross-section data to estimate cost function of hospitals faces an avoidable problem, namely, systematic differences between individuals that are hard to be noticed, such as quality, management ability and case mix index among hospitals. It is highly possible that these differences (generally called unobservable effect), if related to the explanatory variable in cost function, may lead to the problem of omitted variable bias. Using OLS and other methods to estimate parameters under this condition will lead to errors that are inconsistent. A good method for this problem is to employ balanced panel data and systematic estimation method to deal with omitted variables and contemporaneous correlative issues occurred in cost function estimation. This article intends to find some clues for the examination of hospital cost and cost theory by establishing a cost function model with 4- years balanced panel data of 377 hospitals in Henan Province in China, by carrying out a case study on economy of scale, economy of scope and marginal cost of public hospitals in China with the method of parameter estimation.

Methods

It is shown by basic price theory that, under condition of short-term balance, the curves of marginal cost (MC) and average cost (AC) are generally U-shaped: initially, MC and AC drop with the increase of output, but both of them rise after the output reaches a certain level. As a priori condition, in case the curves of MC and AC are U-shaped, the function form shall be in quadratic form and the total cost function shall be in cubic form. In case the economic meaning of cost function of hospital does not change essentially, the economic theoretical expectations shall be satisfied. The following equation is proposed based on conditions above:

$$TC = Pe^{a_0+a_1 beds}e^{f+a+u} \qquad (1)$$

Then,

$$\ln TC - \ln P = a_0 + a_1 beds + f + d + u \qquad (2)$$

Where:

$$f = A + a_1 inp + a_2 inp^2 + a_3 inp^3 + b_1 outp + b_2 outp^2 + b_3 outp^3 + \sum_{i=1}^{k} c_k X_k \qquad (3)$$

TC stands for total cost of hospital, beds stands for number of hospital beds, inpatients is hospitalized patients, outp stands for number of outpatients and X_k is the explanatory variable influencing hospital cost.

"Beds" is regarded as the proxy variable for hospital scale because hospitals can not adjust the number of them in a short term. Empirical studies show that when the coefficient of beds is positive and statistically significant, the hospitals were not at their long run equilibrium.

Integrating (1), (2) and (3) leads to a cost function in cubic form as the following:

$$\ln TC = a_0 + a_1 beds + a_2 workers + b_1 \ln P + c_{11} inp + c_{21} inp^2 + c_{31} inp^3$$
$$+ c_{12} outp + c_{22} outp^2 + c_{32} outp^3 + d_{l*2} inp * outp + \sum_{i=1}^{k} e_k X_k \qquad (4)$$

Equation (4) contains two output variables, inpatients and outpatients, one scale variable, beds, and a series of proxy variables employed to describe hospital level and the social and economic condition it is in to estimate the parameters for calculations of MC, economy of scale and economy of scope. The formula for calculating MC is as the following:

$$MC_i = TC(c_{1i} + 2c_{2i}Y_i + 3c_{3i}Y^2_i + d_{l*2}Y_j) \qquad (5)$$

Where, Y_i stands for output variable, Y_i stands for outpatients and Yj represents inpatients. Studies of Baumol (1976), Panzar and Willig (1977) have shown that it is significantly meaningful to find out whether economy of scale and economy of scope exist in public institutions, especially those that are price-fixing. These studies also prove that the process for measuring economy of scale of multi-output institutions is much more complicated than that for institutions with single output.

Vita (1990), Barnum and Kuntzin (1993) proposed that under short-term balanced condition, that is, when output mix and the scale variable of beds do not change, the main reason for output growth is the increasing investment of variable cost, then the equation for short-term economy of scale should be:

$$S = \frac{TC}{\sum_{i=1}^{k} MC_i Y_i} = \frac{1}{\sum_{i=1}^{k} e_{CY_i}} \qquad (6)$$

Where, MC_i represents the MC of output i, $e_{CY_i} = 抖\ln C / \ \ln Y_i$ stands for the elasticity of output i on cost.

In the long run, output increases with the growth of beds and patients, and part of the growth should attribute to change of scale, which is called economy of scale (EOS), whose formula is as follows:

$$EOS = \frac{1-\sigma_{TC,beds}}{\sum_{i=1}^{k} \sigma_{TC,Y_i}} \qquad (7)$$

Where, $\sigma_{a,b}$ stands for the elasticity of a upon b. In case EOS>1, return to scale is increasing gradually, indicating the output is not at the best scale and MC is higher than AC; when EOS =1, return to scale is unchanged; when EOS <1, return to scale is decreasing gradually, signifying the output level is excessive.

Study of economy of scope is mainly purposed to test output combination is effective, such as whether outpatient and inpatient service shall be provided in a combined way. Barnum and Kuntzin (1993) proposed a formula for economy of scope as the following:

$$Scope = \frac{TC(Y_s) + TC(Y_{n-s}) - TC(Y)}{TC(Y)} \qquad (8)$$

Where, Y_s and Y_n stand for outputs s and n of the institution respectively.

