Federal University Hospitals and Stochastic Frontier Model

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Resumo

O objetivo deste trabalho é caracterizar os Hospitais Universitários Federais (HUFs) brasileiros em termos de sua importância, suas fraquezas, suas fortalezas e suas necessidades. Além disso, o trabalho vai analisar a relação entre os HUFs e o sistema hospitalar SUS, tentando explicar como eles podem melhorar a qualidade do atendimento e racionalizar esta relação. Revisitamos alguns estudos para entender a melhor maneira dos hospitais organizarem sua governança. Finalmente, rodamos um modelo de fronteira estocástica no intuito de construir rankings de eficiência para os hospitais e analisar o quanto eles poderiam aumentar sua produção com os insumos que possuem. Os resultados encontrados nos estudos revisitados mostram que a melhor maneira de organizar a governança é através do modelo de Organizações Sociais (OS), na qual o governo contrata um operador privado sem fins lucrativos para administrar as unidades. No entanto, as unidades continuam sendo propriedade do governo e 100% financiada pelo governo sob um contrato de desempenho baseado em resultado com riscos financeiros. Os resultados encontrados no modelo de fronteira mostram que os hospitais estão mais perto da eficiência na produção ambulatorial que na produção hospitalar. Entretanto, esta analise não leva em consideração a gravidade dos casos, que é o que pode estar produzindo estes resultados. Comparando o ranking dos hospitais no modelo com o ranking dos hospitais produzido através da taxa de rotatividade dos leitos, obtêm-se resultados similares, o que nos deixa confiante sobre a estratégia utilizada no modelo

Abstract

The aim of this paper is to characterize the Brazilian Federal University Hospitals (FUH), addressing their importance, their strengths, their weaknesses and their needs. Also, the objective of the paper is to analyze the relationship between the FUH and the SUS system, and explain how they could improve the quality of the care rationalizing this relationship. We revisit some studies to understand what is the better way to the FUH organize their governance. Finally, we run a stochastic frontier model to ranking the efficiency of the hospitals and analyze how much they can increase their production with the inputs they have. The results find in the studies revised show that the better way to organize the governance of the hospitals is the Social Organization (OS) model, in which the Government contracts a private, non-profit operator to manage one or more facilities (including all inputs), making full use of assets. However, the facility remains government-owned, and is 100% government-financed under a performance-based management contract with financial risks. The frontier model finds that the hospitals are closer to their efficient frontier in the ambulatory production than in the hospital production. However, these analyzes do not take in consideration the severity of the cases, which could be producing these results. Comparing the ranking of hospitals between the model and the one made through the bed turnover rates yield similar results, what make us confident of the utilized approach.

Palavras-Chaves: Hospitais Universitários; SUS; Fronteira Estocástica.

Key-Words: University Hospitals; SUS; Stochastic Frontier.

JEL: I12; I18

1   Introduction

Over the past generation, Brazil has consistently and successfully reduced poverty and inequality, and at the same time has grown and diversified its economy. However, recent economic growth has been lower than in comparable large emerging economies, and Brazil remains one of the most unequal countries in the world. Brazil is one of the most populous countries in the world, with 192 million inhabitants, and one of the most important global economies, with a GDP of over US $1.6 trillion in 2008. About a fifth of the population still live in poverty, on less than US$2 a day, with about 60% of the poor living in the Northeast. The poor in Brazil suffer a double burden of disease: they are more affected by communicable diseases, as well as non-communicable diseases. This double burden helps propagate the cycle of poverty.

Brazil has attained substantial health gains, but inequality persists, creating constraints to economic progress. In the last two decades, there were notable declines in childhood deaths, and fertility, progress against HIV/AIDS, malaria, tobacco smoking and other epidemics, and major achievements in public health performance, especially surveillance and access to health care, with over 80% of births assisted by health staff. The country has made dramatic progress on health care coverage. However, health outcomes are worse than in other countries with similar income. Brazil's health spending as a percentage of GDP and per capita expenditure on health (at purchasing parity rates) places Brazil in the upper quintile among Latin American countries, while health indicators such as child and maternal mortality, place Brazil among the bottom quintile in the region.

Evidence shows that Brazil's health inequalities are polarized at the national and intra-regional levels, with the North and Northeast presenting, in general, worse health indicators than other regions. Inequity persists in access and quality of service throughout the country, and the health system is plagued by inefficiencies. In addition, like all sectors, health is also affected by general issues of governance failures as well as poor management and weak performance of health institutions due, notably, to the lack of incentives and accountability measures that would ensure that services are accessible and of acceptable quality.

While the Brazilian health system has gone through several significant reforms, hospitals have been left largely untouched, with a few notable exceptions. The consolidation of

health financing, the organization of the health sector into a national health service (Sistema Unico de Saude - SUS), the establishment of the Indigenous Health subsystem, the development of a national surveillance and public health system, and an increased emphasis on primary care, have been key factors in health improvements. The reform of the public health system – Reforma Sanitaria – initiated in the late 1970s, led to the establishment in 1988 of the Unified Health System – the Sistema Único de Saúde (SUS), which is financed from the national budget, and offers universal coverage. In the 1990s, the government proceeded with the decentralization of the health system from the federal level to states and municipalities.

Although hospitals are critical to the health of Brazilian people, are de facto health care delivery system in Brazil, and consume about 70% of the public health budget, have received scant attention as health care organizations. Issues of hospital performance, however defined, have been left mainly to the individual facility.[1]

In this context, the Government of Brazil created a program to revitalize the Federal University Hospitals (FUH) in Brazil, which used to be centers of excellence. However, decades of neglect have left them with a deteriorated infrastructure and antiquated management. The FUH confront many issues: (i) antiquated governance and management, with poor budgeting, accounting and information about costs, and lack of flexibility to manage human resource; (ii) lack of adequate financing, and consequent significant deficits, (iii) limited use of evidence-based health protocols, and poor integration into the local and regional health networks; (iv) declining education standards and lack of standardized research processes, and (v) deteriorated infrastructure and old equipment, with lack of operation and maintenance funding and mechanisms.

