Original Article

Health resource allocation and productive efficiency of Chinese county hospitals: Data from 1993 to 2005

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Summary   **This study aims to assess trends in the productive efficiency of China's county hospitals during the economic transition using data from 1993 to 2005. A data envelopment analysis (DEA) framework was used to calculate the efficiency score of county hospitals in all 31 provinces. A C^{2}R model and a BC^2 model were devised to respectively calculate overall and scale efficiency and pure technical efficiency at the hospital's current scale. Models included four inputs (number of medical staff; number of beds; value of fixed capital; and hospital expenditures) and three outputs (outpatient and emergency visits, number of inpatients, and hospital revenue) in total. As the results, geographical disparities in health resource allocation and county hospital productivity were noted. From 1993 to 2005, the number of county hospitals increased and their inputs, *e.g.* fixed capital in particular, grew rapidly. However, the amount of both outpatient and inpatient services declined somewhat especially in the middle and the western regions. The overall efficiency at the national level decreased slightly. County hospitals in the eastern region tended to have better overall, scale, and technical efficiency in comparison to the middle and the western regions. In conclusion, county hospitals are inefficient due to their enlarged scale and the reduced amount of health care services they provide. This issue should be addressed especially in the middle and the western regions, where health resources are far more limited and yet wasted. The effects of ongoing health sector reform on the productivity of county hospitals must be monitored and evaluated.**

Keywords: County hospital, productivity, data envelopment analysis (DEA), China

1. Introduction

Productive efficiency is a key determinant of health system performance. It is about producing the maximum amount of health services, and ultimately health outcomes, from an available quantity of health system inputs, including finances, infrastructure, and human resources. As hospitals are the main providers of health care services and account for a large share of health expenditures, their productive efficiency must be monitored and evaluated as part of the policymaking process in order to optimize the utilization of available health resources and mobilize additional resources for the health system through increased efficiency.

In China, the economic transition from a central planned economy to a market-driven economy has resulted in unprecedented economic growth over the past three decades. That said, the equitable distribution of the benefits of this economic growth remains a concern, as disparities in income and wealth between urban and rural populations and between the east and the west have substantially widened. The economic transition also brought about profound changes in the health system, such as a decreased reliance on state

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funding, decentralization of public health services, increased hospital autonomy, and freedom of movement of health workers (*1-3*). Market-oriented health sector reform coincided with a soaring burden of individual medical expenses and a huge health gap paralleling socioeconomic and geographical status (*4-8*). According to World Health Report 2000, China's health system ranked 144th, and among the five performance indicators its fairness of financial distribution in the health system ranked 188th among the 191 countries in the World Health Organization (WHO) (*9*).

The Chinese government is now highly aware of these issues and has actively responded to them. A new reform seeking reasonable distribution of health resources and emphasizing core issues of equity and accessibility has been launched by infusing a large amount of public finances. This action plan emphasizes services at the rural and grass roots level, such as infrastructure and human resource development of the three-tiered network at the county, town, and village levels (*10*).

County hospitals are the main provider of a large share of services including treatment and emergency services, disease prevention, vaccination, health education, maternal and child health care services, and reproductive services for rural residents (*11*), who account for 80% of the Chinese population overall. These hospitals serve as the flagship in the three-tiered rural health care system. They take in 25.44% of basic and 36.19% of special government subsidies for the rural health care system (*12*). Like other hospitals, county hospitals were given a great deal of autonomy with no public finances as part of the market-oriented reform of the health sector. The productive efficiency of county hospitals must be comprehensively investigated in terms of geographical disparities, trends in health resource allocation and health services provision, and possible increased efficiency in order to rationally allocate health resources to the rural health system and effectively provide health care services to rural residents. Previous studies on the efficiency of Chinese hospitals were mainly small-scale investigations (*13,14*) while studies on efficiency over time at the national level are lacking. This study sought to assess the productive efficiency of Chinese county hospitals, to examine trends in health resource allocation and health services provision, and to explore the potential for increased efficiency in order to provide policymakers with evidence of improved performance.