Carey (1997) and Weaver (2004) applied the methods to set-up of cost function model of hospitals. This study uses the formula for economy of scale as follows with reference to their method.

$$S=\frac{1}{\sum_{i=1}^{2} Y_i(c_{1i}+2c_{2i}Y_i+3c_{3i}Y^2{}_i+d_{1*2}Y_j)} \quad (9)$$

$$EOS=\frac{1-a_1 beds}{\sum_{i=1}^{2} Y_i(c_{1i}+2c_{2i}Y_i+3c_{3i}Y^2{}_i+d_{1*2}Y_j)} \quad (10)$$

The formula for economy of scope is as the following:

$$SCOPE=\frac{-2*d_{1*2}inp*outp}{\sum_{i=1}^{2} Y_i(c_{1i}+2c_{2i}Y_i+3c_{3i}Y^2{}_i+d_{1*2}Y_j)} \quad (11)$$

SCOPE>0 means it is more effective to provide outpatient and inpatient services in a combined way. SCOPE<0 signifies the services shall be offered separately. In this study, the coefficient of d_{1*2} in formula (4) decides whether economy of scope exists. When the coefficient is negative, there is economy of scope. When it is positive, there is no economy of scope.

Data

Data for this study are mainly from financial statements of health department in Henan, a central province in China with a population of about 100 million. Like in other provinces, public hospitals in Henan are the backbone in terms medical service in the province. In 2012, numbers of beds and workers of such hospitals in Henan accounted for 93% and 82% of the total respectively, accounting for 69% and 95% respectively for total outpatient service and inpatient service across the province. 613 out of 915 public hospitals in Henan are run by governmental departments. This study uses data of 377 comprehensive and special hospitals from 2008 to 2011 and there are 1,508 sample observation values.

Total variable cost is the dependent variable in this study. According to requirements for hospital cost examination in China, total cost includes personnel cost, medical material cost, drug cost, management cost and depreciation cost of fixed assets, excluding capital expenditure.

Empirical studies show that a key factor for cost function is the selection of price variable. Most previous studies used personnel cost as the price variable for hospital cost, which brings about a problem difficult to handle: Price variable and other explanatory variables are highly correlated and these correlations are difficult to deal with. For instance, personnel cost is also high if the hospital has many beds. Getting ideas from Carey (1997), the rate between the average personnel cost in hospital and average salary for workers in local state-owned institutions is figured out to set up the salary index so as to avoid possible multicollinearity between the price variable and other explanatory variables in the model.

Number of beds is chosen as the variable to show scale difference of hospitals in this study. Generally, a larger hospital has more beds and workers and higher cost for operation. The scales of the sample hospitals in our study exhibit considerable variation. For example ,the cost for operation of the largest hospital with 4,615 beds was over RMB 3.16 billion yuan in 2011.

Several explanatory variables like outpatients, discharged patients and occupied beds were combined when output variables were considered. The study shows that, when the rate of bed use is high, the combination of outpatients and inpatients performed better than the combination of outpatients and inpatient bed days. Occupied bed days and number of beds have a higher correlation, which is a result similar to that of the study by Weaver (2004). The Pearson correlation between the former combination and the latter one are 98.5 and 81 respectively.

This study encountered some trouble in calculating the index for disease condition. As China is not practicing a full-scale classified diagnosis and treatment system, public hospitals transfer patients to higher level hospitals only when the lower level hospitals can not satisfy technical requirements. The result of this practice is that the case mix index for higher level hospitals to receive patients is not obviously lower than that for lower level hospitals. In fact, entity complexity indexes (ECI) of sample institutions were calculated in this study. The result showed that the ECI of most level-2 hospitals was higher than that of level-3 hospitals, which was an unsatisfactory result. The ECT of the second biggest hospital in the samples was 0.533 in 2010, ranking the 7th in eight of the samples whose ECT results have been calculated. That was why the cast mix index of the sample hospitals was calculated in this study, which was a method adopted in the study by Weaver (2004). The formula is as the following:

$$Index_i=ALOS_i(OCC_i/OCC_s)$$

Where, ALOSi is the average hospitalization days for hospital i, OCCi is the rate of bed use and OCCs is the average admission rate of the sample hospitals.

Many models of cost function of hospital evaluated market concentration into the model as a control variable. Studies by Robinson and Luft (1985) and White (1987) have shown hospital cost is higher in areas where concentration of medical market is high because non-price factor and quality competitions are fiercer. The index for market concentration is not included in this study for two reasons. First, public hospitals have a monopoly position in Henan because the largest medical institution in an administrative area is always a public hospital run by the government. Second, public hospitals follow prices fixed by the government, which differ very little across the province.

At last, the study included a series of dummy variables that are divided into two classifications: The first type includes those that reflect hospital location. Generally, cost of city hospitals is higher than that of county hospitals. Hospitals are divided into general hospitals and special hospitals so as to tell their cost difference in both cities and counties. The second type includes those that reflect influence of economic development level upon hospital cost. In this study, 18 city-level administrations are divided into five levels of regions (region level-1 is the most advanced) according to their GDP ranking.

Variables included in the model are listed in Table-1, among which cost variable has been deflated to 2008 RMB by making use of CPI.