The aim of this paper is to describe the characteristics of the Federal University Hospitals, try to understand the context in which they are inserted and, using a stochastic frontier model to analyze the efficiency of their production. The next section describes the data we use in the paper. The third section describes the mainly characteristics of FUH and starts the discussion about efficiency through the analysis of descriptive statistics and efficiency indicators. The fourth section describes the stochastic frontier model used to

[1] La Forgia G, Couttolenc B 2008.

ranking efficiency of the hospitals. The fifth section analyzes the results. Finally, the sixth section concludes the paper.

2   Data

The data we use in this paper are from two different datasets. For the next section we use data from the "Pesquisa de Assistência Médica e Sanitária", AMS 2005. With this dataset we compare the characteristics of the FUH with characteristics of other hospitals, divided in the following categories: total hospital system; total public hospitals; total private hospitals; total teaching hospitals; total public teaching hospitals; and total private teaching hospitals.

 At the same time we use data from the National Program for the Restructuring of Federal University Hospitals (REHUF) system from the Ministry of Education (MEC) to analyze deeply the FUH in the next section, and to calculate our frontier model in the final sections of the paper. REHUF dataset has more information about indicators than AMS, with some information of infectious rates, occupancy bed rates and cesarean rates, besides information about human resources, infra-structure and equipment. We use data from 2008 because is the last data for the indicators.

3   FUH context

FUH are quite important in the context of both the Unified Health System (SUS) and the tertiary education system in Brazil. Among the almost 6,000 hospitals integrated into the SUS, 63 are jointly certified as Federal University Hospitals (FUH), a relatively small number while belies their importance. The FUH represent one third of the total teaching hospitals registered in Brazil. As a result of their multiple functions, FUHs play important roles in health care delivery, education and research. These hospitals provide a significant share of the secondary and tertiary care[2] in the country, and contribute to the provision of primary health care. In many states or regions, they are the sole source of qualified health care at tertiary complexity level.

Most of the FUH are large hospitals, although there is significant variation in size, infrastructure and technology, human resources, qualifications and management among them. Brazilian FUH have about 10,000 beds (average of 250 per hospital), which represents 6.65% of total hospital beds in the public network. However, about 10% of those cannot be used due to infrastructure problems. Although FUH represent only 2.6% of the Brazilian hospital sector, they account for more than 10% of the SUS beds and ambulatory care at hospital level; 26% of the intensive care beds and 38% of the high complexity care; and carry out 70% of transplants and around half of the cardiovascular surgeries and neurosurgeries performed in Brazil (see Figure 1). However, while the average number of beds is much higher in FHU than in all other types of hospitals, the average number of inpatient admissions is much lower than in private teaching hospitals (see Figure 2 and Figure 3), suggesting a lower occupancy rate and higher average length of stay in these hospitals.
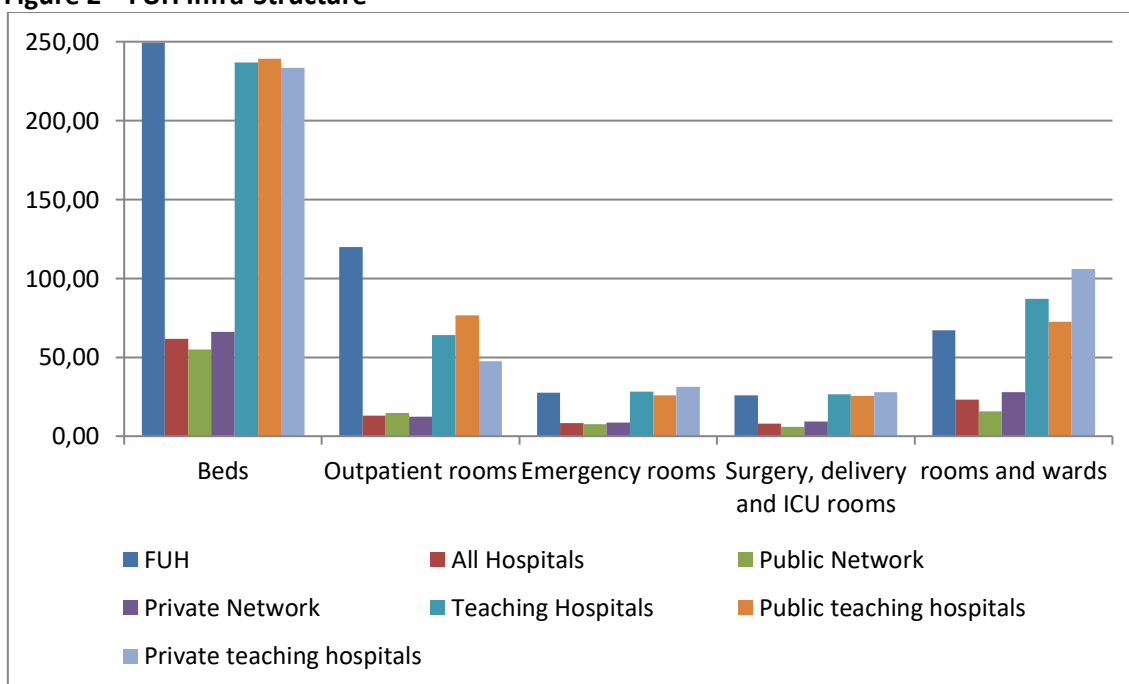
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[2] Secondary and tertiary care is designated as medium - and high- complexity care in Brazil.