2. Methods

2.1. *Data sources and hospitals studied*

Data are from the Health Service Management Budget Accounting Report in 1993, 1995, 1997, and 1999 and the Annual National Health Financing Report in 2001, 2003, and 2005. Both reports are issued by the Ministry of Health and have similar content.

The hospitals studied were all county hospitals in all 31 provinces, autonomies, and municipalities of mainland China. Based on their geographical location and socioeconomic status indicated by GDP per capita and average income, those provinces are officially divided into three groups in general: the developed eastern region, the moderately developed middle region, and the least developed western region.

2.2. *Efficiency and DEA framework*

As a non-parametric method first developed by Charnes *et al.* (*15*), data envelopment analysis (DEA) incorporates multiple output and input variables to score the efficiency of a decision-making unit (DMU), or county hospitals in each province, relative to a group of DMUs. It constructs a production possibilities frontier through the best performance of DMUs at different scales of operation. County hospitals comprising the best practice frontier are assigned an efficiency score of 100%. The efficiency of those below the frontier is measured by their distance from it. Inefficient county hospitals are assigned a score between one and zero. For hospitals with inefficiency, DEA can also indicate the amounts of over-supplied inputs or under-produced outputs in order to achieve maximum productive efficiency.

In this study, a C^2R model was used to calculate overall efficiency and a BC^2 model was used to calculate pure technical efficiency at the hospital's current scale, as described below:

$$Max\ h_0 = \frac{\sum_{r=1}^{s} u^T y_{rj0}}{\sum_{i=1}^{m} u^T x_{rj0}}$$

Subject to

$$\frac{\sum_{r=1}^{s} u^T y_{rj0}}{\sum_{i=1}^{m} u^T x_{ij0}} \leq 1, \quad j = 1, 2, ..., n$$

$$u \geq 0, r = 1, 2, ..., s\ \text{and}\ v \geq 0, i = 1, 2, ..., m \quad \text{Eq.1}$$

Where y_{rj} = the amount of output r produced by county hospital j, x_{ij} = the amount of input m used by county hospital j, s = the sort of output, m = the sort of input, u_r = the weight given to output r, v_i = the weight given to input i, n = the number of county hospitals, j_0 = county hospitals studied.

Model 1 is a fractional programming model that can be converted into the linear forms of C^2R model (model 2) and BC^2 model (model 3) so that linear programming can be applied.

$$min\ [\theta - \xi\ (e^T s^- + e^T s^+)],$$

$$\sum_{j=1}^{n} x_j \lambda_j + s^- = \theta x_0, \quad \sum_{j=1}^{n} y_j \lambda_j + s^+ = y_0,$$

$$\lambda_j \geq 0, j = 1, 2, ..., n, s^- \geq 0, s^+ \geq 0, \theta \in E \quad \text{Eq.2}$$

Where θ = the factor by which an input set x_0 is adjusted to attain the minimum input level x_j in county hospital j, in order to reach the efficient frontier, ξ = infinitesimal variable, λ = intensity variables to identify efficient production, s^- = the vector variable of inputs, s^+ = the vector variable of outputs,

Based on model 2, overall efficiency is such that if $\theta = 1$, DMU-j is efficient; if $\theta < 1$, DMU-j is inefficient. Regarding scale efficiency,

$$K = \sum_{j=1}^{n} \lambda_j,$$

where K is the value of the return to scale for DMU-j. An increasing return to scale exists if K is less than one (K < 1), a constant return to scale if K is equal to one (K = 1), and a decreasing return to scale if K is greater than one (K > 1).

$$min\ [\theta - \xi\,(e^{'T}s^- + e^T s^+)],$$
$$s.t. \sum_{j=1}^{n} x_j\lambda_j + s^- = \theta x_0,\ \ \sum_{j=1}^{n} y_j\lambda_j + s^+ = y_0$$
$$\sum_{j=1}^{n} \lambda_j = 1$$
$$\lambda_j \geq 0, j = 1, 2, ..., n, s^- \geq 0, s^+ \geq 0, \theta \in E \qquad Eq.3$$

The production technology set of this BC^2 model is described as:

$$T_{BC^2} = \{(x,y)|x \geq \sum_{j=1}^{n} x_j\lambda_j,\ y \leq \sum_{j=1}^{n} y_j\lambda_j,\ \lambda_j \geq 0, j = 1, 2, ..., n\}$$

In model 3, pure technical productivity of DMU-j is efficient when $\theta = 1$ while it is inefficient when $\theta < 1$.