Table 1.Descriptive Statistics of Variables

	2008	2009	2010	2011
COST(0000,RMB)	5289	6707	8039	9896
	(10018.14)	(14020.53)	(17235.71)	(22289.92)
WAGE INDEX	1.18	1.17	1.18	1.22
	(0.47)	(0.46)	(0.46)	(0.54)
BEDS	291.70	327.42	361.75	392.30
	(301.01)	(361.10)	(410.15)	(452.83)
WORKERS	390	413	445	480
	354	390	456	487
Inpatients0000	0.95	1.08	1.21	1.36
	(0.99)	(1.21)	(1.44)	(1.73)
Outpatients0000	14.66	15.56	16.84	18.41
	(15.38)	(17.16)	(19.80)	(22.81)
Case mix index	7.21	7.31	7.74	8.33
	(4.14)	(4.06)	(4.25)	(4.23)
Urban	0.27	0.27	0.27	0.27
	(0.44)	(0.44)	(0.44)	(0.44)
Urban spcialty dummy	0.15	0.15	0.15	0.15
	(0.36)	(0.36)	(0.36)	(0.36)
County dummy	0.29	0.29	0.29	0.29
	(0.45)	(0.45)	(0.45)	(0.45)
County specialty dummy	0.29	0.29	0.29	0.29
	(0.46)	(0.46)	(0.46)	(0.46)
_1ST area dummy	0.18	0.18	0.18	0.18
	(0.39)	(0.39)	(0.39)	(0.39)
_2ND area dummy	0.18	0.18	0.18	0.18
	(0.39)	(0.39)	(0.39)	(0.39)
_3RD area dummy	0.22	0.22	0.22	0.22
	(0.41)	(0.41)	(0.41)	(0.41)
_4TH area dummy	0.19	0.19	0.19	0.19
	(0.40)	(0.40)	(0.40)	(0.40)
_5TH area dummy	0.23	0.23	0.23	0.23
	(0.42)	(0.42)	(0.42)	(0.42)
N=377				

* Standard deviation in parentheses.

Estimation

Firstly, Eviews (version 7.2) was adopted to estimate cross-section data of equation (4) by Ordinary Least Squares (OLS). The Durbin-Watson stat (DB) values for the estimates from 2008 to 2011 were 1.85, 1.99, 2 and 2.08 respectively, indicating no auto-correlation problems. Test for heteroscedasticity upon the estimates adopted Breusch-Pagan-Godfrey and White methods, the F-statistics for the former method were 2.89, 4.05, 3.38 and 3.31 respectively, rejecting hypothesis of homoscedasticity at 5% critical level; results by the second methods were 1.21, 1.21, 1.10 and 0.89, not rejecting hypothesis of homoscedasticity at 5% critical level. Heteroscedasticity, which does not affect impartiality of the parameter for estimation, increases variance of the parameter. In order to make the research more reliable, weighted least squares estimation (WLS) was adopted to re-estimate the parameters with the reciprocal of variance as the weight, though the method of White does not turn down hypothesis of homoscedasticity. The results were quite effective: t values of all parameters were smaller and significant at 1% critical level; statistics by Durbin-Watson stat did not change much; weighted R2 increased to about 0.99 from 0.886, 0.883, 0.891 and 0.887 respectively; the issue of heteroscedasticity was settled properly and estimation results of the model were optimized. The results by GLS method are as shown in Table-2.