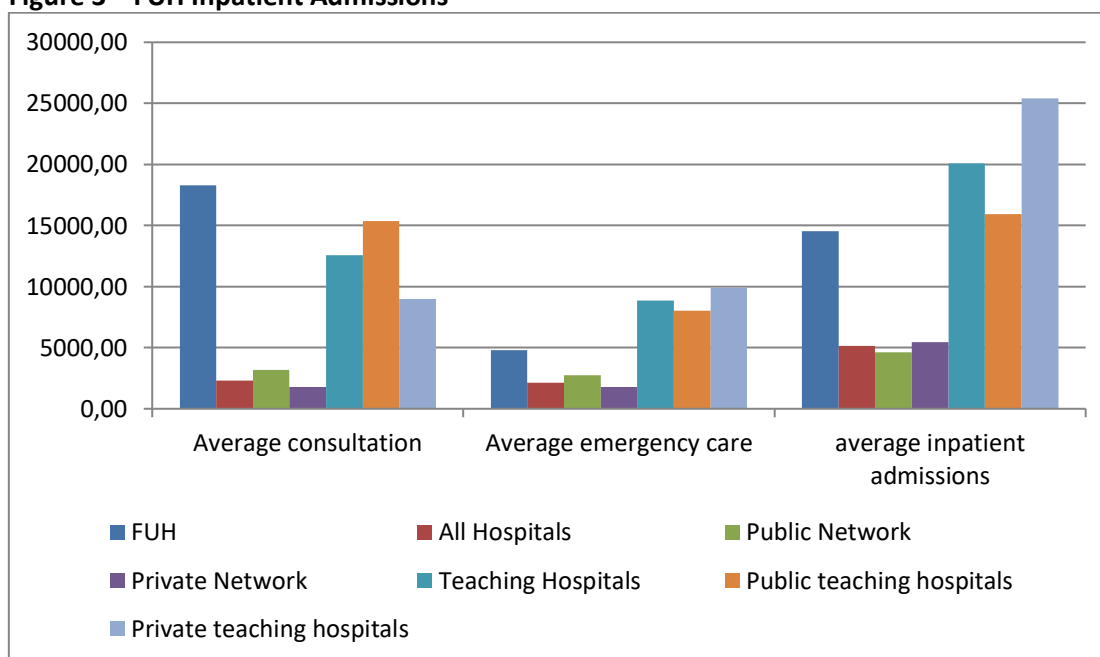**Figure 1 – FUH as Share of Public Hospitals**
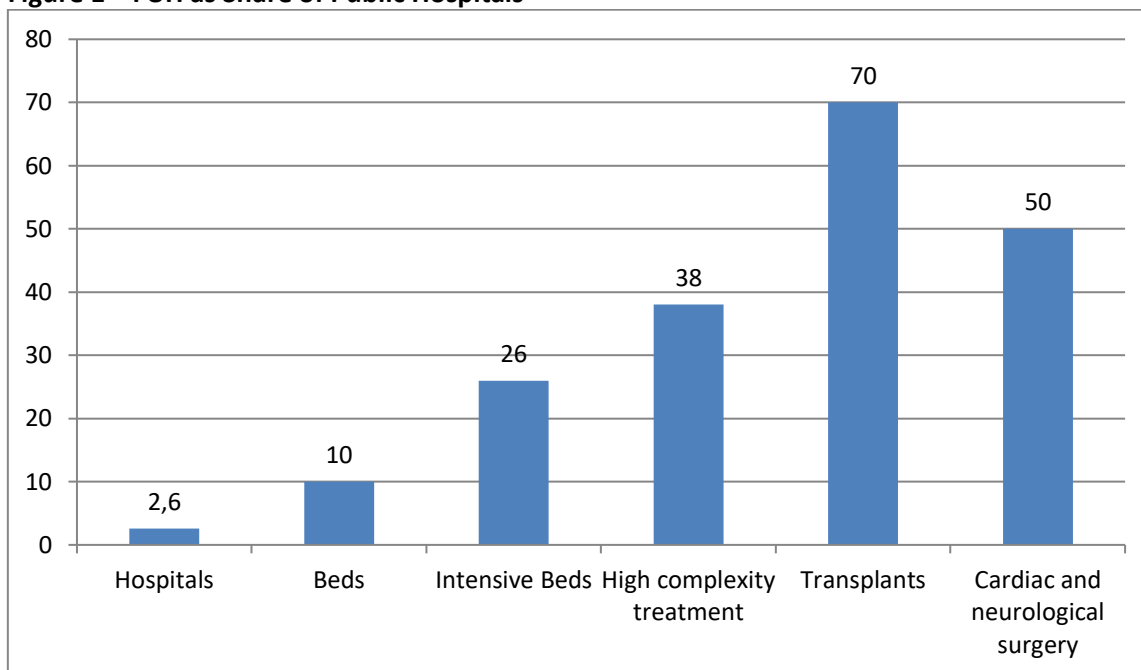
Source: : Authors' elaboration using data from AMS, 2005.

Figure 2 – FUH Infra-Structure

Source: : Authors' elaboration using data from AMS, 2005.

Figure 3 – FUH Inpatient Admissions

Source: : Authors' elaboration using data from AMS, 2005.

On the other hand, the same figures show that the average consultation of FUH is higher than private teaching hospitals suggesting that FUH yield also higher number of ambulatory production. We can interpret this in two ways: FUH is having a function higher than they should have in ambulatory production (indicating some kind of inefficiency of the hospitals), or FUH is taking care of people that otherwise would have no care, indicating an inefficiency in the primary public network. Both explanations have as a consequence, the need to improve efficiency of public health system, either within the hospitals or improving the access to primary health care.

Federal University Hospitals with more beds seem to be more efficient and deliver more quality health services than smaller FUH. Using the bed occupancy rate (BOR) as an indicator of efficiency, Table 1 shows that occupancy rate in hospitals with 50 to 99 beds is below 50%, while in hospitals with 500 or more beds, is higher than 75%. Adult and pediatric infection rates are lower in larger FUH, suggesting higher patient safety.

Table 2 presents FUH average length of stay by specialty and hospital size. The results also indicate that higher hospitals have smaller length of stay suggesting a better efficiency in management.

The FUH in Brazil train most students of medicine, nursing, nutrition and other health professions, and publish the highest share of scientific papers in the Brazilian medical field. At present, the FUH train 71,800 students in different health areas and employ 4,700 medical interns. Due to the FUH research, between 1981 and 2006 Brazilian scientific production in medicine increased from 0.3% to 1.5% of global scientific production in this field. Research developed in these hospitals facilitated 1,244 master's theses and 535 doctoral dissertations. However, shortage of funds and professionals may partly explain the declining standards in medical education according to national higher education tests (ENEN), as pointed out in a World Bank study[3].