2.3. *Input and output indicators*

The DEA model was estimated with seven variables in total: four inputs and three outputs. The four inputs were labor, constructed in terms of the number of medical staff; the number of beds; value of fixed capital; and hospital expenditures. The three outputs included outpatient and emergency visits, number of inpatients, and hospital revenue. The selection of these input and output indicators was based on availability of data, a conceptual framework of hospital management, and consultation with an expert panel.

2.4. *Unit cost calculation*

Unit costs of outpatient and emergency services and inpatient services are calculated as below: Costs of inpatient services = (Fixed Capital × 0.125 + Medical expenditures) × 40%/outpatient and emergency visits; Costs of outpatient services = (Fixed Capital × 0.125 + Medical expenditures) × 60%/days beds were occupied.

With a depreciation rate of 0.125, outpatient and emergency services and inpatient services were estimated, based on Financial Regulations for

Hospitals (*16*), to account for 40% and 60% of hospital expenditures, respectively.

2.5. *Discounting*

To facilitate comparison of different years, data on currency values such as the value of fixed capital, medical income, and expenditures were discounted based on the retail sale index (Table 1) (*17*). The baseline was the year of 2005.

3. Results

In general, the number of county hospitals increased from 2,696 hospitals in 1993 to 3,391 hospitals in 2005. The average annual increase in the eastern region, the middle region and the western region was 2.19%, 2.42% and 1.26%, respectively, and the number increased 1.93% for the country overall.

3.1. *Trends in health resource allocation*

The average number of medical staff in county hospitals has increased slightly. The average annual increase in the eastern, middle, and western regions was 1.97%, 0.56% and 0.44%, respectively, and 1.14% for the country overall.

Fixed capital included buildings and equipment. Its overall value rose rapidly during the 12 years studied, as the average annual increase reached 15.9%

Table 1. Retail sale index from 1993 to 2005

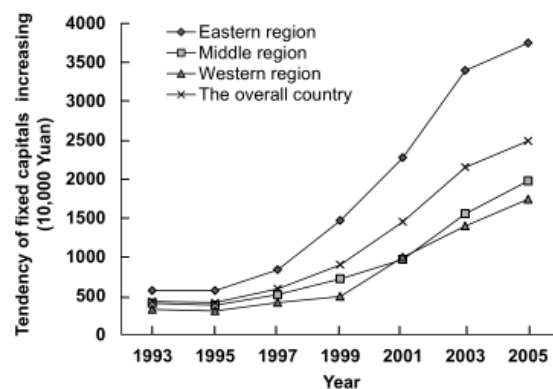| Year	Retail sale index
1993	70.94
1995	99.11
1997	105.98
1999	100.14
2001	97.86
2003	96.49
2005	100.00

Source: National Statistics 2006.

Figure 1. Rapid increase in fixed capital.

and the value in 2005 was 5.84 times that in 1993 (Figure 1). The average annual increase of the value of buildings was 12.0% for the country overall. The value of equipment grew even faster, as the average annual increase remained almost 20% and the value in 2005 was 8.8 times that in 1993.