Table 2. Results of WLS and Fixed effects Model

Viariables	OLS				Fixed effects
	2008	2009	2010	2011	
Intercept	15.2943	15.4864	15.4572	15.4963	15.51681
	(1.09E-02)	(9.61E-03)	(1.49E-02)	(9.32E-03)	(2.81E-02)
Inpatient	1.2806	0.7202	0.9267	0.6350	0.50543
	(2.29E-02)	(2.25E-02)	(1.74E-02)	(1.05E-02)	(4.44E-02)
Inpatientsquared	-0.4062	-0.1034	-0.1683	-0.0786	-0.06081
	(9.41E-03)	(7.28E-03)	(4.46E-03)	(2.76E-03)	(1.08E-02)
Inpatient cubed	0.0491	0.0141	0.0087	0.0016	0.00259
	(1.91E-03)	(3.06E-04)	(1.74E-04)	(1.41E-04)	(5.46E-04)
Outpatients	0.0363	0.0482	0.0357	0.0388	0.03691
	(1.20E-03)	(1.35E-03)	(1.15E-03)	(6.99E-04)	(3.68E-03)
Outpatients squared	-0.0003	-0.0004	-0.0004	-0.0006	-0.00042
	(4.29E-05)	(3.56E-05)	(2.69E-05)	(2.49E-05)	(8.54E-05)
Outpatients cubed	3.02E-06	4.92E-06	4.10E-06	3.82E-06	2.30E-06
	(2.74E-07)	(1.44E-07)	(1.17E-07)	(1.05E-07)	(2.97E-07)
Inp*Outp	-0.0135	-0.0181	-0.0103	-0.0065	-0.00559
	(6.80E-04)	(6.85E-04)	(6.89E-04)	(3.00E-04)	(1.26E-03)
BEDS	2.47E-04	2.30E-04	1.63E-04	4.05E-04	3.47E-04
	(3.51E-05)	(2.24E-05)	(4.08E-05)	(2.30E-05)	(1.10E-04)
WORKERS	0.0018	0.0018	0.0016	0.0013	0.00159
	(2.78E-05)	(3.18E-05)	(3.24E-05)	(2.07E-05)	(9.18E-05)
Case mix index	0.0062	0.0136	0.0222	0.0259	0.01329
	(8.30E-04)	(8.23E-04)	(1.13E-03)	(1.02E-03)	(3.23E-03)
Urban dummy	0.1733	0.1494	0.2229	0.1972	-
	(8.94E-03)	(8.92E-03)	(1.10E-02)	(7.14E-03)	-
County dummy	0.1280	0.1963	0.1714	0.1711	-
	(1.17E-02)	(1.03E-02)	(3.47E-03)	(7.36E-03)	-
Urban spcialty dummy	0.1332	0.0530	0.1268	0.0986	-
	(9.27E-03)	(1.09E-02)	(9.51E-03)	(5.69E-03)	-
_2ND area dummy	-0.1934	-0.1900	-0.2285	-0.1282	-
	(1.18E-02)	(1.13E-02)	(1.24E-02)	(8.15E-03)	-
_3RD area dummy	-0.2643	-0.1735	-0.1998	-0.0538	-
	(1.04E-02)	(1.01E-02)	(1.12E-02)	(8.54E-03)	-
_4TH area dummy	-0.2903	-0.2149	-0.1459	-0.0677	-
	(1.03E-02)	(7.58E-03)	(1.27E-02)	(7.85E-03)	-
_5TH area dummy	-0.2183	-0.2742	-0.2018	-0.1298	-
	(1.03E-02)	(9.00E-03)	(1.30E-02)	(8.53E-03)	-
Weighted R^2	9.99E-01	9.99E-01	9.98E-01	1.00E+00	-
Unweighted R^2	0.886	0.883	0.891	0.886	0.850

* Standard deviation in parentheses.

As what has been mentioned before, the difficulty in estimation of cost function of hospital lies in treatment of non-observable effect. Estimated parameters may be biased or invalid if non-observable factors such as management ability and quality are not separated from explanatory variables. Studies by Gujiarati and Wooldridge have shown that panel data have both time and space dimensions. Panel data can provide data of more information value by mixing time sequence and cross-section data; the variance and effectiveness of variables can be improved by increasing their variability and weakening co-linearity among variables. Estimation methods for panel data can be classified into two types: fixed effect method and random effect method. The former can estimate differences among cross-section units but it can neither handle time-invariat variables, particularly some externally-generated dummy variables, nor handle cross-section unit data beyond the samples. The latter regards differences among cross-section units as a distribution and can handle data of cross-section units beyond the samples. But the precondition is that non-observable effect shall have no relation with observable control variables. In the case of cost function estimation of hospitals, this hypothesis demands that non-observable factors like management ability and quality have no relation with variables like average hospitalization days, which is obviously unreasonable.

As a group of balanced panel data of four years was available, the next job in this study was to find a proper method to estimate the data. The estimation had two purposes: guaranteeing the unbiasedness and effectiveness of estimated parameters by separating influence of such non-observable factors like management ability and quality on the model; guaranteeing robustness in the calculation of economy of scale and economy of scope in comparison with WLS estimated results. Empirical studies have shown that it is highly possible that non-observable factors such as management ability and quality are correlated with observable control variables. The method of Hausman test did a hypothesis test on variables included in the model. The result (Chi-square statistic: 87.1) rejected at 1% critical level the hypothesis that random effect model shall be adopted, showing that fixed effect model for parameter estimation shall be used in this study. In order to compare with WLS results, estimation results of fixed effect model are listed in Table-3. Fixed effect model gets rid of the highly impossible hypothesis that non-observable effect is not correlated with explanatory variables, but it demands to estimate parameters as many as the sample numbers, which is hard to deal with even for panel data with large samples. Chamberlain (1982, 1984) and Mundlak (1978) suggested an alternative, which was used by Carey (1997) to estimate cost function of 1,733 hospitals in America from 1987 to 1991.