Table 1. FUH Size and Performance*

Beds	HUF #	HUF %	Occupancy rate	Infection Rate Adult ICU	Infection Rate Pediatric ICU	Infection Rate Neo-natal ICU	Turnover Bed Rate	Cesarean Rate high risk***
< 50	8	17.39						
50-99	3	6.52	47.58				3.54	44.75
100-199	13	28.26	55.27	25.32	18.80	28.59	3.01	61.10
200-499	17	36.96	62.19	19.82	9.48	24.05	2.93	65.99
500 or +	5	10.87	76.03	10.18	6.39	31.18	4.16	50.85
Average			60.80	20.61	10.50	25.25	3.17	59.92

Source: Authors' elaboration using data from REHUF, MEC. *With the exception of the number of beds, all other statistics are based on information about hospitals that report above zero values;**Among the 5 hospitals with 500 beds or more, only the Hospital of Uberlândia carries out low-risk cesarean sections;*** Only the UFRJ Maternity School, with 50 -99 beds , carries out high-risk cesareans.

Table 2. FUH Length of Stay by Specialty and Hospital Size

Number of Beds	Total	Pediatrics	Obstetrics	Gynecology	Adult ICU	Pediatrics ICU	Neo-natal ICU
50-99	3.91	7.86	1.26	2.65			1.08
100-199	6.57	7.83	4.58	5.84	10.52	5.29	14.63
200-499	6.88	6.39	5.33	3.20	10.95	9.93	29.07
500 or +	5.35	9.14	4.68	2.69	5.82	5.95	12.73
Average	6.26	7.24	4.57	3.56	9.86	7.22	19.72

Source: Authors' elaboration using data from REHUF, MEC. With the exception of the number of beds, all other statistics are based on information about hospitals that report above zero values.

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[3] La Forgia G, Couttolenc B 2008, pages 287-289.

FUH operate under different ownership, governance and management arrangements. These hospitals are governed by Federal Universities, which are autonomous entities linked to the Ministry of Education (MEC). In 2009, there were 47 Federal University Hospitals under the administration of 32 Federal Universities. The prevailing management model of the FUH is direct public administration, with a few exceptions, such as the Federal Hospital of Porto Alegre (HCPA), linked to the Federal University of the State of Rio Grande do Sul, which is a public enterprise; the Hospital Sao Paulo, which belongs to the Federal University of Sao Paulo (UNIFESP), and is a non-profit private institution; and the autonomous hospital of the municipality of Venda Nova, from the University of Minas Gerais, which is managed by a private non-profit foundation established to on purpose. Most of the FHU managers are selected by the University Dean, but some are directly elected by the hospital staff, teachers and, in some case, by the students.

The federal government has been considering adopting governance and management arrangements that increase hospital autonomy, flexibility and efficiency. Resistance to change has, however, proved to be an obstacle to rapid adoption of these new models. State University Hospitals in Brazil are also managed by social organizations, public-private consortia, private foundations and other management arrangements. The MOH submitted to Congress a proposal for the establishment of Health Foundations that would have management autonomy, and allow for contracting staff under private sector labor market regulations, but the proposal has been pending approval.

In Brazil, hospitals with autonomous management have better performance than hospitals under direct public management.[4] In the management by a Social Organization (OS) model, the Government contracts a private, non-profit operator to manage one or more facilities (including all inputs), making full use of assets. However, the facility remains government-owned, and is 100% government-financed under a performance-based management contract with financial risks. A study matched 12 OS with 12 direct administration facilities on bed size, discharges, physicians per bed and complexity. Some

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[4] La Forgia G & Couttolenc B. 2008

hospitals managed by social organizations (OS) have improved performance as compared to hospitals managed by direct administration.

The study concluded that the:

- Government needs to enhance the autonomy and accountability of public hospitals.

- Government and private payers of hospital care need to wield their funding power to influence hospital behavior.

- Brazil needs to improve coordination among hospitals and between hospitals and other types of providers.

- The quality of all hospitals must be raised to acceptable standards.

- The absence of reliable information about quality, efficiency, and costs of hospital services underlies all issues and hampers any effort to improve performance.

A survey of nearly 400 hospitals in Argentina, Brazil, Colombia and Mexico also found that the corporate and private governance types were generally associated with better performance.[5] The study identified four governance types based on organizational elements theorized to affect hospital behavior: (i) budgetary unit of government; (ii) autonomous unit of government; (iii) corporate unit of a private conglomerate or broader, private hospital system; or lastly (iv) a private and autonomous unit. These types were compared in five analyses: (a) administrators' ratings of their own hospital's performance; (b) hospital performance indicators, such as occupancy and costs per bed; (c) performance tracking vis-à-vis standards; (d) ratings of criteria for selecting leadership; and (e) hospital administrators' qualifications. Performance differences were noted for facility and equipment upkeep, availability of medicines and auxiliary services, administrative and labor efficiency, and clinical quality, including the level of nursing training. Hospitals governed under private and corporate models tended to have more non-clinical, business-oriented leadership, while the budgetary governance type seems to be obligated to pursue a more broadly defined set of accountabilities. Freeing hospitals from institutional and governmental control, referred to as facility-based management, seems to be associated with better hospital performance. The values underlying facility independence, however,

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[5] Bogue R, Hall C, La Forgia G 2006. Hospital Governance in Latin America. Results from a Four Nation Survey.

must exist simultaneously with other socially or politically defined priorities and accountabilities. Commitment to pursue higher-performing governance models will be possible only through thoughtful examination of the internal and external contexts that shape hospital behaviors, including market strategies, regulations, local definitions of autonomy, and the scope and distribution of stakeholder incentives.

Even so, Table 3 shows that the majority of public hospitals remains at direct administration. This may be an obstacle to increase efficiency in the administration of FUH.

Financing of the FUH is a serious problem. Fees paid by the SUS do not cover FUH spending, and the hospitals have become progressively short of funds. The network of university hospitals has a significant budget of almost R$4 billion a year. In 2008, the FUH total income was R$3.7 billion, but FUH expenditures were estimated to be R$ 3.9 billion, which indicates a deficit of about R$200 million (about US$130 million). Table 4 shows that in 2008, 69% of the public funds to finance FUH current expenditures were transferred by the MOE to pay for staff, interns and maintenance. The remainder came from the MOH, which pays for health services delivered to the SUS (which represent 12% of total SUS payments for hospitalization services), and for teaching incentives (Incentive Factor to Develop Teaching and Research Activities - FIDEPS). Increaseing the SUS share from 30% to 50% of the FUH costs will help to remedy the problem of chronic deficits of university hospitals. However, to improve accountability, transparency and administrative efficiency, these resources should be cautiously administered through modern systems of management of hospital costs.