At both the national level and provincial level, the number of beds gradually increased. The percentage of beds occupied decreased from 71.8% in 1993 to 59.6% in 2005 (Figure 2), and in almost all provinces this percentage was far below 84%, the standard set by the Ministry of Health.
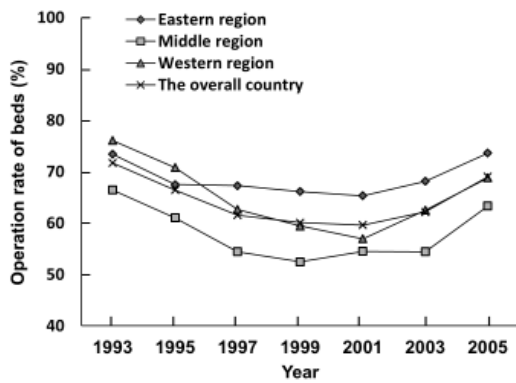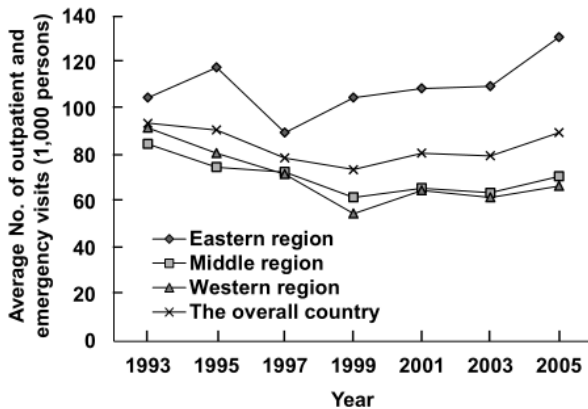

Figure 2. Beds operancy.

3.2. Amounts and costs of medical services

The number of average annual outpatient and emergency visits for the country overall decreased from 94,000 in 1993 to 74,000 in 1999 and then rose to 90,000 in 2005. The average number of inpatients also tended to decline annually particularly in the middle and western regions. The cost of both outpatient and emergency services and inpatient services increased 5 times from 1993 to 2005, with an average rate of 14.5% and 14.4% at the national level, respectively. The western region had the most rapid increase in outpatient and emergency services, 16.3% (Figure 3).

From 1993 to 2005, county hospitals in China had double-digit increases in revenue and expenditures of 13.5% and 13.6%, respectively. Most county hospitals, and especially those in the middle and the western regions, had a severe deficit (Figure 4). At the national level, government subsidies accounted for 7% of county hospital revenue.

3.3. Productive efficiency based on DEA models

3.3.1. Overall efficiency

Generally, overall efficiency at the national level decreased slightly from 1993 to 2005 (Figure 5). In 2005, there were 16 provinces where the overall
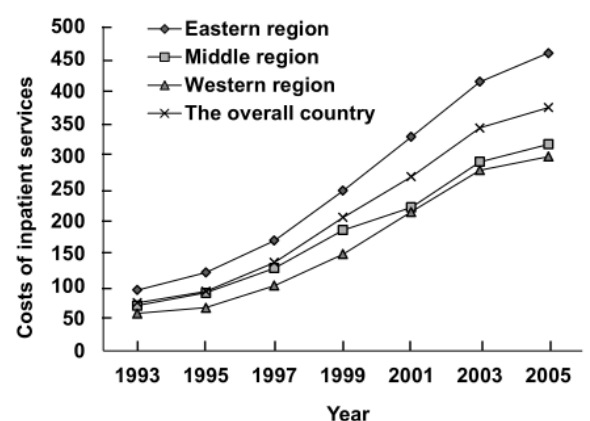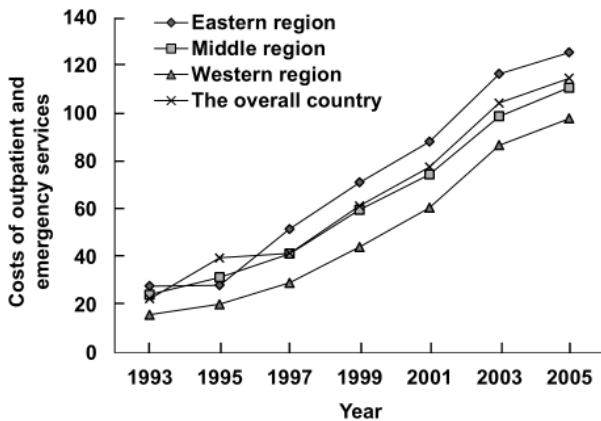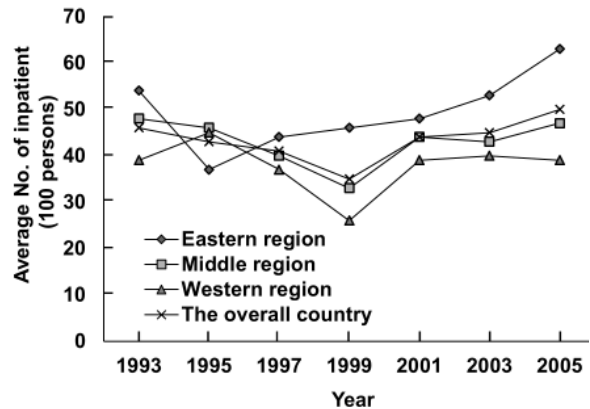