Table 3. Results of SUR Model

Viariables	SUR			
	2008	2009	2010	2011
Intercept	15.255	15.379	15.470	15.624
	(0.044)	(0.042)	(0.043)	(0.045)
Inpatient				
2008	0.391	-0.055	-0.143	-0.236
	(0.060)	(0.025)	(0.039)	(0.040)
2009	0.054	0.457	-0.001	-0.025
	(0.030)	(0.057)	(0.034)	(0.040)
2010	-0.080	0.006	0.537	-0.008
	(0.042)	(0.031)	(0.060)	(0.035)
2011	-0.094	-0.079	-0.033	0.565
	(0.032)	(0.026)	(0.025)	(0.062)
Inp squared	-0.066	-0.084	-0.091	-0.090
	(0.015)	(0.014)	(0.015)	(0.015)
Inp cubed	2.30E-03	2.81E-03	2.99E-03	2.55E-03
	(0.001)	(0.001)	(0.001)	(0.001)
Outpatient				
2008	0.032	-0.001	-0.002	-0.004
	(0.004)	(0.002)	(0.002)	(0.002)
2009	-0.002	0.030	0.003	-0.001
	(0.002)	(0.004)	(0.002)	(0.003)
2010	0.002	0.003	0.030	0.003
	(0.002)	(0.002)	(0.004)	(0.002)
2011	0.001	-0.001	0.000	0.034
	(0.002)	(0.001)	(0.001)	(0.005)
Outp squared	-4.55E-04	-4.31E-04	-4.15E-04	-4.95E-04
	(8.53E-05)	(8.15E-05)	(8.50E-05)	(8.77E-05)
Outp cubed	1.97E-06	1.80E-06	1.91E-06	2.27E-06
	(3.09E-07)	(2.96E-07)	(3.08E-07)	(3.18E-07)
Inp*Outp	-0.003	-0.002	-0.003	-0.002
	(0.001)	(0.001)	(0.001)	(0.002)
BEDS				
2008	1.85E-04	-5.11E-05	-2.29E-04	-3.87E-04
	(2.06E-04)	(1.98E-04)	(2.07E-04)	(2.13E-04)
2009	5.88E-04	6.33E-04	3.16E-04	5.42E-04
	(2.48E-04)	(2.36E-04)	(2.47E-04)	(2.55E-04)
2010	-1.89E-04	-1.16E-04	3.18E-04	-3.03E-04
	(2.20E-04)	(2.10E-04)	(2.17E-04)	(2.25E-04)
2011	5.91E-04	5.86E-04	5.36E-04	1.14E-03
	(1.60E-04)	(1.52E-04)	(1.59E-04)	(1.59E-04)
WORKERS	1.25E-03	1.25E-03	1.25E-03	1.28E-03

	(9.58E-05)	(9.13E-05)	(9.50E-05)	(9.82E-05)
CMI				
2008	0.002	-0.005	-0.006	-0.009
	(0.004)	(0.004)	(0.004)	(0.004)
2009	-0.005	-0.001	-0.004	-0.003
	(0.004)	(0.004)	(0.004)	(0.004)
2010	0.009	0.007	0.016	0.012
	(0.004)	(0.004)	(0.004)	(0.004)
2011	0.022	0.029	0.026	0.033
	(0.004)	(0.004)	(0.004)	(0.004)
City	0.210	0.226	0.259	0.204
	(0.040)	(0.038)	(0.039)	(0.041)
COUNTY	0.492	0.501	0.524	0.464
	(0.040)	(0.038)	(0.040)	(0.041)
Urban Spe	0.189	0.212	0.235	0.183
	(0.039)	(0.037)	(0.038)	(0.040)
_2ND area	-0.161	-0.135	-0.171	-0.150
	(0.040)	(0.038)	(0.039)	(0.041)
_3RD area	-0.195	-0.152	-0.158	-0.160
	(0.038)	(0.036)	(0.037)	(0.039)
_4TH area	-0.254	-0.173	-0.172	-0.236
	(0.039)	(0.037)	(0.039)	(0.040)
_5TH area	-0.225	-0.190	-0.170	-0.162
	(0.038)	(0.036)	(0.038)	(0.039)
* Standard deviation in parentheses.				

A method similar to Carey (1997) was employed in the later part of this study, and some adjustments were completed to turn out a model as the following:

$$\ln(TC_{it}/P_{it}) = a + \sum_{t=2008}^{2011}(a_1 beds_{it} + c_{11} inp_{it} + c_{12} outp_{it} + e_1 cmi_{it}) + a_2 workers_{it} + c_{21} inp_{it}^{2} + c_{31} inp_{it}^{3} + c_{22} outp_{it}^{2}$$

$$+ c_{32} outp_{it}^{3} + d_{1*2} inp_{it} * outp_{it} + \sum_{i=2}^{k} e_k X_{kit}$$

The numbers of inpatients and outpatients in the four years were included into the model to get the estimated parameter for calculating values of economy of scale and economy of scope; variables of beds and cmi were also included to measure the influence on cost by non-observable factors such as management ability and quality1. All these have been reflected by the method of Carey (1997). The difference was that we used SUR in the estimation package in Eviews 7.2 to get the results and list them in Table-3. SUR (Seemingly Unrelated Regression) method was also adopted for equation (12) to provide four parameters, namely, beds, cmi, inpatients and outpatients, for each equation (annual) to indicate the parameters are likewise overidentified in the system estimation. Minimum distance estimation (MDE) method was employed to get rid of redundancy parameters, the results are listed in Table-4.

Table 4.Results of MDE

Viariables	MDE			
	2008	2009	2010	2011
C11(Inpatients)	0.428	0.496	0.575	0.639
	(0.035)	(0.021)	(0.034)	(0.056)
C12(Outpatients)	0.032	0.030	0.029	0.034
	(0.001)	(0.001)	(0.001)	(0.001)
X2(20)=56.62				

Estimated parameters of outpatients and inpatients for each year obtained by WLS and SUR were figured out by means of equation (4) and equation (12). The parameters were put into equations (9), (10) and (11) to get values of economy of scale and economy of scope of hospitals in Henan from 2008 to 2011. In this process, the dependant variables, which were in logarithmic form, needed to be changed into constants to complete the computation. The method employed in this research were from Duan (1983), namely, smearing estimate. The results are as shown in Table-5.