Table 3. Organizational Arrangements in Public and Private Hospitals in Brazil 2005

Classification	Arrangement	No.	%
Publicly-owned Hospitals			
Direct Administration	• Federal, State and Municipal-managed facilities	2,585	35
Indirect Administration	• Autonomous Management Unit (*Autarquia*) • Public Foundation (Fundação Pública)	62 75	2
Autonomous Administration	• Autonomous Social Services (Serviços sociais autônomos) • Public Enterprise (*Empresa Pública*) • Support Foundations (Fundações de Apoio) • **Social Organizations (Organizações sociais)**	6 19 46[b] 17	1
Privately-owned Hospitals			
Non-profit	• Private Foundations • Philanthropic/charitable associations and societies • Cooperative/employee union	107 1,700 44	25
For-profit	• Corporate	2,765	37
TOTAL		7,426	100

Source: Authors' elaboration using data from AMS, 2005.

Multiple sources of funding make budgeting, accounting, costing, resource mobilization and overall system management extremely difficult. In addition to federal transfers of funds from MOE and MOH, some FUH receive payment for services provided to private insurers, as well as private donations, and national and international funds for research.[6] However, financial flows related with these additional transfers are not transparent, the resources are not under the direct control of the MOE or even hospital management, and there is no accounting of how much these additional funds represent in the total financing of the FUH. Despite their little amount compared with the regular FUH income, each payment system comes with its own embedded incentives, which may affect decisions by hospital managers. In the worst case, competing incentives may cancel each other out. The MOE estimates that these other sources amounted to R\$133.8 million in 2008. According to recent regulation[7], all FHU have to be classified as independent budgetary units, establishing their own budget and a proper accounting plan, but most have not yet made the transition and still work under the accounting system of the Federal University from which each depends.

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[6] The Hospital of Porto Alegre (HCPA) in Parana, the Hospital Miguel Riet Correa Junior, from the University of Rio Grande, and the Hospital of the Federal University of São Paulo provide services to private health plans. The former two hospitals also receive private patients paying out-of-pocket.

[7] MEC Internal Normative (Portaria) Number 4 of April 29, 2008.

Adding to resource and management woes, most hospital funding is not linked to performance. As many other Brazilian Federal public institutions, FUH do not receive incentives to be managed by performance. Currently, most hospitals budgets are based on historical expenditures, and are not linked either to expected or achieved results. The FHU need start linking budgetary needs to a corporate plan and targets, and the staff should be trained to be able to prepare and follow up on the implementation of hospital budgets.

Table 4. Transfers to Federal University Hospitals in 2008

Source and Budget Item	Value R$ millions	Distribution %
Ministry of Education	2,472.9	69.3
Civil Servants Payroll	2,212.4	62.0
Student Internships	123.2	3.4
Others maintenance costs	137.3	5.9
Ministry of Health	1,097.5	30.7
Payment for Health Services	815.4	22.8
Teaching Incentives	282.1	7.9
Total Transfers	**3,570.4**	**100.0**

Source: MEC

Outsourcing of support services in hospitals is still a controversial subject. However, many university hospitals have outsourced laundry, catering, transportation, security and even medical lab tests. This is an area to be explored carefully, ensuring transparency and competitiveness, to guarantee that these hospitals lower costs but obtain quality support services.

Staffing issues are also affecting FUH performance. FUH employ, on average, more employees than other hospitals of the public, and private and teaching hospitals system, although with a similar distribution by qualifications. FUH employ nearly 70,000 workers; 5,700 of them are teachers of different medical specialties and health professions. More than half of the FUH personnel are civil servants, 30% have regular contracts according to the private sector labor laws (CLTs), and 18% work under various types of temporary and irregular contracts. Between 2002 and 2008, 5,200 vacancies were not filled; in 2009 and 2010, it is expected that staff retirement will generate an additional 2,500 vacancies. It is estimated that, throughout the system, 1,900 beds cannot be utilized if some of these vacancies are not filled. However, by the end of 2010, current federal regulations mandate that all temporary and CLT contracts terminate and all FUH are staffed by civil servants admitted by public competition. Table 5 presents FUH staff distribution by hospital size. FUH physicians per bed rate average is 0.9.

FUH should to be part of health networks to regulate the adequate use of their facilities. FHU are very specialized and expensive institutions, which should focus on medium and high complexity health care in their various areas of expertise complement primary health care and low complexity health care offered by other SUS facilities. However, most FUH

are entirely supply driven, and attend all the demand that flows into their doors, and some are not included in the local regulatory schemes that coordinate the patient flow on the basis of reference and counter-reference processes. As a result, many FHU receive patients that are not referred by primary health care doctors and use hospital facilities to treat health issues that could be addressed at less complex levels of care. However, cases such as the Municipality of Curitiba, in the State of Parana, show that strengthening the local health regulatory system is crucial to improve and rationalize the use of FUH beds and specialized ambulatory facilities, reducing the waste of public funds and contributing to the right use of human resources and equipment. In addition, there is little coordination among different FUH to rationalize supply of beds, medical expertise or specialized equipment.

Table 5. HUF Staff by Hospital Size

Number of Beds	Physicians per bed	Nurse per bed	Auxiliary to nurse per bed	Physicians per nurse	Physicians per auxiliary nurse	Nurse per auxiliary to nurse
50-99	0.99	0.40	1.28	2.54	0.75	0.30
100-199	0.66	0.35	1.45	1.88	0.49	0.26
200-499	1.09	0.63	2.08	1.82	0.51	0.30
500 or +	0.89	0.52	1.87	1.80	0.53	0.29
Average	0.90	0.50	1.75	1.90	0.52	0.28

Source: Authors' elaboration using data from REHUF, MEC. With the exception of the number of beds, all other statistics are based on information about hospitals that report above zero values.

Federal funds for investment in infrastructure did not materialize in the last years, and as a result infrastructure deteriorated, old equipment was not replaced, and operation and maintenance processes were not fully developed. In the last two years, most of federal hospitals in Brazil have not had investments in civil works and equipment with strong negative effects in the quantity and quality of the services delivered to the population, and negative consequences in terms of future income generation from provision of health care to SUS and the private sector. The FUH are entitled to receive federal funds for investments from two multi-year programs, which would amount to R$7.4 billion for the period 2008-2011. However, in the last two years these transfers were not made, while the hospital physical infrastructure has been deteriorating and equipment has become outdated.