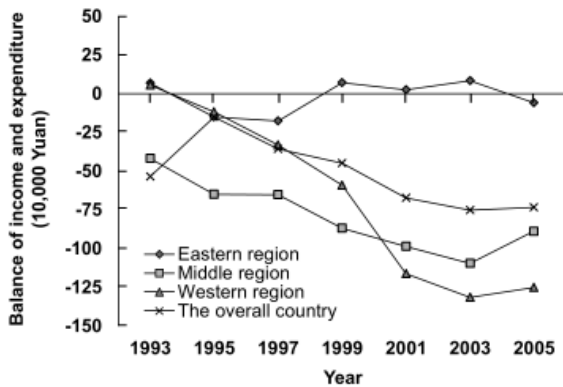**Figure 3. Amount and cost of health care services provided by county hospitals.**

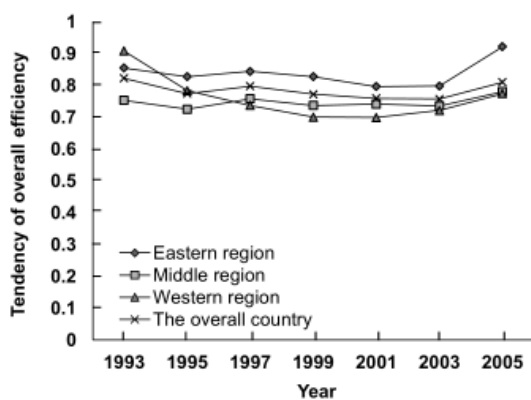**Figure 4. Balance of income and expenditures of county hospitals.**

Figure 5. Overall efficiency based on DEA models.

efficiency of county hospitals decreased in comparison to 1993. In the eastern region, the average overall efficiency score increased from 0.854 in 1993 to 0.921 in 2005 and was higher than that in the middle and western regions. In the middle region, the score changed little. In the western region, however, it tended to decrease during the 12 years studied.

In 1993, county hospitals in 7 provinces (19.4%) were efficient although those in the remaining 25 provinces were inefficient. Among those provinces with inefficient county hospitals, four scored less than 70% and the score in the Tibet Autonomous Region was 0.505, the lowest. In contrast, in 2005 8 provinces (25.8%) reached the efficiency frontier and all of them were in the eastern region. The number of provinces with a score of less than 70% increased to eight. County hospitals in the Tibet Autonomous Region still had the worst efficiency, achieving only 46.6% of the frontier.

3.3.2. *Scale efficiency*

The score of scale efficiency was also measured by the C^2R model. In 1993, there were 4 provinces where county hospitals had decreasing returns to scale (14.9%), 7 provinces had constant returns to scale (22.6%), and 20 provinces had increasing returns to scale (64.5%).

In 2005, 17 provinces had decreasing returns to scale (54.8%), 8 provinces had constant returns to scale (25.8%), and 6 provinces had increasing returns to scale (19.4%). Except for Hainan Province, provinces that had county hospitals with increasing returns to scale were located in the western region.

3.3.3. *Pure technical efficiency*

At the national level, in all years but 2003 pure technical efficiency reached the frontier. County hospitals in the eastern region have a higher pure technical efficiency score than those in the middle and western regions. Provinces that had county hospitals with pure technical efficiency were decreased by 9.7%, from 11 (35.5%) in 1993 to 8 (25.8%) in 2005.