Table 5. Calculation results of WLS and Sur										
Viariables	mean	Type				Area				
		urban	county	cspec	uspec	1st	2nd	3rd	4th	5th
outp(0000)										
2008	14.7	21.7	19.2	5.6	10.9	21.6	10.7	13.6	13.2	14.4
2009	15.6	23.8	19.9	6.0	11.2	23.7	11.8	14.2	13.3	15.2
2010	16.8	25.8	21.5	6.4	12.0	26.0	12.8	15.5	13.9	16.5
2011	18.4	28.8	23.7	6.6	12.7	28.3	13.4	17.1	15.3	18.2
inp(0000)										
2008	1.0	1.2	1.6	0.3	0.5	1.2	0.8	0.9	0.9	1.0
2009	1.1	1.4	1.7	0.4	0.6	1.4	0.8	1.0	1.0	1.2
2010	1.2	1.6	1.9	0.4	0.7	1.6	0.9	1.1	1.2	1.3
2011	1.4	1.9	2.1	0.4	0.8	1.9	0.9	1.2	1.3	1.4
beds										
2008	292	477	354	104	205	400	248	273	267	278
2009	327	542	395	120	218	471	261	302	290	321
2010	362	602	429	132	251	525	283	323	342	346
2011	392	654	474	136	268	566	293	357	385	371
WLS Model										
mcoutp										
2008	82	107	28	29	71	184	114	115	124	110
2009	125	143	33	46	117	136	113	111	116	93
2010	100	93	31	39	94	88	91	89	95	77
2011	120	72	42	48	114	75	113	100	118	96
mcinp										
2008	2046	1237	907	886	1992	1183	1981	1859	2060	1634
2009	2941	2824	611	1635	3360	4867	4697	4398	4658	3773
2010	3695	3325	1358	1540	3627	3147	3436	3300	3457	2840
2011	2817	3309	1438	872	2307	3245	2316	2268	2534	2258
S										
2008	1.32	1.96	3.51	1.46	1.19	1.94	1.19	1.25	1.26	1.38
2009	1.63	2.83	2.96	2.04	1.57	2.78	1.52	1.56	1.54	1.65
2010	1.28	2.16	2.38	1.65	1.26	2.16	1.21	1.23	1.21	1.30
2011	1.35	2.24	1.97	2.04	1.43	2.16	1.36	1.33	1.30	1.36
Eos										
2008	1.23	1.73	3.20	1.42	1.13	1.75	1.11	1.17	1.18	1.29
2009	1.51	2.48	2.69	1.99	1.49	2.47	1.43	1.45	1.44	1.53
2010	1.20	1.95	2.21	1.61	1.21	1.97	1.15	1.16	1.15	1.23
2011	1.14	1.65	1.59	1.93	1.28	1.66	1.20	1.14	1.10	1.15
scope										
2008	0.04	0.05	0.10	0.04	0.03	0.05	0.03	0.03	0.03	0.04
2009	0.06	0.10	0.11	0.07	0.06	0.10	0.06	0.06	0.06	0.06
2010	0.03	0.04	0.05	0.03	0.03	0.04	0.03	0.03	0.03	0.03
2011	0.02	0.03	0.03	0.03	0.02	0.03	0.02	0.02	0.02	0.02
SUR Model										
mcoutp										
2008	92	131	66	27	66	224	119	124	136	131
2009	107	142	76	30	79	132	85	89	99	87
2010	112	131	73	34	86	123	89	94	105	92
2011	135	133	79	44	111	133	113	109	128	112
mcinp										
2008	1643	2800	1090	461	1216	4777	2025	2215	2381	2261
2009	2335	3813	1419	653	1814	3569	1840	1955	2038	1800
2010	3043	4534	1800	901	2423	4307	2405	2556	2635	2377
2011	3319	5137	2014	909	2525	4942	2550	2618	2856	2660
S										
2008	1.82	1.80	1.78	3.38	2.24	1.80	2.02	1.87	1.86	1.79
2009	1.62	1.67	1.66	2.92	1.99	1.66	1.79	1.67	1.66	1.60
2010	1.42	1.56	1.54	2.47	1.69	1.57	1.55	1.44	1.43	1.41
2011	1.14	1.34	1.26	2.04	1.35	1.32	1.26	1.16	1.15	1.13
Eos										
2008	1.72	1.64	1.66	3.31	2.16	1.67	1.93	1.78	1.77	1.70
2009	1.28	1.09	1.24	2.70	1.71	1.17	1.50	1.35	1.35	1.28
2010	1.25	1.26	1.33	2.37	1.55	1.31	1.41	1.29	1.28	1.25
2011	0.63	0.34	0.58	1.72	0.94	0.47	0.84	0.69	0.65	0.66
scope										
2008	0.009	0.009	0.009	0.017	0.011	0.009	0.010	0.010	0.010	0.009
2009	0.006	0.006	0.006	0.011	0.007	0.006	0.007	0.006	0.006	0.006
2010	0.007	0.008	0.008	0.012	0.008	0.008	0.008	0.007	0.007	0.007
2011	0.005	0.006	0.006	0.010	0.006	0.006	0.006	0.006	0.006	0.005