In this context, the Government issued the Decree 7082 instituting the Federal University Hospitals Program (REHUF), with the aim of reforming Brazil's Federal University Hospitals to modernize the infrastructure and the management of these institutions. The Decree aims at renewing management processes, improve financing mechanisms,

establish information systems and upgrade equipment and hospital infrastructure which deteriorated over the years. The decree will be regulated by an inter-ministerial legal agreement under preparation, and to be signed by the MOE, Ministry of Health (MOH), and Ministry of Planning, Budgeting and Management (MPOG).

The REHUF program has two components, the renovation of the hospitals physical structure and the modernization of its governance and management. In the renovation component, the MEC prioritized some hospitals in worse conditions, as well as the most important areas within each hospital. Overall, MEC infrastructure plans are justified and the specific projects for each hospital were judged to be of good quality. In the area of governance and management, the MOPG, MEC and MOH have been agreeing on issues related to financial, clinical and human resource management, and governance of the hospitals under the REHUF Program. The Program supports the dissemination of information systems developed in the Clinical Hospital of Porto Alegre (HCPA).

4   The Stochastic Frontier Model

Stochastic Frontier Analysis is a method of economic modeling. It has its starting point in the stochastic production frontier models simultaneously introduced by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977).

The production frontier model without random component can be written as:

$$y_i = f(x_i; \beta).TE \tag{1}$$

where y_i is the observed scalar output of the producer i, $i=1,..I$, x_i is a vector of N inputs used by the producer i, $f(x_i, \beta)$ is the production frontier, and β is a vector of technology parameters to be estimated.

TE_i denotes the technical efficiency defined as the ratio of observed output to maximum feasible output. $TE_i = 1$ shows that the i-th firm obtains the maximum feasible output, while $TE_i < 1$ provides a measure of the shortfall of the observed output from maximum feasible output.

A stochastic component that describes random shocks affecting the production process is added. These shocks are not directly attributable to the producer or the underlying technology. We denote these effects with $\exp\{v_i\}$. Each producer is facing a different shock, but we assume the shocks are random and they are described by a common distribution.

The stochastic production frontier will become:

$$y_i = f(x_i; \beta).TE.\exp\{v_i\} \tag{2}$$

We assume that TE_i is also a stochastic variable, with a specific distribution function, common to all producers.

We can also write it as an exponential $TE_i = \exp\{-u_i\}$, where $u_i \geq 0$, since we required $TE_i \leq 1$.

Now, if we also assume that $f(x_i, \beta)$ takes the log-linear Cobb-Douglas form, the model can be written as:

$$\ln y_i = \beta_0 + \sum_n \beta_n \ln x_{ni} + v_i - u_i \tag{3}$$

where v_i is the "noise" component, which we will almost always consider as a two-sided normally distributed variable, and u_i is the non-negative technical inefficiency component. Together they constitute a compound error term, with a specific distribution to be determined, hence the name of "composed error model" as is often referred.

We work with a production function model as in equation 3. We divide the analysis in three parts. The first one considers the total output of the hospitals (total number of inpatient care plus ambulatory care) as a dependent variable, the second one considers only the hospital production and the third one considers only the ambulatory production.

In the first case we use the following variables as explanatory variables: Total number of beds; total number of employed workers (including physicians); total number of equipments; total number of rooms (ambulatory, emergency, inpatient room, etc)

In the second model we use only the hospital production and we consider the following explanatory variables: Total number of beds; Equipments for sustaining life; total number of employed workers (including physicians); total number of rooms for surgery, inpatient rooms and emergency rooms.

Finally, in the third model we consider only the ambulatory production and use the following explanatory variables: Equipments (except for sustaining life); total number of employed workers; total number of ambulatory rooms.

5   Results

Tables 6, 7 and 8 show the first results. By Table 6, it is straightforward to see that the efficiency of hospital grows with the size of the hospitals. However, the very small ones are also efficient. Analyzing these 3 small hospitals (between 50 and 99 beds) we can see that they are very specialized hospitals and their occupancy rate is not very high. They are two maternity hospitals and one pediatric institute. So, it seems that unless the hospital is very specialized, it benefits from scale and is more efficient as higher its structure. This can be confirmed by the indicators we presented in tables 1 and 2 showing that hospitals with more than 500 beds have higher bed occupancy rate, higher turnover rates and smaller length of stay, even knowing that they usually receive most serious cases.

Table 6. HUF Efficiency by Hospital Size

Size	Number of Hospitals	Average Total Efficiency	Average Hospital Efficiency	Average Ambulatory Efficiency
50-99	3	0.712	0.624	0.691
100-199	12	0.655	0.364	0.507
200-499	15	0.736	0.471	0.662
500+	5	0.760	0.620	0.698
Average		0.710	0.469	0.618

Source: Authors' elaboration using data from REHUF, MEC.

In the same way, Table 7 presents the results by physicians per bed rate. The idea is to see if less efficient hospitals have more human resources problems. We present the average efficiency resulted of the models presented above and also the average of some indicators to confirm the results. Again, it seems that hospitals with more than 1 physician per bed have higher average efficiency and better indicators than the ones with less than 1 physician per bed. They have, on average, higher bed occupancy rate (67.02), smaller length of stay (5.28) and higher turnover bed rate (3.67). In the model of ambulatory production, however they are not the most efficient ones, indicating that human resources are a problem to hospital production, but not to ambulatory production. This makes sense, as the hospital cannot has full ITU and inpatient hospital rooms without physicians to take care of the patients. On the other hand, the ambulatory production is less dependent of the physician per bed rate.

Table 7. HUF Efficiency by Physicians/beds Rate

Physicians/Beds	Number of Hospitals	Average Total Efficiency	Average Hospital Efficiency	Average Ambulatory Efficiency	Occupancy Rate	Length of Stay	Turnover Bed Rate
0 - 0.5	9	0.68	0.36	0.59	52.76	6.06	2.66
0.5 - 0.75	8	0.69	0.44	0.52	63.22	6.93	3.15
0.75 - 1.0	11	0.78	0.47	0.71	58.89	6.11	3.15
>1.0	10	0.67	0.56	0.61	67.02	5.28	3.67

Source: Authors' elaboration using data from REHUF, MEC.