3.3.4. *Input-output projection analysis*

An input-output projection analysis of those provinces having county hospitals with overall inefficiency in 2005 was also performed in order to examine over-supplied inputs and expected outputs by measuring the distance from them to their efficient peers. Results indicated that a reduction of 300,376 medical staff, a reduction of 310,975 beds, a reduction of 30,763,150,000 RMB of the value of fixed capital, or a reduction of 16,444,130,000 RMB in hospital expenditures will result in input savings at levels of 19.05%, 27.02%, 19.05%, and 19.05%, respectively. The distance to efficient practice also suggested the level of wasted health resources, which was 8% in the eastern region and more than 20% in the middle and western regions.

4. Discussion

This is the first study to examine the productive efficiency of all of China's county hospitals within the scope of the market-oriented health sector reform. From 1993 to 2005, the number of county hospitals increased and their inputs, *e.g.* fixed capital in particular, grew rapidly. Consequently, the costs of both outpatient and emergency services and inpatient services increased substantially. During the past two decades, county hospitals obtained autonomy with no public finances and were increasingly commercialized. Stimulated by market competition, they vastly enlarged their scale, including building extensions, bed installation, and the purchase of advanced equipment.

This expanded scale had both a positive and negative effect on the development of county hospitals and the accessibility of health care services. First, many county hospitals suffered severe deficits due to investment, worsening their financial situation. Second, the fact is that county hospitals enjoy few government subsidies, so their revenue mainly derives from drug costs and medical costs (*18*), and there are pervasive financial

incentives to over-provide services and over-use drugs in order to make a profit (*19-21*). Actually, like county hospitals, the enlarged scale and the financial incentives of all kinds of hospitals could be explained by soaring health expenditures, which are evident as a double-digit increase far exceeding the increase in individual income (*22*). Most rural residents paid out-of-pocket and were not covered by medical insurance, and rural cooperative medical schemes (CMS) in particular collapsed with the economic transition (*23-25*). Thus, increasing costs and fees of county hospitals resulted in a heavy burden for rural residents.

The rapid rise of medical and drug costs and lack of coverage by medical insurance for the rural population may have contributed to the decline in amounts of services provided by county hospitals, despite their expanded scale (*12,26*). The 2003 National Health Services Survey indicated that medical insurance covered only 21% of rural residents before CMS were re-established and that unaffordable medical costs were the main obstacle to access to health care services, particularly among rural residents (*22*). Beds were not being efficiently utilized. A previous survey agreed, indicating that the usage of large-scale advanced medical devices was less than 50% in many Chinese provinces (*27*). The poor utilization of newly invested inputs caused health resources to be wasted and impacted the return to scale, influencing overall efficiency.

This study revealed geographical disparities in health resource allocation and county hospital productivity, and gaps expanded during the 12 years studied. County hospitals in the eastern region tended to have slightly higher overall, scale and technical efficiency since their better socioeconomic status and financial capacity, larger population, and more convenient physical accessibility boosted the utilization of health care services there. The current findings also suggest considerable waste of health resources in the middle and western regions.

Based on the current findings, the dominant pattern in which Chinese county hospitals developed during the previous market-oriented reform of the health sector can be characterized as a significant expansion of scale along with commercialization. However, the amount of health care services these hospitals provided declined. The overall efficiency, return to scale, and pure technique efficiency of these hospitals decreased on the national level, and gaps in these indices among the eastern, middle, and western regions expanded. Such inefficiency of county hospitals, especially in the middle and western regions, should be addressed by the government-driven reform scheme, which has advocated a substantial increase in public investment, universal medical insurance coverage particularly for the rural population, restructuring of management systems, and corrections for increased

commercialization in public hospitals (*10*). For most county hospitals with a decreased return to scale, regional health plans now emphasize improved utilization and quality of health care services in place of an expanded scale. In this regard, wide coverage by medical insurance with substantial risk pooling and containment of soaring medical expenditures will ensure the affordability and accessibility of health care services for the rural population (*28*). At their current scale, county hospitals are primarily tasked with developing human resources and improving medical skills and staff performance in order to optimize their management structures to effectively utilize inputs and improve the quality of health care services. Moreover, public financing is needed to close the expanded geographical gaps in health resource allocation and accessibility of health care services accompanying the profound impacts of decentralization. The effects of ongoing reform on the productivity of county hospitals must be monitored and evaluated to continue providing evidence for regional health plans.

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