Results

It is shown in Table-2 that WLS estimates of each year in the four years comply with expectations. The coefficients for inpatient and outpatient are positive, the coefficient for quadratic term is negative and the coefficient for cubic term is positive, showing compliance with economic description about cost function of short-term cubic term. Price theories have shown that curves for MC and AC for short-term production are both U-shaped due to progressive decrease of marginal salary – At the beginning, MC and AC drop with the increase of output, but they will both increase after output arrives at a certain level. The product terms of inpatients and outpatients are negative and are obvious at the level of 1%, indicating the existence of economy of scope. The coefficient of beds is positive and obvious, not objecting the expectation that the hospital is in a short-term balanced state. CMI is positive and noticeable, indicating forward influence on hospital cost by complexity degree of diseases.

In WLS results classified by hospital type and region, the control group of special hospitals at county-level has lower cost, a result meeting expectation. The results for control group of region level 1 also meet expectation because cost is relatively high in regions where economy is more developed. It needs to be pointed out that the results by region may not be consistent completely. For instance, cost of hospitals in region level-5 is higher than that of hospitals in region level-3 and level-4. This might be because hospitals in populous region level-5 get more patients. The sample averages by region show that outpatients and inpatients in hospitals in region type-5 are 30,000 and 2,000 more respectively. This is a reflection that explanatory variables in the model are controlled effectively. Table-2 also shows that the results from fixed effect (FE) model are similar to those obtained by WLS method, indicating consistence with previous research on cost function of hospitals.

The comparison between RUR results in Talble-3 and WLS results in Table-2 is very meaningful. Variations of same coefficient among different years are considerable when the data are regressed annually. For instance, WLS results show that inpatients coefficient in 2008 is over 2 times higher than that in 2011. Similar results also occur in comparisons of coefficient other than coefficient outpatients. Regression results of panel data show an opposite tendency. Coefficient variation is noticeably smaller and in the same direction. The difference of the two lies that coefficients beds and cmi in SUR model are not obvious. The reason for quietness of the former is within expectation, indicating that as the sample hospitals became larger increasingly, the number of beds got smaller influence on hospital cost as a proxy variable. The reason for quietness of the latter is complicated, and the reason may be that the sample hospitals are not practicing a classified diagnosis and treatment system. Table-3 shows that all proxy variables for hospital expect county dummy are significant at the level of 1% and are in consistent with WLS results in Table-2. What is out of expectation is that SUR results show costs of comprehensive hospitals at county-level are much higher than those of special hospitals at the same level, even higher than those of city hospitals. It is reasonable to believe that this is due to non-observable factors such as management ability. The business of county-level public hospitals in Henan grew rapidly from 2008 to 2011, but management failed to catch up with this trend. So it is not surprising that their costs are higher than those in cities after same factors are controlled. The description about region variable of hospital in SUR result is nearly the same as that of WLS results.

On Table-4 are inpatients and outpatients coefficients obtained through MDE. SUR model offers inpatients and outpatients coefficients of each year during the four years from 2008 to 2011. Thus, 4*2*4=32 coefficients are available. 24 redundant coefficients need to be got rid of because only 4*2=8 coefficients are needed in the following computation. MDE method can be adopted to reconcile these competing estimators. While restriction on the model is imposed, the reduced form complies with X2 (20) distribution. X2 (20) is 31.41 at 5% obvious level. The result on Table-4 is 56.62, turning down the hypothesis to impose proper restrictions on the model. In consideration of results by comparing SUR and WLS, this cannot be explained reasonably. Thus, it is believed that SUR might comply with facts on a higher degree and data in Table-4 are employed in the following calculation.

On Table-5 are values of marginal cost (MC), short-term economy of scale (S), long-term economy of scale (EOS) and economy of scope (SCOPE) from WLS and SUR respectively under the condition of sample average. WLS results in Table-5 show that economy of scale and economy of scope existed in public hospitals in Henan during the four years from 2008 to 2011, but the trends were different. For instance, outpatient marginal costs in the four years were RMB 82 yuan, 125 yuan, 100 yuan and 120 yuan, indicating a fluctuation. It is not strange, as cross-section data of each year shall be regressed separately, the data of each year is a separate model and there might be structural changes among the models. Chow test of data structure has also proved this. The data of the four year were mixed for estimation by the models of this research and Chow tests were conducted at three different times. The result of F was 7.297. At 5% obvious level, the value of F (54, 1436) was 1.346, turning down the hypothesis that there was no structural changes among the data of the four years.

Different trends are indicated by SUR results in Table-5. It is shown by the 4-year panel estimates that economy of scale and economy of scope existed in public hospitals in Henan in the three years from 2008 to 2010 and they decreased progressively. At 2011 when EOS is lower than 1, long-term economy of scale did not exist. Outpatient MC and inpatient MC both increased progressively in the four years with same changing tendency.

The research by Carey (1997) has shown that another test hypothesis for coefficient change in SUR model is that annual inpatients and outpatients are not allowed to change. In other words, the coefficients of every year shall be the same. X2(6) is 12.59 at obvious level of 5%. But MDE estimated X2 (6) is 52.28 after being adjusted in the model of this research, which rejects the hypothesis.