Finally, Table 8 shows the results by region. It is very clear that the less efficient hospitals are in the Northeast region. The two hospitals in North region have terrible hospital efficiency and good ambulatory efficiency. Looking at the indicators we can see that they have high occupancy rate, but at the same time they have the highest length of stay of the sample. This, in turn, makes their turnover bed rate the smallest ones and also their hospital efficiency[8]. On the other hand we can see that hospitals in South region and Southeast region present the best indicators and the best results in the hospital and ambulatory efficiency models. The best occupancy bed rate average is in the South Region (83.06%) and the worst is in the Center-West Region (34.86%). However, Center-West region has relatively well performance when looking to other indicators like length of stay and also in the model estimates. Anyway, is important to attempt for the fact that the hospitals in the region need to improve their occupancy bed rate.

Table 8. HUF Efficiency by Region

Region	Number of Hospitals	Average Total Efficiency	Average Hospital Efficiency	Average Ambulatory Efficiency	Occupancy Rate	Length of Stay	Turnover Bed Rate
Norte	2	0.87	0.07	0.91	74.73	13.02	1.73
Nordeste	13	0.62	0.38	0.49	50.89	4.69	2.90
Centro-Oeste	5	0.75	0.68	0.61	34.86	3.08	3.64
Sudeste	12	0.73	0.48	0.67	67.91	6.72	3.21
Sul	6	0.77	0.60	0.68	83.06	7.83	3.75

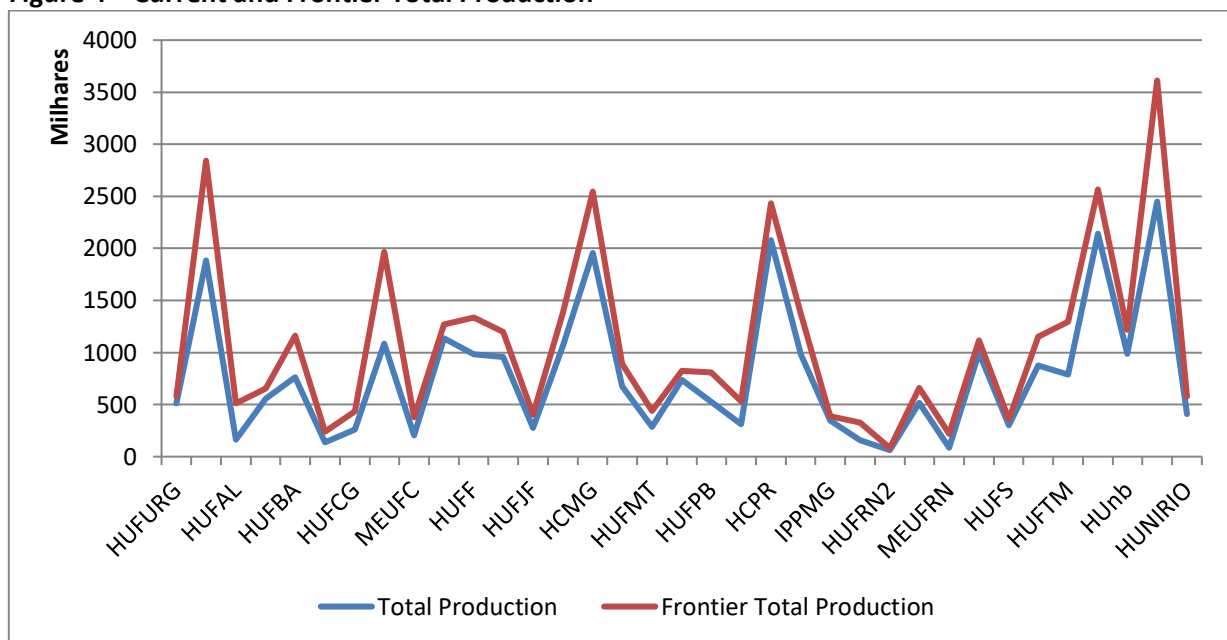Source: Authors' elaboration using data from REHUF, MEC.

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[8] As the model of hospital efficiency is, in certain way, a measure of the hospital production given the hospital structure, it is very correlated with turnover bed rate, that is an indicator of hospital inpatient admissions given the number of beds.

The three tables presented also show that the ambulatory efficiency of FUH is much higher than the hospital efficiency. This can be explained by the fact that we are not using any measure to weight by the severity of the cases. Then, the majority of the cases in the ambulatory production are less serious cases it is easier to produce more with the same infra-structure than in the hospital production. But, as we are interest in the relative efficiency among the hospitals of each model, this is not a big problem.

One other thing we can show is the distance between the current production of the hospital and the possible production if the hospital is completely efficient. Again, what we will show doesn't take into consideration the average severity of the cases each hospital take care, so some hospitals, actually, can be in a different position from the one we will show because of the severity of the their cases. Further analysis using DEA model with multiple outputs is necessary to try to understand what more can be done by the hospitals. Improvement in indicators reliability, like average infection rates is also necessary.

The Figures 4, 5 and 6 show the current production of each hospital and the production they would have in the case they are in the efficient frontier, respectively, for the completed model, for the hospital production model and for the ambulatory production model. As we can see, the distance to the frontier is higher in the hospital production model than in the other ones. This is reflecting the fact that is more difficult improve hospital production because the severity of the cases, as we discussed before.