Discussion

The scale of public hotels in Henan expanded rapidly from 2008 to 2011. As indicated in Table-5, the beds (sample average) of such 377 hospitals increased from 292 in 2008 to 392 in 2011, an increase of 34% in four years. Scale growth brought about increase of output. Outpatients and inpatients grew from 147,000 and 9,500 in 2008 to 184,000 and 13,600, up 25% and 42% respectively. Correspondingly, average cost of hospitals increased from 52.89 million yuan to 98.96 million yuan, a growth of 47%. Larger scale means more consumption of resources by hospitals. Estimation on total health cost in Henan showed that about 58.6 of medical resources were consumed by hospitals1.

Now the discussion will focus on the two questions proposed at the beginning of this article. Economic principles on production behaviors of hospitals shall be employed to answer the two questions. As far as the first question is concerned, it is known that, from a microeconomic perspective, if hospitals are regarded as organizations with input-and-output functions, expansion of scale will impose two influences on efficiency of production: With growth of scale, hospitals can invest more equipment, human resources and other factors of production. More advanced technologies will be used and internal division of jobs will be more reasonable and professional. Thus, more patients will be treated and marginal cost will be lower. In fact, development of about 10 years has witnessed a great progress in terms of house, large equipment like CT and MRI, modernity and allocation of equipment, and medical service ability in public hospitals in Henan.

However, looking at this issue from a different perspective, we know that there are problems in management system because scale expansion means more administration layers in hospitals, which may lead to low efficiency in internal resource allocation, rise of operation cost and even negative influence on medical safety and service quality. This is just an indication of progressive reduction of MC. It is worth to notice that factors influencing efficiency of internal resource allocation are often unobservable, like management ability, quality and safety, which are mentioned many times in this study. But the influence of these factors is real, even huge. Thus, economy of scale and economy of scope existed in the sample hospitals in the four years when WLS model of panel data was used, because those non-observable factors were not considered. When those factors were separated from SUR model, the results were totally different. Economy of scale decreased progressively with scale expansion, and diseconomy of scale occurred in 2011. This reminds researchers that non-observable factors shall be handled properly when studying cost function of hospitals. Otherwise, the mistake of variable omission may happen, which may impose negative impact on research results.

As far as the second question is concerned, traditional cost theories hold that with the expansion of hospital scale, MC will decrease progressively due to the function of large-scale economy until production level is proper. If scale continues to rise, MC will increase due to diseconomy in management. This is well reflected in this study. In SUR model, it has been noticed by this study that cost of county-level hospitals are the highest among all hospitals, and outpatient and inpatient MC of all types hospitals in all kinds of regions increased progressively year on year, showing that attention shall be paid to improvement of management ability while hospitals are expanding.

There are very few references for studies, especially WLS and SUR studies, on economy of scale and economy of scope of hospitals in developing countries, particularly China. The study by Barnum and Kuntzin (1993) on economy of scale of public hospitals in China has found that economy of scale in hospitals at lower levels were more obvious, a result found out also in this study. SUR results in Table-5 show that results of city and county-level special hospitals reflect scale merit better. For instance, the value of S for city hospitals, county-level hospitals, city special hospitals and county-level special hospitals in 2008 were 1.80, 1.78, 3.38 and 2.24 respectively. The study by

Weaver (2004) with OLS method was a study on panel data of 654 hospitals in Vietnam in 1996, which indicating big differences in terms of economy of scale in different types of hospitals and hospitals in different regions. The results of their study showed that MC of hospitals in Vietnam was extremely low. Averagely, inpatient MC was USD 34.04 dollars (RMB 200 yuan), outpatient MC was USD 0.46 dollars (RMB 3 yuan), only 1/10 and 1/30 respectively of WLS results of this study for 2008.

Previous studies on cost function of hospitals also paid more attention to the influence of medical insurance on hospital cost.Medical insurance backed up by Chinese government has been developing rapidly.Basic medical insurance in Henan basically completed overall coverage at the end of 2012. This study does not include the variable of medical insurance due to lack of data. We have planned to conduct a special study on the influence of medical insurance on hospital cost.

Conclusion

Based on panel data of cost of public hospitals in Henan Province, China, in four years from 2008 to 2011, this study estimates parameters via WLS and SUR models to calculate values of economy of scale and economy of scope and analyzes them. It is shown by WLS results that economy of scale differs greatly among hospitals of different types and in different regions; SUR results show that hospitals at lower levels are more obvious in terms of economy of scale and economy of scale among hospitals in different regions does not vary much. With the growth of scale, economy of scale tends to decrease due to influence of non-observable factors like management ability.

While comparing estimated results from WLS and SUR models, we also find that attentions shall be paid to influence of non-observable factors on calculation results when studying cost function of hospitals. While using SUR model of panel data, it is not necessary to propose the hypothesis that non-observable effects have no relation with control variables in order to allow variables to change with time. Furthermore, it can separate the influence of management ability and case mix index (CMI) on management ability and, to some extent, overcome influence of omitted variables on model validity, making results of parameter estimation more effective.

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