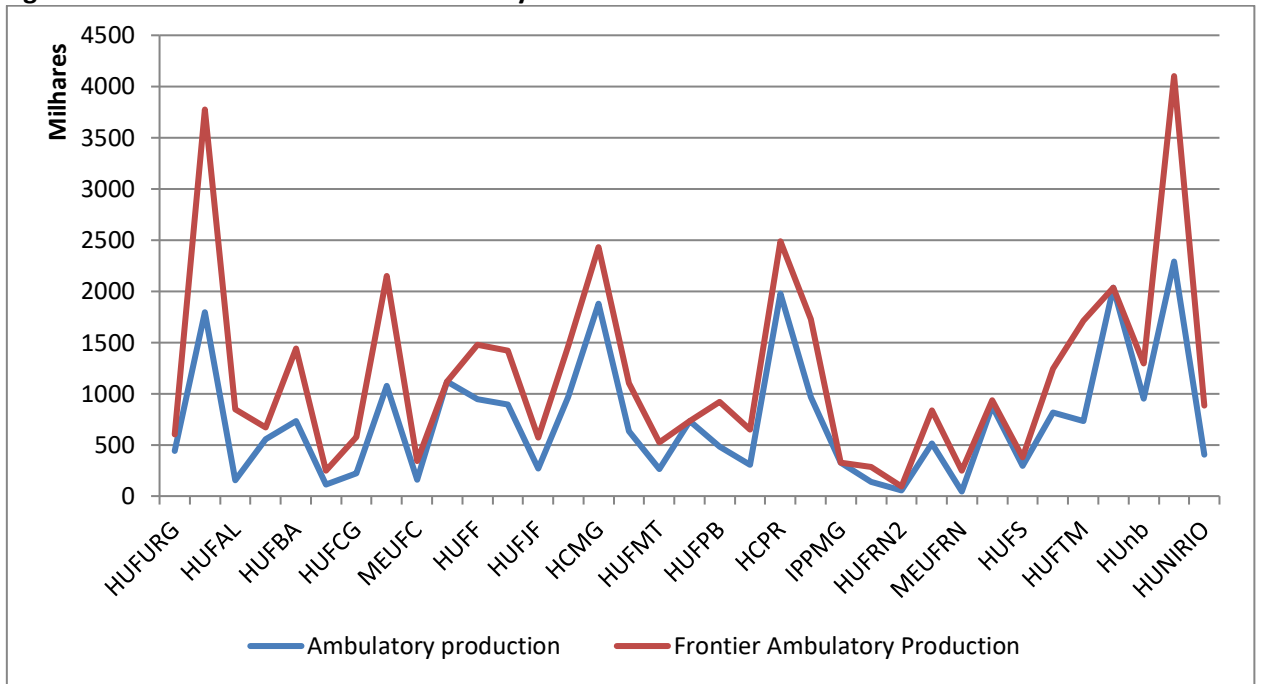**Figure 4 – Current and Frontier Total Production**

Source: Authors' elaboration using data from REHUF, MEC.

Figure 5 – Current and Frontier Hospital Production
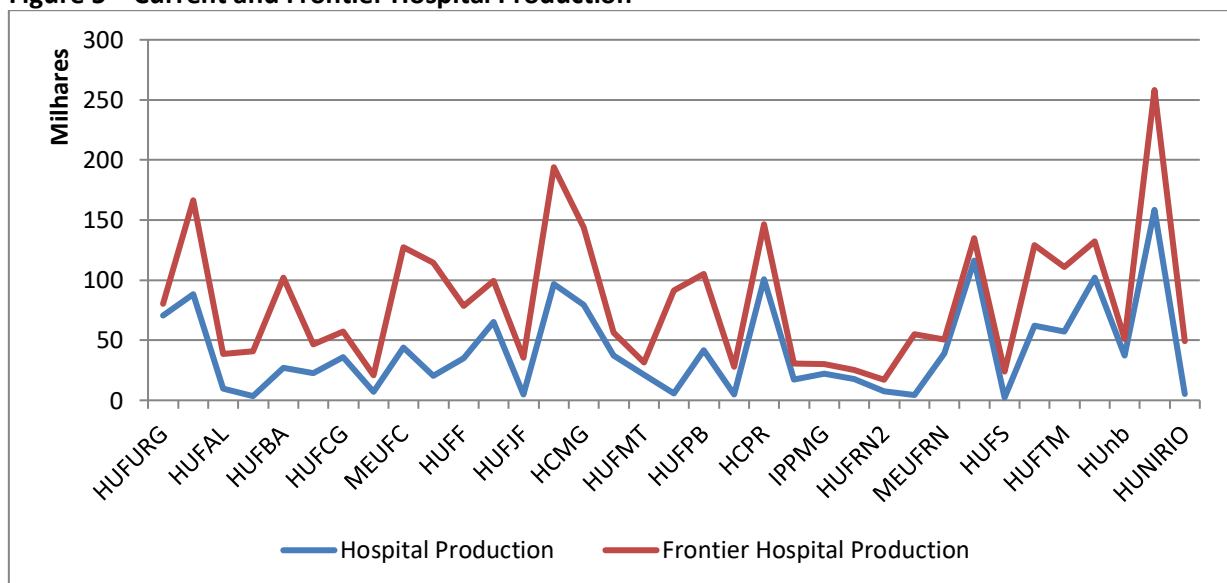
Source: Authors' elaboration using data from REHUF, MEC.

Figure 6 – Current and Frontier Ambulatory Production

Source: Authors' elaboration using data from REHUF, MEC.

6   Conclusion

It is straightforward to conclude that the Federal University hospitals have a huge importance in the Brazilian hospital system. Most part of SUS high complexity care has been done in these hospitals. They also have been responsible for the formation of a big share of medical residents, giving them a wide importance in the teaching doctor system.

At the same time, the hospitals became a long period with many problems of financing, management and contracting staff. Only now, has been done by the government an effort to put the hospital accounts in equilibrium, and to reorganize and restructure the FUH. Also the attempt to improve the managerial system, bringing the HCPA electronic system of information, would improve the quality of care, and with better information would also improve the possibility of making studies of high quality, which in turn can again improve the quality of the hospitals. So, the REHUF program is a hope to improve and rationalize a system that has been forgotten for many time, and to make it more integrate with the entire SUS system, to have a better focus in high and medium complexity, as the primary health care should be done by the basic units, as the family health units and other basic health units.

The paper shows that higher hospitals are more efficient, unless the hospital is very specialized. Then, a good policy could be to increase the size of general hospitals and to make the small ones work only with specialties. Also, the paper shows the importance of improving northeast total efficiency and north hospital efficiency. Finally, for most hospitals it is clear necessary hire more physicians to improve the efficiency and the bed occupancy rate. Solve the human resources problem is one of the most difficult challenges policy makers have to improve the efficiency and quality of Federal University hospitals.

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